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Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals

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Abstract

Objectives – To review the nonradiologist use of ultrasound (US) in the setting of emergency and critical care, the development, clinical applications, and standardization of veterinary abdominal and thoracic focused assessment with sonography for trauma (FAST) techniques.

Etiology – Since the 1990s, the 4-point FAST US technique has been used for injury surveillance in people with blunt and penetrating trauma. FAST screens for free fluid in the abdominal, pleural, and pericardial cavities with high sensitivity and specificity. More recently, an extended FAST scan was developed for the rapid detection of pneumothorax. These techniques and newly created scans have been applied to other critically ill, nontraumatized, subsets of human patients. As a result, the terminology related to this field, eg, extended FAST, HHFAST, FFAST, FAFF, BOAST, SLOH, bedside US, '$ Approach,' protocols, and objectives have become convoluted despite having similar goals.

Diagnosis – The importance of US in the setting of emergency medicine is highlighted by the fact that this diagnostic modality has become an integral part of the core curriculum for nonradiologists including the American College of Surgeons, American College of Emergency Physicians, American Board of Emergency Medicine, Society of Academic Emergency Medicine, and all United States Accreditation Council for Graduate Medical Education Emergency Medicine residency programs.

Therapy – Veterinary applications of FAST techniques include an abdominal FAST technique with an abdominal FAST applied fluid scoring system, and a thoracic FAST technique. In an attempt to avoid the creation of numerous acronyms, veterinarians would be well served by making the 'T' in 'FAST' stand for 'Trauma,' 'Triage,' and 'Tracking.'

Prognosis – These veterinary FAST techniques provide an extension of the physical examination for the emergency and critical care veterinarian potentially expediting diagnosis, prompting life-saving maneuvers, and guiding patient management. Further clinical research to determine sensitivity, specificity, and accuracy for specific conditions is warranted.

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Introduction

Since the 1990s, focused assessment with sonography for trauma (FAST) has been a first line, standard of care, screening technique in many algorithms for both blunt and penetrating trauma in people.[1–10] In its original application, a 4-point scan was performed on the abdomen, evaluating for evidence of free fluid in the abdominal, pericardial, and pleural cavities. The utility of FAST protocols is premised upon the generalization that trauma-related free fluid accumulation reflects internal injury and non-trauma–related free fluid accumulation reflects other pathology. FAST is considered a first line diagnostic test in trauma centers in both Europe and North America, and has virtually eliminated the need for diagnostic peritoneal lavage (DPL) at many trauma centers.[2,3,5,11–16] Improved sensitivity (Se) and specificity (Sp) have been demonstrated in people using FAST protocols over radiography for the diagnosis of free abdominal, pleural, and pericardial fluid and they are comparable to computerized tomography

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(CT).[1,2,16–20] More recently, FAST protocols for pneumothorax, pleural effusion, and lung pathology in people have been developed reducing the number of thoracic radiographs and CT scans performed in critically ill patients.[21–29] FAST and emergency ultrasound (US) have become an integral part of patient management resulting in these techniques becoming part of the core curriculum for the American College of Emergency Physicians, American Board of Emergency Medicine, Society of Academic Emergency Medicine, American College of Surgeons, and all United States Accreditation Council for Graduate Medical Education Emergency Medicine residency programs.[30–32]

One of the major advantages of FAST protocols is the rapidity at which they can be performed. Both human and veterinary trauma studies have reported exam times of 3 minutes or less.[2,33–36] Moreover, FAST proficiency is attainable by nonradiologist veterinarians.[33,34,37] FAST is a relatively inexpensive, radiation sparing, point-of care, noninvasive, imaging modality requiring minimal patient restraint that can be performed simultaneously with other interventions.[1,33,34] FAST exams are often performed while the patient is having placement of an IV catheter, being supplemented with oxygen, having blood drawn, or receiving additional treatments.[1,33,34] In contrast, CT, although the gold standard for intraabdominal injury because it detects free fluid, free air, and parenchymal injury, is expensive, not portable or widely available.[1,38] CT in veterinary patients requires a hemodynamically stable patient for safe transport to the radiology suite[4,29] and has the additional risk related to sedation or anesthesia.[38] Because CT exposes the patient and attending staff to radiation, patient interaction during the scan is limited.[39] As a result of these inherent factors along with expense and limited availability, CT does not lend itself to serial examinations as easily as US.[39] Serial FAST examinations and the application of hemoperitoneum fluid scoring systems in people have been shown to improve outcomes including reducing time to surgery, decreasing morbidity and length of hospitalization, and improving survival in trauma and nontrauma patients.[1,5,6,32,40–43]

More recently, a veterinary abdominal fluid scoring system has been developed and demonstrated to correlate with degree of anemia and semiquantitate the degree of intraabdominal injury (eg, hemorrhage).[34] Ongoing or occult hemorrhage remains the number 1 cause of death in human trauma patients during the first 48 hours of hospitalization;[1,44–51] and missed intraabdominal injury is a common finding at surgery or postmortem examinations.[44,52,53] Initial and serial FAST exams provide a means for reliably monitoring these critical patients.[5,6,34] Serial abdominal FAST (AFAST) examinations with an applied fluid score provide a tool for veterinarians to assess the degree of hemorrhage as well as monitor ongoing or resolution of hemorrhage.[34] When used in the proper context, FAST exams may expedite detection of life-threatening problems, thus it may be used to modify interventions and guide therapy, especially in cases with ongoing or occult hemorrhage, which may otherwise go unrecognized by physical examination, vital signs, and laboratory tests.[1,4,16,32,38,40,41,54–60]

The purpose of this review is to discuss the development and clinical applications of veterinary AFAST with its applied fluid scoring system, and thoracic FAST (TFAST) techniques in the emergency and critical care setting and propose recommendations for the standardization and training of these veterinary techniques. The 'T' in 'FAST' could be considered representative within the veterinary community of not only 'Trauma,' but also 'Triage' and 'Tracking' for nontrauma and monitoring applications, respectively. By recognizing that the 'T' in FAST may represent these additional applications, it may help avoid the need for a host of additional acronyms such as extended FAST, HHFAST, FAFF, FFAST, INBU, SLOH, '$ Approach,' BOAST which can be found in the human literature.[23,32,61–65]

The Development of 'AFAST' and an Abdominal Fluid Scoring System

In 2004, Boysen et al[37] studied a novel canine version of the human FAST exam applied to 100 hit-by-car (HBC) dogs. Interestingly, they found that within their case population of 100 dogs, 45% had incurred intraabdominal injury as reflected by a positive FAST exam, ie, the presence of free abdominal fluid. In that study, hemoperitoneum (confirmed by abdominocentesis in 38%; solely identified via FAST in 43%) was the major FAST-diagnosed injury.[37] This percentage was higher than reported previously (38–43% versus 12–23%) before the development of FAST.[37,66–68] The second most common injury detected by Boysen et al[37] was uroabdomen (2%), similarly reported by Simpson et al[68] (3%) in a large recent retrospective study. Regarding uroabdomen, veterinary FAST is advantageous because it can be used to screen for both intraabdominal and retroperitoneal fluid, and the presence of a normal contoured urinary bladder to help rule out rupture of the urinary bladder.[34,37] However, the true Se and Sp for the diagnosis of uroabdomen and the detection of retroperitoneal fluid in veterinary patients in the context of FAST protocols have not been evaluated to the author's knowledge.

In people, the Se and Sp for the detection of retroperitoneal fluid via sonography is problematic because obesity, differences in anatomy causing more air interference from the gastrointestinal tract, and supine positioning (all FAST sites are gravity dependent in people) make it difficult to differentiate free fluid within the peritoneal cavity versus the retroperitoneal space.[1] These issues may be less problematic in dogs placed in lateral recumbency because intraabdominal fat and the potentially gas-filled colon fall away from the nongravity dependent flank view. In lateral recumbency, free abdominal fluid will generally not overlie retroperitoneal fluid at the nongravity flank site. The ability to sonographically distinguish between peritoneal and retroperitoneal fluid in dogs, is not well characterized. Initial and serial AFAST may also prove helpful in reaching an expedient diagnosis in more challenging trauma sequela such as retroperitoneal-related injury including renal, ureteral, and vascular trauma that would otherwise go undiagnosed or missed entirely.[69–82] Finally, the study by Boysen et al[37] clearly demonstrated that proficiency in performing FAST exams can be achieved by nonradiologists, and this is similar to findings in human FAST studies.[1,16,20,37]

Only 2 studies have been performed to date with regards to the detection of traumatic hemoperitoneum in dogs using FAST.[34,37] In both of these prospective studies the authors reported markedly higher rates of hemoperitoneum than documented previously without FAST examinations.[34,37] The study by Boysen et al,[37] however, may have overestimated the incidence of hemoperitoneum in traumatized patients due to several factors when contrasted with the study by Lisciandro et al.[34] These factors include a median time from traumatic event to FAST examination of 240 minutes, a median time from presentation to FAST examination of 60 minutes, a referral population constituting 35% of case population, and 16 cases in which blind abdominocentesis was performed before the FAST examination.[37] With a 4-hour gap between the traumatic event and FAST examination, traumatized dogs may have received fluid resuscitation or had abdominocentesis performed, which may have led to the identification of more FAST-positive dogs. By exacerbating occult parenchymally contained injury (eg, subcapsular splenic hemorrhage or clotted liver laceration) via fluid resuscitation, or by inadvertently puncturing the spleen or other vascular structures, dogs may have iatrogenically become positive. A similar phenomenon in which self-contained parenchymal injury worsens over time evident by the development of free fluid on serial imaging occurs in people.[1,5,61,83] Alternatively, an argument could be made that in the study by Lisciandro et al,[34] hemoperitoneum may have been underestimated because dogs deemed AFAST negative may have died, been euthanized, or sent home as stable outpatients before becoming AFAST positive subsequently. In contrast to the study by Boysen et al,[37] most of dogs described by Lisciandro et al[34] were evaluated in much closer proximity to the traumatic event (median time trauma to presentation was 60 min), had AFAST performed before fluid resuscitation (median time presentation to AFAST <5 min), and 98% were primary presentations (not treated before presentation by another veterinarian). In the study by Lisciandro et al,[34] approximately 20% (6/27) of AFAST-positive dogs *became positive* on their serial AFAST exam. Overall frequency of hemoperitoneum was 27%. These findings emphasize the importance of serial FAST exams, which are recommended in human patients as well.[5,6,34,84,85] Further research comparing initial and serial abdominal fluid scores (AFSs) to blood pressure, advanced imaging, and fluid resuscitation volumes, may prove helpful in optimizing care and clarifying the types of injuries incurred in these dogs.

In the initial study by Boysen et al,[37] approximately 25% of dogs with hemoperitoneum were administered blood products. None of the dogs, however, required surgical intervention to address hemoperitoneum, which was also true in the study by Lisciandro et al[34,37] In a recently published retrospective review of severe blunt trauma in 235 dogs, Simpson et al[68] reported that 6% (3/53) of hemoperitoneum cases required surgical intervention. The Simpson study, however, retrospectively reviewed trauma cases pre-FAST (1997–2003) in contrast to more recent studies[34,37] that were prospective. In an older retrospective case series, Mongil[67] evaluated 28 dogs with traumatic hemoperitoneum that required blood transfusions and found that 32% (9/28) required surgery.[67]

Following the publication by Boysen et al,[37] Lisciandro et al[34] developed a novel abdominal fluid scoring system assigning AFAST-examined dogs an AFS. The purpose of the study was to determine whether a patient's AFS could potentially be used to help guide therapy similar to the clinical use of human hemoperitoneum fluid scoring systems.[5,6,42,86] Human hemoperitoneum scoring systems, however, were created as a means for predicting the need for emergent laparotomy.[40,41] In contrast, because dogs with traumatic hemoperitoneum are more often successfully treated medically (emergent laparotomy remains controversial)[34,37,38,68] the veterinary fluid scoring system was developed to predict the degree of anemia and potential need for blood transfusion.[34] In a prospective study in people, McKenney et al[41] found that of the patients with a high fluid score, 87% required a therapeutic laparotomy; and the Se of the hemoperitoneum score was much higher (83%) when compared with systolic blood pressure (28%) and base deficit (49%).[41] In another study of pediatric patients, no difference was found

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between higher and lower scoring patients in their admission pulse, Glasgow Coma Score, Injury Severity Score, or the proportion of those presenting with hypotension. Lower scoring patients, however, rarely required surgical intervention (1/22) in contrast to the higher scoring patients of which the hemoperitoneum score had an Se of 89%, Sp of 75%, and was 78% accurate in predicting need for emergent laparotomy.[87] Presenting laboratory and physical examination findings documented in people and veterinary patients do not reliably lend themselves to determining the degree of hemorrhage.[61] The AFAST-applied AFS, subsequently described, gives attending veterinarians the ability to assess more reliably the degree of hemorrhage because the fluid score semiquantitates the volume of intraabdominal blood and therefore may alert clinicians to the need for blood transfusions.[34] Moreover, by serially monitoring AFS, cessation of bleeding (static AFS), ongoing hemorrhage (increasing AFS), and resolution via autotransfusion (decreasing AFS), may be determined. Future studies may demonstrate whether the AFAST-applied fluid scoring system can predict the need for emergent laparotomy in dogs.

Because approximately 25% of FAST-positive dogs in the study by Boysen et al[37] required blood transfusions, Lisciandro et al[34] speculated that a veterinary fluid scoring system could semiquantitate the degree of hemorrhage present and be clinically useful in determining the potential need for blood transfusions or surgery in dogs that could not be stabilized medically. The authors further speculated that initial and serial AFAST-applied AFSs would be helpful in detecting ongoing hemorrhage before the patient became overtly hemodynamically unstable. They developed a simple 0–4 abdominal fluid scoring system based on the number of FAST-positive sites, and correlated patient fluid scores with the degree of anemia.[34] Because dogs are flattened in a lateral manner versus anterior-posterior in people, AFAST, applied in the recommended positioning of lateral recumbency,[34,37] provides an inherent depth gauge for the fluid scoring system (Figure 1).[34] In contrast, human hemoperitoneum scores are determined in similar fashion with the addition of a fifth factor of greatest fluid depth because the FAST exam is performed in the supine position, thus all human sites are gravity dependent.[40,41]

In the study by Lisciandro et al[34] none of the 101 dogs were anemic on their initial PCV determination but subsequently, 25% of the dogs with an AFS of 3 or 4 became markedly anemic with PCV <25%. In general, all dogs with AFS 3 or 4 had at least a 20% decrease from their initial PCV; and only a single dog in the lower-scoring group of AFS 1 or 2 became anemic (PCV 30%). In the event a lower-scoring (AFS 1 and 2) dog

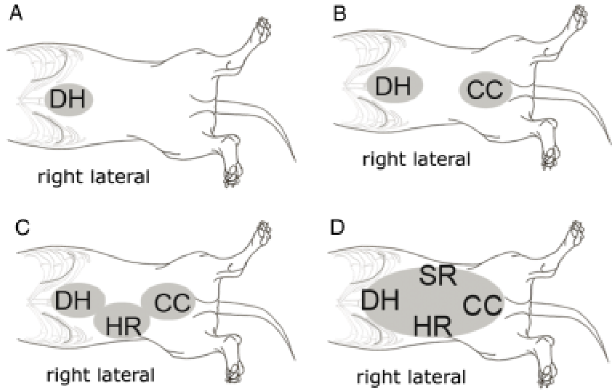

Figure 1: Illustration showing the relationship between abdominal fluid score (AFS) and the location(s) of the respective abdominal focused assessment with sonography for trauma (AFAST)-positive site(s) in right lateral recumbency. The AFS is defined as follows: (a) AFS 1, positive at any one site; pictured is the most common AFS 1 site, the DH view, (b) AFS 2, positive at any 2 sites; pictured are the 2 most common AFS 2 sites, (c) AFS 3, positive at any 3 sites; pictured are the most common AFS 3 sites which now become gravity dependent, (d) AFS 4, positive at all 4 sites. In lateral recumbency, AFAST inherently provides a depth gauge for volume of fluid as shown in the progression from AFS 1 to AFS 4. Note that lower-scoring AFS 1 and AFS 2 hemoperitoneum dogs are most commonly positive at nongravity dependent AFAST sites. DH, diaphragmatico-hepatic; SR, spleno-renal; CC, cysto-colic; HR, hepatorenal.

becomes anemic, the attending clinician to look elsewhere for another source of bleeding. Thus, the use of patient AFS reliably predicted the potential for anemia based on patient score (AFS 1 and 2 group versus AFS 3 and 4 group).[34] Equally as important is recording the location of positive sites because positive sites in lower-scoring dogs (AFS 1 and 2) that increase in AFS (AFS 3 and 4) may help direct surgeons more expediently to the origin of hemorrhage if the bleeding becomes refractory to medical therapy.[34] Sparse information is available regarding the source of hemorrhage in dogs with traumatic hemoperitoneum. Mongil et al[67] found in a small retrospective study that of 12 dogs necropsied or operated, that the source of hemorrhage was the spleen (58%), liver (50%), kidneys (23%), and external iliac artery (8%).[67] Widespread use of the AFAST-applied AFS in a standardized fashion (Table 1) may help clarify the source of bleeding in dogs, and aid in the development of algorithms or guidelines for blood transfusions, and emergent exploratory laparotomy because none currently exist.[38,88]

In the study by Lisciandro et al,[37] subsequent AFAST scans were performed in stable patients 4 hours after the initial AFAST exam similar to guidelines created by the American College of Emergency Physicians. The authors reported that 17% of dogs changed score.

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

Patient positioning	Right or left lateral recumbency (right preferred)
Gall bladder	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)
Diaphragmatico-hepatic (DH) view	
Pleural fluid	Present or absent (mild, moderate, severe)
Pericardial fluid	Present or absent (mild, moderate, severe)
Positive or negative (0 negative, 1 positive)	
Diaphragmatico-hepatic site	0 or 1
Spleno-renal site	0 or 1
Cysto-colic site	0 or 1
Hepato-renal site	0 or 1
Abdominal fluid score: 0–4 (0 negative all quadrants to a maximum score of 4 positive all quadrants)	

The FAST exam is an ultrasound scan used to detect the presence of free abdominal fluid and other conditions as a screening test in order to better direct resuscitation efforts and patient care. FAST allows indirect assessment for evidence of intraabdominal injury or disease and intrathoracic injury or disease. The FAST exam is not intended to replace a formal diagnostic ultrasound exam of the abdomen.

Unstable dogs had serial AFAST exams performed sooner. Of the dogs that changed score, 75% increased their score, which suggested ongoing hemorrhage. Of the dogs that increased in score, 50% were initially AFAST-negative dogs. It is therefore important to be cognizant of the fact that many dogs appeared clinically stable and may have otherwise been treated as outpatients. No AFAST-positive dogs reverted to AFAST negative on the 4-hour serial FAST exam suggesting that serial FAST examinations provide increased Se in diagnosing otherwise occult intraabdominal injury and that it may reduce the frequency of false negatives.[5,42,84]

In summary, by performing at least one serial AFAST examination with the application of the fluid scoring system 4 hours post initial exam, dogs with more serious injury are less likely to be missed. Serial AFAST examinations may be continued (eg, every 4–6 h in stable patients) throughout hospitalization in cases that continue to have increasing fluid scores (having not reached the maximum score (AFS 4), or subsequently scheduled in dogs having worsening anemia, or in both instances. Once dogs reach the maximum score (AFS 4), serial examinations (suggested by the author every 8–12 h) remain helpful for monitoring resolution of hemoperitoneum (scores begin decreasing). In the author's experience, most dogs that stop bleeding, have near resolution of their AFS (ie, AFS decreases to 0) within the subsequent 48 hours. Autotransfusion rates post-trauma have not been directly studied in dogs with hemoperitoneum; however, dogs receiving blood transfusions IP had maximum rises in PCV 48 hours post transfusion.[89]

The Standardization of AFAST and the Abdominal Fluid Scoring System

Several modifications to the AFAST examination should be considered for standardization of the veterinary technique.[34] Although AFAST has been studied in both left and right lateral recumbency,[34,37] the author prefers right lateral recumbency (unless injury makes left lateral recumbency safer or more comfortable) because right lateral recumbency is the standard position for ECG evaluation and echocardiography.[34] It is also arguably a better position for abdominocentesis because iatrogenic puncture of the spleen is less likely because the spleen lies anatomically more left of midline. Additionally teaching the technique may be easier and ensure that sites are adequately surveyed by renaming sites by their intraabdominal target organs[34] rather than their external locations[37] as has been done in some human protocols,[1,4,34,90] eg, diaphragmatico-hepatic (DH) versus subxiphiod; spleno-renal (SR) versus left flank; cysto-colic versus midline over the urinary bladder; hepato-renal (HR) versus right flank (Figure 2).[34,37] Furthermore, a different veterinary imaging order has been suggested by the author starting with DH site, which is the most commonly positive site in low-scoring dogs, and moving in a counterclockwise manner finishing with the most gravity-dependent HR site.[34] Importantly, the left kidney (part of the SR view), a

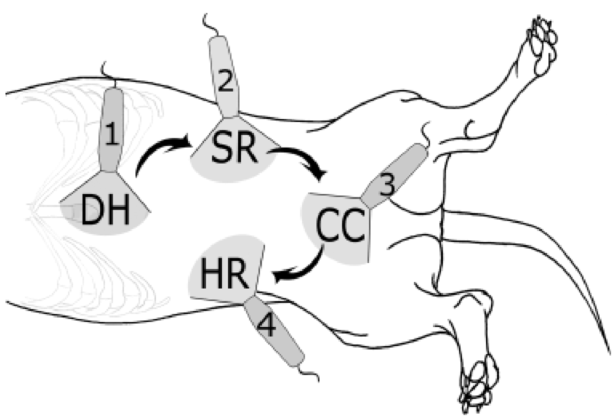

Figure 2: Depiction of the 4-point abdominal focused assessment with sonography for trauma, triage and tracking (AFAST), protocol performed in right lateral recumbency beginning at the diaphragmatico-hepatic (DH) view, followed by the spleno-renal view (SR), the cysto-colic view (CC), and completed at the hepato-renal view (HR). Direction (arrows) and order of AFAST exam (numbered ultrasound probes) are illustrated.

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window into its respective retroperitoneal space, and the gall bladder (part of the DH view) are readily imaged in right lateral recumbency, ie, the left kidney is not obscured by the rib cage (as is the more cranially located right kidney); and the gall bladder (located to the right of midline) is reliably imaged by directing the probe laterally toward the table top.

The author's suggested HR site, which is the most gravity-dependent site in right lateral recumbency, has been modified from use in people (Morison's pouch). Because dogs are laterally compressed, the right kidney and right lateral lobe of the liver are usually less accessible because they are located under the caudal rib cage in contrast to human anatomy. Thus, the HR target organs are not routinely pursued during AFAST, but rather, at the HR view, loops of the gastrointestinal tract are more typically imaged being in the most gravity-dependent region of AFAST. In cases in which the right retroperitoneal space needs imaging due to suspected occult hemorrhage or urine leakage, the right kidney and its associated fossa, are more aggressively pursued often necessitating moving the patient to left lateral or degrees of dorsal recumbency. Clinicians should keep in mind, however, that many injured dogs are less tolerant of more dorsal positioning and the extended duration of the exam needed to acquire the respective target organs (right kidney and its renal fossa of the caudate liver lobe). As the HR view is the most gravity-dependent site (in right lateral recumbency) when positive, it is the most appropriate site to perform abdominocentesis for fluid characterization while at the same time completing the AFAST exam. In lower-scoring dogs, however, abdominocentesis may be performed at any positive site at the attending veterinarian's discretion. Noteworthy, the most common positive sites in lower-scoring dogs (AFS 1) appear to be the DH and cysto-colic nongravity dependent views,[34] and these may be important considerations for AFAST training. Dorsal recumbency should be avoided for AFAST examinations. The published abdominal fluid scoring system[30] was not designed to be performed in dogs in dorsal recumbency and in general is more stressful to the dog because it requires more restraint and potentially compromises breathing in traumatized dogs that commonly have thoracic injury.[33,37,68,91–95]

The use of a standardized template for medical records makes AFAST findings clinically relevant (Table 1). Both patient score (AFS 0–4) and the location of positive sites should be documented within the record. It seems logical that in dogs with AFS of 1 or 2, the respective positive sites would suggest origin of injury, and thus, may be helpful in the event that surgical exploration, interventional radiology, or advanced imaging are subsequently pursued. Additional recorded information should include the presence of an intact urinary bladder, gall bladder, or the identification of a diaphragmatic rupture. By routinely recording this information, it may be possible to relate subsequent findings of imaging, such as radiography, diagnostic US, CT, or at surgery or necropsy, to AFAST findings. These suggestions for standardization of the AFAST examination for veterinary patients are based on the author's extensive experience (>1,000 exams).

The AFAST Examination in Penetrating Trauma

FAST findings in a prospective human study have shown low Se (46–48%) and high Sp (94–98%) for intraabdominal injury when compared with findings on local wound exploration, at surgery or on CT.[96,97] However, a positive FAST exam in people is considered significant and warrants emergent laparotomy.[61,97] The attending clinician, however, also utilizes information acquired via physical examination, local exploration of wounds, radiographic modalities, laparoscopy in decision making regarding the need for surgery in people.[96,97] The authors found that AFAST findings as a first line screening test at triage were less reliable than findings on physical examination, abdominal radiography, and local wound exploration in predicting the presence of intraabdominal injury and need for emergent exploratory laparotomy; and that AFAST rarely changed patient management similar to human studies.[96,97] AFAST was applied to the majority of dogs (41/42) having penetrating trauma (2 gunshot wounds, 1 arrow, and 39 dog attacks) in the TFAST case series of 145 dogs.[33] The clinical utility of initial and serial AFAST use, however, is unknown for this subset of traumatized veterinary patients and warrants further investigation because major decision making often involves distinguishing medical from surgical cases and that the predominant type of penetrating trauma differs in dogs (bite wounds) from people (projectiles and stab wounds). Importantly, the attending veterinarian should be aware of the potential low yield of AFAST and rely on more traditional guidelines in decision making.[98] Until further research has evaluated the clinical utility in this subset of patients, AFAST should probably be considered an ancillary test due to its low Se for detecting injury in penetrating abdominal trauma.

Both the human and veterinary literature describe the sonographic diagnosis of pneumoperitoneum, as an indication for emergent exploratory laparotomy.[99,100] Such surveillance is not an objective of AFAST; however, the sonographic appearance of pneumoperitoneum should be included in AFAST training because sonography does not transmit through air and its presence would potentially confound the study. Moreover, the prompt recognition or suspicion of pneumoperitoneum during an AFAST exam would potentially have a positive effect in patient management, eg, prompt an abdominal radiograph or an emergent exploratory laparotomy. Lateral recumbency or dorsal recumbency with laterally directed imaging is preferred by veterinary radiologists when pneumoperitoneum is present to avoid air because it rises and interferes with sonographic examination. Pneumoperitoneum may also occur iatrogenically, eg, postabdominal surgery, laparoscopy, interventional radiology, percutaneous biopsy, DPL, abdominocentesis. Thus, it seems plausible that with patients positioned in right lateral recumbency, the nongravity dependent SR (HR in left lateral recumbency) views would lend themselves for the detection of free-IP air. There is no information regarding the Se and Sp for the detection of pneumoperitoneum using sonography or comparing imaging modalities, or patient positioning. The limitations posed by free air and the sonographic diagnosis of pneumoperitoneum warrant further study. In contrast to the limited usefulness and unreliability of radiography in blunt trauma,[34] radiography remains an integral part of all penetrating trauma evaluations.[98] In summary, penetrating trauma evaluations should include radiographic examination, and possibly serial AFAST examinations to aid in decision making.

The AFAST Examination in Nontraumatic Cases

In dogs that present for nontraumatic signs such as collapse, episodic weakness or disorientation without clear seizure activity, and undifferentiated hypotension, the use of the FAST and bedside sonographic techniques are invaluable for rapid detection of potentially life-threatening problems.[43,65] In the author's experience, many of these patients will have nonspecific findings based on physical examination, laboratory, and radiographic imaging, but will have pathology rapidly diagnosed on triage by an AFAST exam. Results of an AFAST provide the attending clinician with an extension of the physical examination and expedites the timely diagnosis of many conditions often delayed or missed by traditional means, eg, hemoperitoneum,[55] hemothorax, acute cardiac tamponade, ruptured viscous, acute peritonitis, and anaphylaxis (thickened gall bladder wall).[101]

A good example where FAST exams may be applicable in nontraumatic cases is in patients with acute cardiac tamponade. This condition is often under-recognized by physical examination or thoracic radiography, but readily diagnosed using US.[1,16,20,102,103] In these patients, if cardiac tamponade is not detected and the need for pericardiocentesis overlooked, then fluid resuscitation may lead to rapid deterioration. Performing an additional TFAST exam may provide the attending clinician not only with the rapid diagnosis of cardiac tamponade, but additionally enable the identification of comorbidities such as ascites, pleural effusion, and pulmonary edema. The information obtained through the combination FAST examination of both body cavities has the potential to guide clinical course.

The FAST techniques may also be used to preempt a formal diagnostic US analogous to a cursory physical exam at triage preempting a full physical examination. Lastly, FAST examinations may be used for monitoring the progression and resolution of otherwise occult or unrecognized conditions by traditional means in trauma and nontraumatic patients. The extension of the physical examination provided by point-of-care sonography including FAST techniques have been shown to positively affect patient management and outcome in people.[5,6,16,29,104]

With the advent of FAST examinations, the yield of abdominocentesis has improved dramatically compared with the previously reported success rate obtained via a 4-quadrant blind abdominocentesis (94–97% versus 50–78%, respectively).[34,37,66,67,105,106] In cases where the fluid pocket is too small or in a location that cannot be safely aspirated, DPL is a diagnostic alternative. The attending clinician, however, should realize that DPL usage may confound subsequent imaging by the iatrogenic placement of fluid and possibly air into the peritoneal cavity.[1,107] The ability to perform serial FAST examinations to monitor effusions and continue to fluid score patients is another advantage.

Pneumoperitoneum, an indication for emergent surgical intervention, may also be detected by US[99,100] and warrants further study. In a retrospective case series of dogs and cats with gastrointestinal perforation, 37% of patients (7/19) had free-IP air detected by supervised radiology residents or board-certified veterinary radiologists.[100] Despite the expertise required for reliable US diagnosis of pneumoperitoneum, it behooves the attending clinician performing AFAST to be cognizant of artifacts created by free IP air because its presence may confound the exam quality. Lastly, postoperative high-risk cases for peritonitis, eg, postoperative gastrointestinal surgery patients, or those recovering from gall bladder surgery or urogenital surgery, may be monitored in a similar manner by recording positive sites and using serial AFS scoring. Performing AFAST scans gives the attending clinician the opportunity to detect complications early and the location of AFAST-positive sites may suggest the source of pathology. Monitoring patients with serial AFS could potentially prompt changes in patient management and allow

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expedient management of emerging complications. The use of AFAST for 'Tracking' or monitoring clinical conditions warrants further study in various subsets of critically ill veterinary patients.

The AFAST Advantage Over Physical Examination, Abdominal Radiography, DPL, and CT

Historically, clinicians have based the diagnosis of traumatic hemoperitoneum unreliably on clinical suspicion, physical examination, laboratory findings, and abdominal radiography[1,4,16,30,33–36,47–53,88,107] with definitive diagnosis based on abdominocentesis and fluid characterization.[30,33,54,72] Although physical examination and laboratory findings have been compared between AFAST-negative and AFAST-positive dogs, such differences generally are not clinically helpful,[30,54] especially regarding dogs with lower AFS scores because many compensate and are hemodynamically stable despite hemorrhage.[30,47] Regarding DPL, FAST has nearly replaced this technique at most human trauma centers.[2,4,11–15] Importantly, clinicians should be aware that the use of DPL potentially limits the clinical utility of subsequent physical examination findings and advanced imaging because of possible abdominal wall pain, inadvertent puncture of intraabdominal organs, and the introduction of free fluid or air into the abdomen.[1,107] FAST is commonly used for screening patient need for CT, which remains the gold standard for the detection of intraabdominal injury in human patients because it has the highest Se and Sp for free fluid and importantly parenchymal injuries when compared with other modalities.[16] CT has several significant limitations, however, including availability, nonportability, amenability to serial exams, radiation exposure limiting patient interaction, to name a few. Moreover, the patient must be hemodynamically stable for transport[4]; and complications during transit are well known to occur in human hospitals.[29] Confirmatory CT studies may also require the use of contrast medium and thereby pose further risk to traumatized patients.[108–110] Finally, CT has been regarded as overly sensitive in detecting clinically irrelevant injury, called CTomas, leading to unwarranted interventions.[1,5,83]

Limitations, Pitfalls, and Conclusions for AFAST Training and Serial Use

Demonstrating clinical competency at performing FAST remains controversial in people with a wide range of suggested number of exams (50–400 exams) required to be performed to demonstrate proficiency in this technique.[111] Recommendations for training include lecture time, hands-on training, followed by proctored exams on actual patients in the clinical setting.[16,20,30,31,111–113] In the study by Shackford et al,[111] a detailed protocol was implemented which factored in prevalence of disease, initial operator performance, Se, Sp, error rate, and determined the need for follow-up training and the required number of exams for operator to gain proficiency at the techniques. It appears that this also depends on the individual's previous US experience and in one's learning curve.[111]

It is important that training programs for veterinarians similarly acknowledge limitations of the technique including its potential for false positives and false negatives relative to the respective FAST sites and the possibility of inconclusive exams.[1,20,111,114] Briefly, false positive AFAST scans are most common at the DH and SR sites in the author's experience in proctoring examinations by colleagues. At the DH view, the gall bladder and the common bile duct can appear as hypoechoic, sharp angles, similar to free fluid depending on the plane of imaging. Similarly, hepatic veins, especially when congested as a result of both trauma and non-trauma–related conditions, and the caudal vena cava may be mistaken for free abdominal and pleural fluid, respectively. With adequate training via established veterinary guidelines created similar to those in human medicine, these obstacles can easily be overcome. At the SR view, bowel loops and adjacent great vessels and their tributaries may appear as hypoechoic linear stripes[20] or sharp-angled triangles suggesting free fluid. Use of color Doppler mode,[115] when available, can help discern free fluid from vascular structures, but this is often unnecessary if suspect areas are evaluated carefully by tracing their course. In people, false positives most commonly involve retroperitoneal hemorrhage mistaken for free intraabdominal fluid. This is because humans undergoing FAST exams are placed in the supine position and are anatomically flattened in an anterior-posterior manner. As a result, the peritoneal and retroperitoneal spaces are in greater proximity to one another in contrast to dogs that are placed in lateral recumbency and are anatomically compressed in a lateral manner. Because of these differences the distinction between the 2 spaces may be less problematic in dogs. To the author's knowledge, no studies have been performed evaluating Se and Sp for the sonographic detection of retroperitoneal fluid. In addition, the intrapelvic region in people is a common site of major hemorrhage missed by FAST examination.[116,117] To the author's knowledge, significant pelvic bleeding causing anemia has not been reported in dogs; however, the complication does occur in cats.[118] Finally, inconclusive FAST exams may occur in obese people or those with subcutaneous emphysema.[1] Although this has not been formally studied in veterinary patients, this has not been a significant limitation in the author's experience.

In summary, a serial 4-hour post initial AFAST is recommended similar to human guidelines[85] in all stable hospitalized patients due to the fact that placing human patients on even modest rates of fluid therapy has the potential to exacerbate occult hemorrhage or low-grade hemorrhage; and in veterinary patients serial AFAST allows semiquantifying degrees of hemorrhage by comparing initial and serial AFS.[55,119–122] Moreover, the serial exam increases the Se of FAST and may positively impact patient outcome.[1,5,6,84] Serial AFAST examinations allow clinicians to monitor for ongoing hemorrhage (eg, increasing AFS) and possibly its resolution (eg, decreasing AFS). Based on findings by Lisciandro et al,[34] in which dogs with pneumothorax and pelvic fractures were often AFAST positive on initial exam, or more likely to become positive on the serial exams than dogs without these injuries, it may be appropriate that dogs with these types of injuries warrant a serial AFAST survey to evaluate for developing hemoperitoneum even when AFAST negative on initial exam.

The Development of TFAST

Interestingly, Boysen et al[37] found that intrathoracic trauma (eg, pleural effusion) could be identified from the traditional FAST exam using the subxiphoid site (DH view) as a window into the pleural and pericardial spaces.[37] This corresponds to findings in human studies which have demonstrated the subxiphoid site to have excellent Se and Sp and to be superior to thoracic radiography for the detection of pleural and pericardial effusions (PE).[1,2,8,9,16,21–26,102,103,123–125] Because of anatomical differences in thoracic cavities of people and dogs, there are important implications to be aware. For example, the heart rests on the diaphragm in people but not reliably in dogs. Thus, the subxiphoid site in veterinary patients has inherent limitations. This location, the AFAST DH view, is helpful for the detection of pleural and pericardial fluid based on the author's experience; however, additional studies comparing imaging modalities are warranted. The value of this site for the detection of pneumothorax has not been evaluated. In 2005, Lisciandro et al[33] set out to investigate whether they could develop a clinically relevant TFAST protocol to complement the AFAST exam for rapid global patient evaluation.

The reluctance to adopt the use of US to evaluate the thorax in people and small animals has historically related to the belief that air was an insurmountable obstacle to proper imaging.[21,22,126–128] Because the diagnosis of pneumothorax relies on the interpretation of artifacts and not actual imaging of lung parenchyma, inaccurate and confusing descriptions regarding the US assisted diagnosis of pneumothorax in people have been published.[21,22,114,129,130] The use of US for the identification of pneumothorax has only recently been accurately described in people.[21,22,27] It was also believed that the ultrasonographic diagnosis of pneumothorax was an 'all-or-none' phenomenon.[21,22,131,132] In other words, only the presence but not the degree of pneumothorax (partial versus massive) could be determined, and therefore, the information was of limited clinical use.[21,22,130]

Since 2001, Kirkpatrick and colleagues have published several studies on an 'extended FAST' examination, which utilizes US to diagnose pneumothorax, the number 1 most preventable cause of death in human trauma patients.[23–26,133] In 2005, Lichtenstein et al[131] described using the 'lung point' to assess the degree of pneumothorax (partial versus massive) present.[131] This was a major step forward in promoting thoracic US use in people with trauma[21,22,131,132] and as a result, the use of US to diagnose pneumothorax has become more commonplace in human medicine not only in trauma, but nontraumatized, and critically ill patients as well.[21,22] Similarly, small animal veterinary clinicians have largely underutilized lung US despite being a well-known clinical application in large animal medicine for more than 20 years.[134–139] Currently, lung US is being favorably compared with CT in both traumatized people[8–10,21,23–26,123–125,140–142] and also in respiratory compromised patients in both the emergency and critical care settings.[21,22,27,28,39,143–145] It appears that in fact, US-diagnosed pneumothorax may have superior Se and Sp compared with thoracic radiography.[1,8,10,139,146–149] In human medicine, thoracic radiography performs poorly in the diagnosis of trauma-induced pneumothorax missing up to 55–72% of cases. Pneumothorax found on CT but missed by radiography is referred to as 'occult pneumothorax.'[10,21,140,146,150]

The use of thoracic sonography is emerging as a reliable tool to aid in the diagnosis of pulmonary contusions, cardiogenic and noncardiogenic pulmonary edema, acute respiratory distress syndrome, pneumonia, and pulmonary thromboembolism with high Se and Sp when compared with CT.[27,28,39,143,151,152] Lung US has many advantages: It is a point-of-care technique that is radiation sparing, it can be rapidly and safely applied in serial fashion, and lastly, it is noninvasive and performs better (higher Se) that thoracic radiography in many pulmonary conditions.[22,29,39,140,152] The author has used the complete TFAST technique in a variety of clinical conditions including pulmonary contusions, cardiogenic and noncardiogenic pulmonary edema, and pneumothorax. In addition, the author has been able to follow the resolution or recurrence of pneumothorax,[33] pleural and PE, cardiogenic and non-

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cardiogenic pulmonary edema, through serial monitoring using the TFAST.

Evolution of the TFAST Exam

The TFAST examination originally included 4 views[33] including the right and left chest tube site (CTS) for pneumothorax, and the right and left pericardial sites (PCS) for pericardial and pleural fluid and estimation of volume status (Figure 3).[33] Unlike the AFAST examination, where the patient is positioned in lateral recumbency for the exam, TFAST may be performed in lateral or sternal recumbency, which is generally less stressful and safer for respiratory compromised patients. Moreover, sternal recumbency is used to assess the degree of pneumothorax by searching for the so called 'lung point.' Dorsal recumbency is not advised because this positioning can be dangerous in patients with respiratory distress. As with the AFAST examination, the fur is not clipped, but is parted and wetted with alcohol.

The currently used TFAST exam by the author includes 5 views with the addition of the AFAST DH site because of its increased Se for the presence of pleural and PE in people.[1,20,102,103] In fact, the view has highest Se and Sp, for the diagnosis of PE in people.[123] The CTS is the first site evaluated during the examination and is

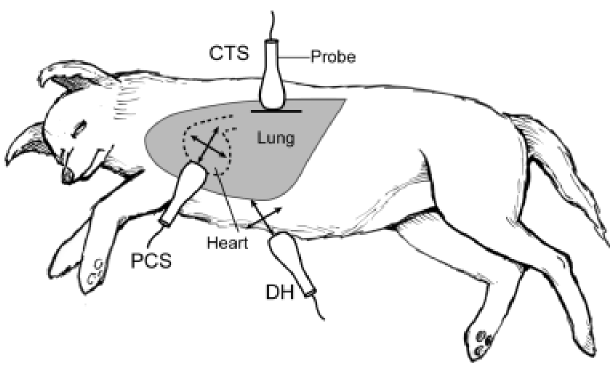

Figure 3: Depiction of the new modified 5-point thoracic focused assessment with sonography for trauma, triage and tracking (TFAST) protocol performed in right lateral or sternal (safer position for compromised patients) recumbency consisting of bilateral chest tube site (CTS) views, pericardial site (PCS) views, and the diaphragmatico-hepatic (DH) view. At the CTS view, the ultrasound (US) probe is held only horizontally in stationary fashion for evaluation of the presence of glide sign or lung rockets each excluding pneumothorax (bold solid line with no arrows). At the PCS view, the US probe is moved through the short- and long-axis views to rule out pleural and pericardial fluid (bold lines with arrows). The DH view, the fifth point, is used to detect the presence of pleural and pericardial fluid. Note that as depicted only 4 of the 5 TFAST views are imaged in lateral recumbency. The opposing (right side) CTS view (not shown) is imaged once the patient is moved to sternal recumbency.

performed on both the right and left sides of the patient. This CTS site is familiar to emergency and critical care veterinarians as the highest outward point (seventh or eighth intercostal spaces) of the dog's thorax dorsal to the xiphiod where a chest tube would be placed. The CTS is a stationary view whereas all other TFAST (and AFAST) views are dynamic with fanning of the probe; and is examined with the probe held horizontally for the greatest degree of interface between the lung and chest wall, or more specifically, the parietal (chest wall) and visceral (lung) pleura. The ribs and their respective hypoechoic shadows are identified as landmarks to locate the pleural-pulmonary interface (PP-line) representing the strong interface between US and air. Together the ribs and PP-line create the appropriate orientation for observing the 'glide sign.'[21,22,33] The glide sign can be described as the normal to-and-fro motion of the lung gliding along the chest wall, and it is observed when there is no pleural space, pulmonary, or chest wall pathology present.[127] The PP-line is not to be confused by subsequent equidistant A-line artifacts through the far field (Figure 4) or obscured by SC air (Figure 5).[21,22,33] Using B-mode, still images in the absence of pulmonary or pleural space disease or chest wall trauma appear identical for the normal view and pneumothorax.[21–23,26,33] US-diagnosed pneumothorax is immediately ruled out by the presence of lung rockets (also referred to as comet tail artifacts or B-lines).[21,27,28,33,39,143,153] Ultrasound lung rockets (ULRs) are defined as hyperechoic lines originating from the PP-line. They must obliterate A-lines, extend to the far field, and move in a pendulous fashion with inspiration and expiration.[21–23,27,33,39,143,153] In summary, US-diagnosed pneumothorax is a real time, hands-on technique that is ruled out if the glide sign or ULRs are observed (Figure 6). In the author's experience, CTS views are the best TFAST sites for diagnosing pneumothorax and for screening for lung pathology. It also provides the ability for rapid diagnosis of pulmonary contusions when ULRs are observed in trauma patients.[154] Other injury is suspected when the 'step sign,' a deviation from the normal linear continuity of the PP-line, is observed. This may include intercostal tears, rib fractures, hemothorax (ventrally positioned PCS is a better view), and diaphragmatic rupture. These TFAST findings have been described previously and illustrated.[33] Finally, the 'lung point,' where the lung resumes contact with the chest wall, can be identified by moving the probe ventrally along the thorax to determine the degree of pneumothorax with the patient placed in sternal recumbency (Figure 7).

Following the examination of the CTS views, the left and right PCS are examined. These sites are similar to the parasternal views for echocardiography. The PCS

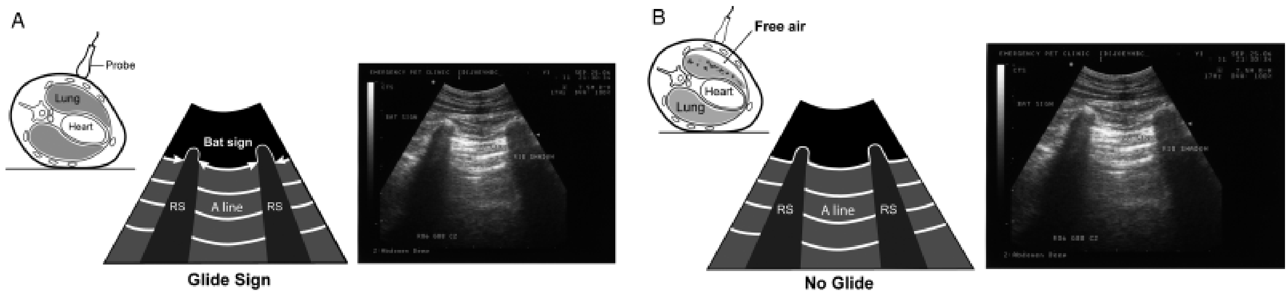

Figure 4: (a) Normal B-mode still image CTS view orientation for thoracic focused assessment with sonography for trauma, triage and tracking (TFAST). The 'bat sign' composed of adjacent ribs with the PP-line (bright white line) interposed between, is likened to a flying bat. Along the PP-line, the presence of a glide sign indicates normal apposition of lung against the thoracic wall, thus ruling out pneumothorax. The bold white arrows indicate motion to and fro during inspiration and expiration (bold line with arrows, glide sign). (b) CTS view illustrating pneumothorax, where the glide sign is absent, as a real-time finding, depicted by lack of arrows along the PP-line. *Note*: B-mode still images are identical to illustrate that a normal PP-line is indistinguishable from the presence of free pleural air; and the dynamic presence or absence of the glide sign is the distinguishing feature between a normal pleural space and pneumothorax. CTS, chest tube site; PTX, pneumothorax; RS, rib shadow; A-line, air reverberation artifact; PP-line, pulmonary-pleural interface.

views are located caudal to the point of the elbow or often rapidly detected adjacent to the point where the heart beat is palpated through the thoracic wall. At these sites, the ventral thoracic cavity is scanned for pleural fluid and the pericardial sac for PE. Also, evaluation of volume status may be subjectively made by the left ventricular short-axis view, the 'mushroom view,' and can also be serially monitored noninvasively as the patient is resuscitated.[a,155,156]

Finally, TFAST should include the AFAST DH site. The author strongly recommends the 'new' 5-point standardized TFAST exam. The DH view has less lung interference (air) and the liver and gall bladder serve as acoustic windows into the thoracic cavity. The veterinary DH may prove a more sensitive site for detection of intrathoracic effusions (pleural and PE) than the PCS view.[2,9,104,123–125] With further study, the DH view may also prove helpful with the diagnosis of pneumothorax because a glide sign exists between the lung and pleural surface of the diaphragm. Through experience the author has found that most degrees of PE including acute cardiac tamponade can be readily detected via the DH view. A standardized template for TFAST examination is proposed on (Table 2).

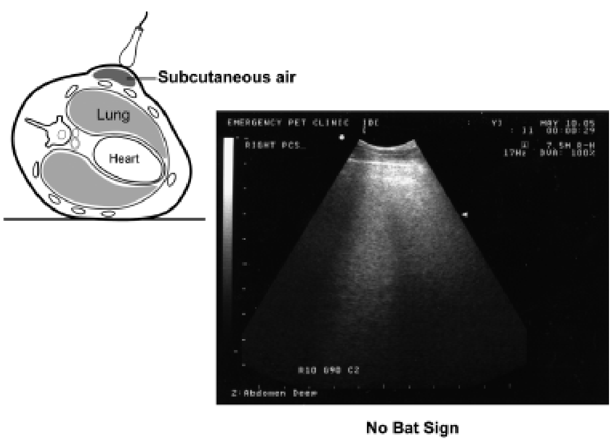

Figure 5: CTS view of the thoracic focused assessment with sonography for trauma, triage and tracking (TFAST) exam in which orientation of the 'bat sign' is not possible due to interference from SQE; thus, study is nondiagnostic. Gentle pressure at the probe-skin interface often displaces SQE and allows for proper orientation and TFAST examination in most instances. CTS, chest tube site; SQE, subcutaneous emphysema.

The Clinical Applications of TFAST in Blunt and Penetrating Trauma

In a clinical prospective study published in 2008, a 4-point TFAST exam was applied to 145 traumatized

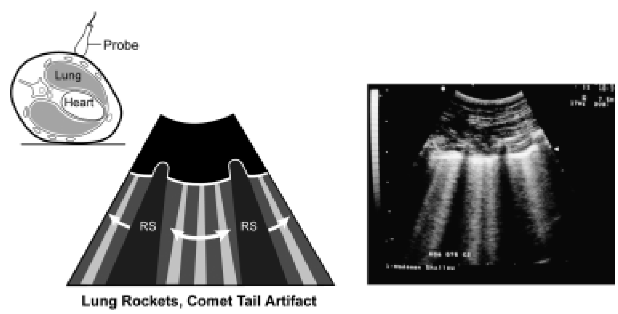

Figure 6: CTS view of the thoracic focused assessment with sonography for trauma, triage and tracking (TFAST) exam illustrating lung rockets (also referred to as comet tail artifacts or B-lines) that must extend from the pulmonary-pleural interface to the far field obliterating A-lines (reverberation artifact) as echogenic streaks that oscillate (bold arrows) with inspiration and expiration. Their presence rapidly rules out pneumothorax and may represent interstitial syndrome (interlobar edema or 'wet lungs'). CTS, chest tube site; RS, rib shadow; PTX, pneumothorax.

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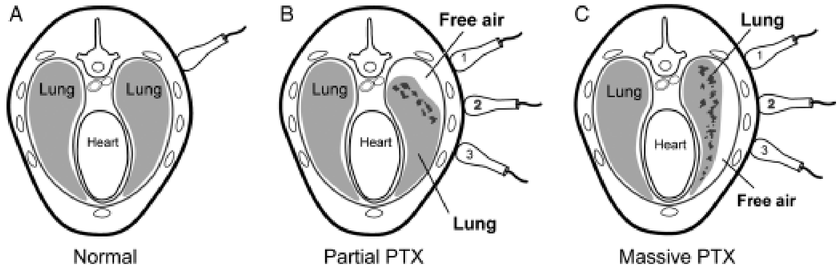

Figure 7: Cross-sectional canine thoraces depicting the quantification of the degree of pneumothorax as partial or massive by searching for the lung point with the patient positioned in sternal recumbency (safer than lateral recumbency in compromised patients). In the absence of the glide sign, lung rockets, or comet tail artifacts, 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) Pneumothorax has been identified at position 1 and the lung point at position 2 suggests the pneumothorax to be partial. (c) Pneumothorax has been identified and a lung point is nonexistent at any of the 3 probe positions, suggesting massive pneumothorax. CTS, chest tube site; PTX, pneumothorax.

dogs.[33] Of these patients, 103 incurred blunt trauma, (primarily HBC, $n = 93$) and the remaining 42 dogs incurred penetrating trauma cases (primarily bite wounds, $n = 39$). Authors found high overall accuracy (90%) and Sp (93%), but poorer Se (78%) in the detection of pneumothorax when compared with thoracic radiography.[33] They concluded that in anxious, painful, panting dogs, especially HBC dogs, observation of the glide sign, which rules out pneumothorax was more problematic. More specifically, the to-and-fro horizontal movement of the lung against the thoracic wall, the glide sign, was difficult to observe in dogs with rapid, shallow breathing especially for less experienced clinicians.[33] With the presence of lung rockets, pneumothorax is rapidly ruled out because this artifact requires the absence of free air in the pleural space.[33] With experience, confounding respiratory patterns can often be overcome with various manipulations of the probe or patient reevaluation postanalgesia. The higher Se (93%) and Sp (96%) in cases with penetrating trauma (patients had slower, deeper breathing pattern) supported their conclusion.[33] Furthermore, proficiency in performing the TFAST examination requires more experience than AFAST.[29] The nonradiologist veterinarian performing the most exams ($n = 77$), had excellent Se (95%) and Sp (96%)[33] comparable to findings in human studies.[10,27,28,133,149] Similar to the AFAST exam, median time for a TFAST was 3 minutes, although volume status evaluation was not routinely included in all dogs.[33]

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

*CTS glide sign	*Present (normal)* – no pneumothorax *or* *Absent* – Pneumothorax
*CTS lung rockets	*Present (no PTX)* – interstitial lung fluid (edema, hemorrhage) *or* *Absent* – no interstitial lung fluid (edema, hemorrhage)
*CTS step sign	*Present* – concurrent thoracic wall trauma (rib fractures, hematoma, intercostal muscle tear) or pleural space disease is suspected *or* *Absent* – no concurrent thoracic wall trauma or pleural space disease is suspected
*PCS view	*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*
Diaphragmatico-hepatic (DH) view: there is no apparent pericardial or pleural fluid present *or* there is pericardial effusion (mild, moderate, severe) or pleural effusion (mild, moderate, severe)	

*Right and left sides are listed in templates for the CTS and PCS views. The FAST exam is an ultrasound scan used to help detect chest wall, lung, and pleural and pericardial space problems as a screening test in order to better direct resuscitation efforts and patient care. FAST is not intended to replace chest radiographs or formal diagnostic echocardiography.
CTS, chest tube site; PCS, pericardial sac; LV, left ventricle; PTX, pneumothorax.

Advanced TFAST

The TFAST technique provides much more information than the presence or absence of pneumothorax and other thorax-related injury in traumatized dogs. The technique is clinically helpful in respiratory compromised patients because US can detect some types of pulmonary pathology. The major principle lies in the concept of the wet versus the dry lung; and the major artifact is the lung rocket.[21,22,27,143,153] ULRs, require the following features: they must arise from the pleural line, are wedge-shaped, echogenic, extending indefinitely through the far field erasing A-lines, and move with the glide sign when the glide sign is present (Figure 6).[21,22,27,34,94,134] ULRs represent interstitial syndrome, or interlobar edema, and are analogous to radiographic Kerley B-lines.[21,22,27,39,143,153] Importantly, the great majority of human lungs with interstitial syndrome have disease extending to the periphery of the lung, thus accessible to US detection.[27,28,39,143] Whether this occurs in dogs is unknown. ULRs are easily and rapidly recognized by the nonradiologist. Their presence immediately rules out pneumothorax while having significant clinical implications for the presence or absence of various pulmonary conditions. ULRs can be used both diagnostically and as a therapeutic monitoring tool in pulmonary, cardiac, and critically ill patients.[22,27,28,39,103,143,152]

In trauma cases, the author has found that ULRs at the TFAST CTS view generally represent pulmonary contusions similar to findings in people. Pulmonary contusions may be occult on radiographs, suggesting that US may possibly be more an Se imaging modality for this condition.[154] In nontraumatic respiratory cases, ULRs are likewise considered abnormal at the CTS view and their presence (wet lung) suggests either cardiogenic or noncardiogenic pulmonary edema. On the other hand, the absence (dry lung) of ULRs with an observed glide sign and A-lines makes it doubtful such conditions are present with high Se and Sp (>95%) in people.[22,27,28,39,103,143,151,152] In other words, the TFAST CTS view may be utilized to determine whether the lungs are 'wet' (presence of ULRs), or 'dry' (the presence of a glide sign and A-lines), or for the presence of pneumothorax (an absent glide sign with A-lines) (Figures 8–10).

In the author's experience, TFAST lung evaluation has been extremely helpful in case management because the presence of ULRs prompted diuretic therapy, reevaluation of fluid therapy, and additional imaging such as radiographs or echocardiography. Using TFAST is helpful for patient surveillance of critically ill patients

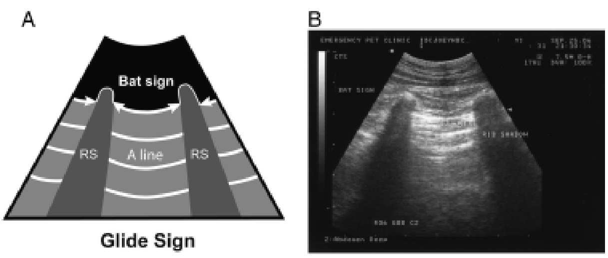

Figure 8: The CTS view of the thoracic focused assessment with sonography for trauma, triage and tracking (TFAST) exam. (a) The line drawing depicts a 'dry lung' when a glide sign is present. The strong ultrasound-air interface creates equidistant reverberation artifacts extending past the pleural-pulmonary line (PP-line) called A-lines (A = air). The arrows at the PP-line represent the glide sign. Note these A-lines are present in pneumothorax, the difference being the observation of the glide sign. (b) The B-mode still image of 'dry lung' when the glide sign is observed. CTS, chest tube site.

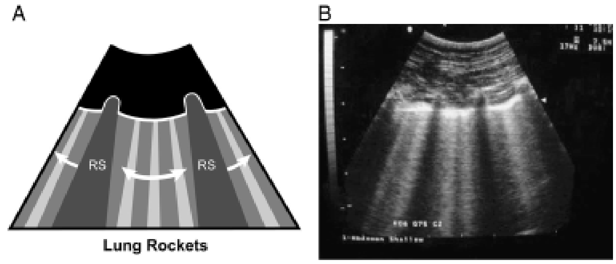

Figure 9: Interstitial syndrome or wet lung in B-mode ultrasound at the CTS view of the thoracic focused assessment with sonography for trauma, triage and tracking (TFAST) exam. (a) The line drawing depicts a wet lung illustrating lung rockets that must extend from the pulmonary-pleural interface to the far field obliterating A-lines (reverberation artifact) as echogenic streaks that oscillate (bold arrows) like a pendulum with inspiration and expiration. Their presence rapidly rules out pneumothorax but represents interstitial syndrome (interlobar edema or 'wet lungs'). (b) B-mode ultrasound still image of interstitial syndrome or wet lung (interlobar edema). CTS, chest tube site; RS, rib shadow; PTX, pneumothorax.

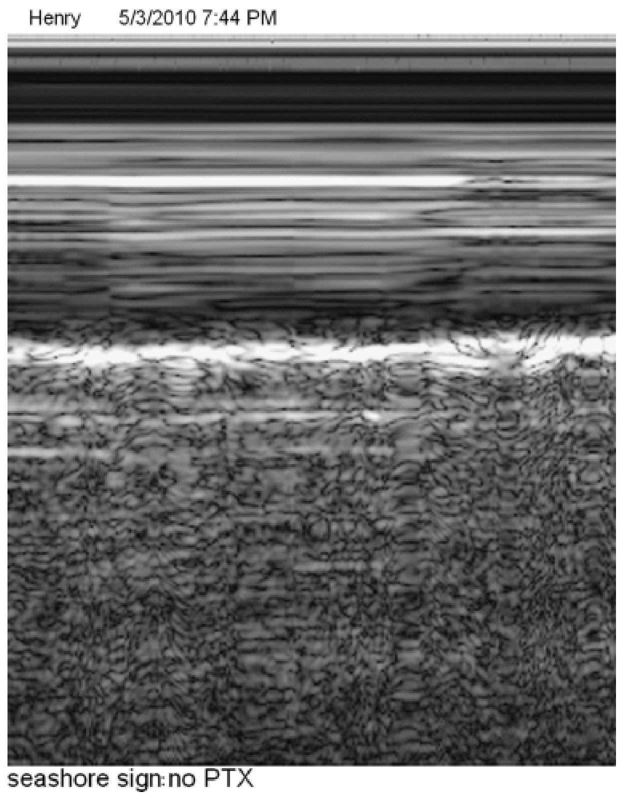

Figure 10: The ultrasound still image at the CTS view of the thoracic focused assessment with sonography for trauma, triage and tracking (TFAST) exam in M-mode shows a grainy, sandy texture beginning at the pleural-pulmonary line (PP-line) and extending to the far field. The B-mode observation of the to-and-fro motion of the glide sign is replaced by the seashore sign in M-mode and rules out pneumothorax. In the near field the skin and SC structures are imaged as bar code lines because there is no movement. The image obtained via a single crystal handheld device. CTS, chest tube site.

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for both the development and also the resolution of many pulmonary conditions.[22,27,28,143,152] Of note, ULRs are normally present along the diaphragm at the DH view and this site is thus not helpful for diagnosing interstitial syndrome. In addition, the frequency of ULRs at the ventral TFAST PCS views in normal dogs and cats has not been evaluated.

By combining wet and dry lung artifacts, it has been demonstrated recently in people that lung US is clinically helpful for aiding the diagnosis of acute respiratory failure. In a prospective study, lung US in adults had good predictive power for asthma/COPD (Se 89%, Sp 97%), pulmonary edema (Se 97%, Sp 95%), pulmonary thromboembolism (Se 81%, Sp 99%), pneumothorax (Se 81%, Sp 100%), and pneumonia (Se 89%, Sp 94%) with an overall diagnostic accuracy of 90.5% when compared with the respective gold standard for diagnosis.[27] In another similarly designed study using lung US in neonates, Se and Sp was excellent for the diagnosis of chest pathology: 92% and 93% for pleural effusion, 90% and 98% for alveolar consolidation, 93% and 93% for interstitial syndrome, 100% and 96% for complete pneumothorax, and 79% and 100% for radio-occult pneumothorax.[28] Utilizing wet and dry lung findings, lung US had good correlation with pulmonary artery occlusion pressures in patients being fluid challenged at-risk for volume overload and the development of pulmonary edema.[143] People with a glide sign and A-lines are unlikely to have pulmonary edema (Se 97%, Sp 95%).[27,143] Lastly, ULRs were shown to be more sensitive than thoracic radiographs in diagnosing acute respiratory distress syndrome in a porcine research model[157] and ULRs have been used for estimating the amount of interstitial edema present in respiratory disease patients.[152] This is particularly important because worsening gas exchange, reduced pulmonary compliance, and presence of pulmonary opacities on radiographs are poor indicators of the severity of pulmonary edema; and that positive fluid balance and pulmonary edema are associated with worse outcomes in critically ill patients.[39] TFAST (and lung US) via its CTS view (right and left sided) provides a clinically relevant technique to survey veterinary patients in the emergency and ICU setting. In the author's opinion, its use should no longer be limited by the current mindset, but become an integral part of emergency and critical care training. Further studies should focus on its clinical utility in different veterinary pulmonary conditions.

The Use of TFAST for PE

Since the author's emergency and critical care practice has been utilizing TFAST during triage, PE have been detected far more frequently than previously. As reported in people, classic signs of PE such as tachycardia, muffled heart sounds, and increased venous pressure are easily missed.[1,147] In people, clinical studies using FAST for the detection of PE have shown excellent Se (100%) and Sp (97–99%)[1,20,102,103] with an accuracy of 97%;[102] and the subxiphiod view, comparable to the veterinary DH view, is considered by some, the diagnostic gold standard.[123] In the author's practice, PE has been detected by TFAST in many dogs that presented for collapse or respiratory distress including cardiac patients, eg, left atrial rupture, in which PE was undetected on thoracic radiograph and physical examination findings. In the author's experience, the modified 5-point TFAST, using the PCS and DH views, quickly identifies PE through multiple views and allows for immediate therapeutic intervention such as pericardiocentesis.

Limitations, Pitfalls, and Conclusions for TFAST

Recognizing potential limitations of TFAST should be an integral part of training.[1,20,114] One of the challenges identified by Lisciandro et al[33] is that the glide sign at the CTS view can be difficult to assess in panting dogs due to the rapid lateral movement of the thorax.[33] Studies have recently been published regarding the use of training modules for nonradiologist physicians. In Noble et al,[155] training was easily attained for the diagnosis of pneumothorax and the presence of pulmonary edema using lung rockets or comet tail artifacts.[155] Recently, a study challenged the Se and Sp for the diagnosis of pneumothorax suggesting that with training using video clips alone, food inspectors and nonmedically trained personnel could be used triage trauma patients for the presence of pneumothorax.[156] The study design, however, incorporated cadaver pigs with controlled ventilatory patterns and experimentally induced pneumothorax, a much different scenario than live traumatized dogs. In summary, thoracic scans require more training for proficiency relative to AFAST scans in people[20,30,31,112–114] similar to what has been shown in AFAST and TFAST in dogs.[33,34,37]

Moreover, in the human literature, it has been demonstrated that US-diagnosed pneumothorax is a real-time diagnosis and transmitted video clips are unreliable for diagnosing pneumothorax[26] and B-mode still images look identical in normal lungs and those with pneumothorax.[21–23] As a result, alternate techniques have been evaluated to assist in the US diagnosis of pneumothorax using M-mode and power Doppler because both provide still image documentation.[21,22,26] For example, using power Doppler, the 'power slide' can be observed with colored pixels along

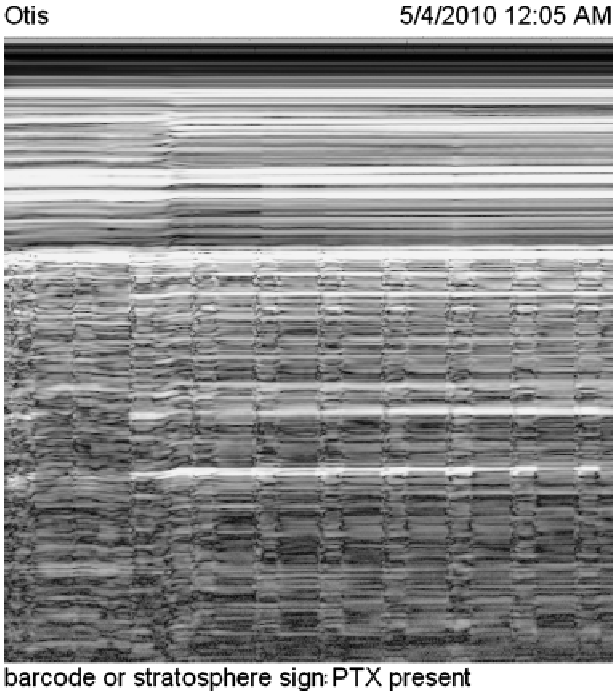

Figure 11: The ultrasound still image in M-mode at the CTS view of the thoracic focused assessment with sonography for trauma, triage and tracking (TFAST) exam depicting the 'bar code sign.' In the near field the skin and SC structures are imaged as bar code lines because there is no movement. In pneumothorax, the distinct bar code lines continue through the far field. Image obtained via a single crystal handheld device. CTS, chest tube site.

the PP-line and be printed for documentation as a still image ruling out pneumothorax.[26] Regarding M-mode, the 'seashore sign,' or the 'stratosphere sign' or 'barcode sign' can be printed as a still image for documenting the absence of or the presence of pneumothorax, respectively (Figures 11 and 12).[21,22,27] In the author's experience, neither M-mode nor power Doppler using real-time US appears reliably helpful in spontaneously ventilating traumatized dogs and cats due to patient thoracic wall movement. These techniques may be helpful, however, in patients with controlled breathing patterns (intubated positive-pressure ventilation or mechanical ventilation). Finally, regarding the detection of PE in people, concurrent hemothorax and hemomediastinum can lead to false negatives with penetrating wounds because it is difficult to determine the fluid location. It is recommended that the FAST examination be repeated serially after thoracocentesis.[103] Training for TFAST must include principles to distinguish pathological findings from artifact or normal structures. Examples of common mistakes due to inexperience include difficulty distinguishing pleural and pericardial spaces,[158] and mistaking variations in size and symmetry of the right ventricular papillary muscles as abnormal.[159,160]

Summary of the Clinical Utility and Future Applications of Veterinary FAST

The author's emergency and critical care practice has performed over 2,500 FAST exams since 2005. The applications of the veterinary FAST techniques extend beyond trauma to include triage and tracking; and proficiency by nonradiologists has been clearly demonstrated. The proposed standardized technique for AFAST and its applied fluid scoring system, and TFAST, provide global quad-cavity (abdomen, retroperitoneal, pleural, and pericardial spaces) patient evaluation called combination FAST (CFAST) when both studies are performed in concert. The clinical utility of these veterinary techniques, however, provides far more clinical information than originally thought with

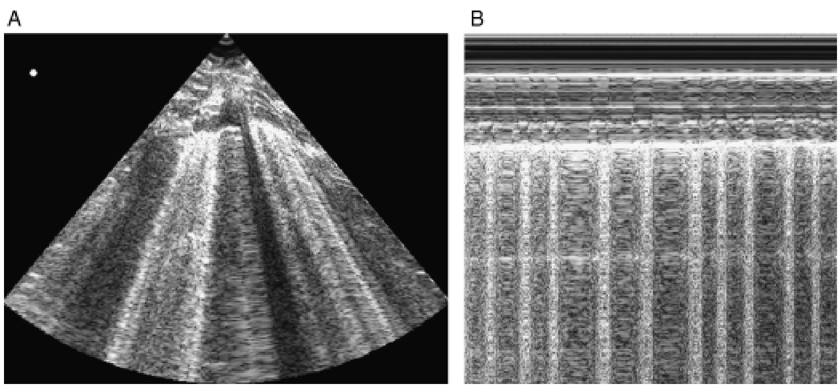

Figure 12: The ultrasound image at the CTS view of the thoracic focused assessment with sonography for trauma, triage and tracking (TFAST) exam in B-mode (a) and M-mode (b) of lung rockets ('wet lung' or interlobar edema), when present rapidly rule out pneumothorax. The near field in B-mode has the bat sign present with rib shadows and the bright white pleural-pulmonary line (PP-line) from which the 'lung rockets' originate. The near field in M-mode of skin and SC structures lack movement, thus are imaged as bar code lines. Image obtained via a single crystal handheld device. CTS, chest tube site.

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many applications in the emergent and critical care setting. Serial AFAST with the application of abdominal fluid scoring system provides a measure for detecting and monitoring cases at-risk for any effusive conditions in the initial and subsequent phases of care including postoperative patients. Serial TFAST likewise allows subsequent tracking (monitoring) for resolution or recurrence of pneumothorax and effusive conditions of the pleural and pericardial spaces. The veterinary FAST techniques may as yet prove valuable in aiding evaluation of patient volume status (pre- and postresuscitation), renal perfusion, lung pathology, and differentiating pulmonary from cardiac disease, to name a few.[63,161,162] These FAST techniques are cost effective, radiation sparing, and rapidly provide important clinical information. Used initially and serially, veterinary FAST potentially expedites diagnosis and prompts interventions that would have otherwise been delayed or omitted altogether.

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Footnote

[a] Durkan SD, Rush JE, Rozanski EA, et al. Echocardiographic findings in dogs with hypovolemia (abstr). J Vet Emerg Crit Care 2005;15:S4.

References

1. Kirkpatrick AW. Clinician-performed focused sonography for the resuscitation of trauma. Crit Care Med 2007; 35(S5):S162–S172.
2. Boulanger BR, McLellan BA, Brenneman FD, et al. Emergent abdominal sonography as a screening test in a new diagnostic algorithm for blunt abdominal trauma. J Trauma 1996; 40:867–874.
3. Boulanger BR, McLellan BA, Brenneman FD, et al. Prospective evidence of the superiority of a sonography-based algorithm in the assessment of blunt abdominal injury. J Trauma 1999; 47: 632–637.
4. Dolich MO, McKenney MG, Varela JE, et al. 2576 ultrasounds for blunt abdominal trauma. J Trauma 2001; 50(1):108–112.
5. Blackbourne LH, Soffer D, McKenney M, et al. Secondary ultrasound examination increases the sensitivity of the FAST exam in blunt trauma. J Trauma 2004; 57:934–938.
6. Ollerton JE, Sugrue M, Balogh Z, et al. Prospective study to evaluate the influence of FAST on trauma patient management. J Trauma 2006; 60:785–791.
7. Rozycki GS, Ballard RB, Feliciano DV, et al. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. Ann Surg 1998; 228:557–567.
8. Knudston JL, Dort JM, Helmer SD, et al. Surgeon-performed ultrasound for pneumothorax in the trauma suite. J Trauma 2004; 56:527–530.
9. Tayal VS, Beatty MA, Marx JA, et al. FAST (focused assessment with sonography in trauma) accurate for cardiac and intraperitoneal injury in penetrating anterior chest trauma. J Ultrasound Med 2004; 23:2467–2472.
10. Rowan KR, Kirkpatrick AW, Liu D, et al. Traumatic pneumothorax detection with thoracic ultrasound: correlation with chest radiography and CT – Initial experience. Radiology 2002; 225: 210–214.
11. Rozycki GS. Surgeon performed US: its use in clinical practice. Ann Surg 1998; 228:16–28.
12. McKenney M, Lentz K, Nunez D, et al. Can ultrasound replace diagnostic peritoneal lavage in the assessment of blunt trauma? J Trauma 1994; 37:439.
13. Rozycki GS, Ochsner MG, Schmidt JA, et al. A prospective study of surgeon performed ultrasound as the primary adjuvant modality for injured patient assessment. J Trauma 1995; 39:492–498.
14. Boulanger BR, Kearney PA, Brenneman FD, et al. FAST utilization in 1999: results of a survey of North American trauma centers. Am Surg 2000; 66:1049–1055.
15. Branney SW, Moore EE, Cantrill SV, et al. Ultrasound based key clinical pathway reduces the use of hospital resources for the evaluation of blunt abdominal trauma. J Trauma 1997; 42:1086–1090.
16. Rozycki GS, Root DH. The diagnosis of intraabdominal visceral injury. J Trauma 2010; 68(5):1019–1023.
17. Biffl WL, Moore EE, Kendall J. Post injury torso ultrasound: FAST should be SLOH. J Trauma 2000; 48(4):781–782.
18. Goletti O, Ghiselli G, Lippolis PV, et al. The role of ultrasonography in blunt abdominal trauma: results in 250 consecutive cases. J Trauma 1994; 36(2):178–181.
19. Healey MA, Simons RK, Winchell RJ, et al. A prospective evaluation of abdominal ultrasound in blunt trauma: is it useful? J Trauma 1996; 40:875–883.
20. Ma JO, Gaddis G. Anechoic stripe size influences accuracy of FAST examination interpretation. Acad Emerg Med 2006; 13(3): 248–253.
21. Lichtenstein DA, Meziere G, Lascols N, et al. Ultrasound diagnosis of occult pneumothorax. Crit Care Med 2005; 33:1231–1238.
22. Lichtenstein DA. Ultrasound in the management of thoracic disease. Crit Care Med 2007; 35(S5):S250–S261.
23. Kirkpatrick AW, Sirois M, Laupland KB, et al. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: the extended focused assessment with sonography for trauma (EFAST). J Trauma 2004; 57:288–295.
24. Hamilton D, Kirkpatrick AW, Nicolaou S, et al. Sonographic detection of pneumothorax and hemothorax in microgravity. Aviat Space Environ Med 2004; 75:272–277.
25. Kirkpatrick AW, Nicolaou S, Rowan K, et al. Thoracic sonography for pneumothorax: the clinical evaluation of an operational space medicine spin-off. Acta Astronaut 2005; 56:831–838.
26. Cunningham J, Kirkpatrick AW, Nicolaou S, et al. Enhanced recognition of ''lung sliding'' with power color Doppler in the diagnosis of pneumothorax. J Trauma 2002; 52:769–772.
27. Lichtestein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. Chest 2008; 134(1):117–125.
28. Lichtenstein DA. Ultrasound examination of the lungs in the intensive care unit. Pediatr Crit Care Med 2009; 10(6):693–698.
29. Peris A, Tutino L, Zagii G, et al. The use of point-of-care bedside lung ultrasound significantly reduces the number of radiographs and computerized tomography scans in critically ill patients. Anesth Analg 2010; 111(3):687–692.
30. Neri L, Storti E, Lichtenstein D. Toward an ultrasound curriculum for critical care medicine. Crit Care Med 2007; 35(S5):S290–S303.
31. Salen PN, Melanson SW, Heller MB. The focused abdominal sonography for trauma (FAST) examination: considerations and recommendations for training physicians in the use of a new clinical tool. Acad Emerg Med 2000; 7:162–168.

32. Camaggi V. Clinical applications of bedside ultrasonography in internal and emergency medicine. Intern Emerg Med 2010. DOI:10.1007/s11739-010-0424-3.
33. 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(3):258–269.
34. Lisciandro GR, Lagutchik MS, Mann KA, et al. Evaluation of an abdominal fluid scoring system determined using abdominal focused assessment with sonography for trauma (AFAST) in 101 dogs with motor vehicle trauma. J Vet Emerg Crit Care 2009; 19(5):426–437.
35. Thomas B, Falcone RE, Vasquez D, et al. Ultrasound evaluation of blunt abdominal trauma: program implementation, initial experience, and learning curve. J Trauma 1997; 42:384–390.
36. Wherrett LJ, Boulanger BR, McLellan BA, et al. Hypotension after blunt abdominal trauma: the role of emergent abdominal sonography in surgical triage. J Trauma 1996; 41:815–820.
37. Boysen SR, Rozanski EA, Tidwell AS, et al. Evaluation of a focused assessment with sonography for trauma protocol to detect free abdominal fluid in dogs involved in motor vehicle accidents. J Am Vet Med Assoc 2004; 225(8):1198–1204.
38. Herold LV, Devey JJ, Kirby R, et al. Clinical evaluation and management of hemoperitoneumin dogs. J Vet Emerg Crit Care 2008; 18(1):40–53.
39. Rajan GR. Ultrasound lung comets: a clinically useful sign in acute respiratory distress syndrome/acute lung injury. Crit Care Med 2007; 35(12):2869–2870.
40. Huang M, Liu M, Kwan J, et al. Ultrasonography for the evaluation of hemoperitoneum during resuscitation: a simple scoring system. J Trauma 1994; 36(2):173–177.
41. McKenney KL, McKenney MG, Cohn SM, et al. Hemoperitoneum score helps determine need for therapeutic laparotomy. J Trauma 2001; 50(4):650–656.
42. Melniker LA, Leibner E, McKenney MG, et al. Randomized controlled clinical trial of point- of-care, limited ultrasonography for trauma in the emergency department: the first sonography outcomes assessment program trial. Ann Emerg Med 2006; 48: 227–235.
43. Blavias M. Emergency paracentesis to determine intraperitoneal fluid identity discovered on bedside ultrasound of unstable patients. J Emerg Med 2005; 29(4):461–465.
44. Sauaia A, Moore FA, Moore EE, et al. Epidemiology of trauma deaths: a reassessment. J Trauma 1995; 38:185–193.
45. Martinowitz U, Holcomb JB, Pusateri AE, et al. Intravenous rFVIIa administered for hemorrhage control in hypothermic coagulopathic swine with grade V liver injuries. J Trauma 2001; 50(4):721–729.
46. Committee on Injury Prevention and Control, Institute of Medicine. In: Bonnie RJ, Fulco CE, Liverman CT. eds. Reducing the Burden of Injury: Advancing Prevention and Tracking. Washington, DC: National Academy Press; 1999, pp. 138–177.
47. Hoyt D, Bulger E, Knudson M, et al. Deaths in the operating room: an analysis of a multi-center experience. J Trauma 1994; 37:426–432.
48. Shackford SR, Mackersie RC, Davis JW, et al. Epidemiology and pathology of trauma deaths occurring in a level 1 trauma center in a regionalized system: the importance of secondary brain injury. J Trauma 1989; 29:1392–1397.
49. Acosta JA, Yang YC, Winchell RJ, et al. Lethal injuries and time to death in a level1 trauma center. J Am Coll Surg 1998; 186: 528–533.
50. Jeroukhimov I, Jewelewicz D, Zaias J, et al. Early injection of high-dose recombinant factor VIIa decreases blood loss and prolongs time from injury to death in experimental liver injury. J Trauma 2002; 53(6):1053–1057.
51. Hodgson NF, Stewart TC, Girotti MJ. Autopsies and death certification in deaths due to blunt trauma: what are we missing? J Surg 2000; 43:130–136.
52. Champion HR. Epidemiological basis for future improvements in trauma care. Semin Hematol 2004; 41:173.
53. Hoyt DB, Bulger EM, Knudson MM, et al. Death in the operating room: an analysis of a multi-center experience. J Trauma 1994; 37:426–432.
54. Driessen B, Brainard B. Fluid therapy for the traumatized patient. J Vet Emerg Crit Care 2006; 16(4):276–299.
55. Muir W. Trauma: physiology, pathophysiology, and clinical implications. J Vet Emerg Crit Care 2006; 16(4):253–263.
56. Cothren CC, Osborn PM, Moore EE, et al. Preperitoneal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift. J Trauma 2007; 62(4):834–842.
57. Dechant JE, Nieto JE, Le Jeune SS. Hemoperitoneum in horses: 67 cases (1989–2004). J Am Vet Med Assoc 2006; 229(2):-253–258.
58. Weninger P, Mauritz W, Fridrich P, et al. Emergency room management of major blunt trauma: evaluation of the multi-slice computerized tomography protocol exemplified by an urban trauma center. J Trauma 2007; 62(3):584–591.
59. Brasel KJ, Guse C, Gentilello LM, et al. Heart rate: is it truly a vital sign? J Trauma 2007; 62(4):812–817.
60. Korner M, Krotz MM, Degenhart C, et al. Current role of emergency ultrasound in patients with major trauma. Radiographics 2008; 28(1):225–242.
61. Kirkpatrick AW, Sirios M, Ball CG, et al. The hand-held ultrasound for penetrating abdominal trauma. Am J Surg 2004; 187: 660–665.
62. Rozycki GS, Knudson MM, Shackford SR, et al. Surgeon-performed bedside organ assessment with sonography after trauma (BOAST): a pilot study from the WTA Multicenter Group. J Trauma 2005; 59(6):1356–1364.
63. Carr BG, Dean AJ, Everett WW, et al. Intensivist bedside ultrasound (INBU) for volume assessment in the intensive care unit: a pilot study. J Trauma 2007; 63(3):495–502.
64. Testa A, Lauritano EC, Gianuzzi R, et al. The role of emergency ultrasound in the diagnosis of acute non-traumatic epigastric pain. Intern Emerg Med 2010; 5(5):401–409.
65. Maitra S, Jarman RD, Halford NW, et al. When is FAST a FAFF?: is FAST scanning useful in non-trauma patients? Ultrasound 2008; 16:165–168.
66. Kolata RJ, Dudley EJ. Motor vehicle accidents in urban dogs: a study of 600 cases. J Am Vet Med Assoc 1975; 167:938–941.
67. Mongil CM, Drobatz KJ, Hendricks JC. Traumatic hemoperitoneum in 28 cases: a retrospective review. J Am Anim Hosp Assoc 1995; 31:217–222.
68. Simpson SA, Syring R, Otto CM. Severe blunt trauma in dogs: 235 cases (1997–2003). J Vet Emerg Crit Care 2009; 19(6): 588–602.
69. Lisciandro GL, Harvey HJ, Beck KA. Automobile-induced obstruction of the caudal vena cava in a dog. J Small Anim Pract 1995; 36(8):368–372.
70. Weisse C, Aronson LR, Drobatz K. Traumatic rupture of the ureters: 10 cases. J Anim Hosp Assoc 2002; 38(2):188–192.
71. Cornelius L, Mahaffey M. Kinking of the intrathoracic caudal vena cava in five dogs. J Small Anim Pract 1985; 26:67–80.
72. Crowe DT, Lorenz MD, Hardie EM, et al. Chronic peritoneal effusion due to partial obstruction caudal vena caval obstruction following blunt abdominal trauma: diagnosis and successful surgical management. J Am Anim Hosp Assoc 1984; 20:231–238.
73. Fine DM, Olivier NB, Walshaw R, et al. Surgical correction of late onset Budd-Chiari-like syndrome in a dog. J Am Vet Med Assoc 1998; 212(6):835–837.
74. Kolata RJ, Cornelius LM, Bjorling DE, et al. Correction of an obstructive lesion of the caudal vena cava in a dog using a temporary intraluminal shunt. Vet Surg 1982; 11:100–104.
75. Parchman MB, Flanders JA. Extrahepatic biliary tract rupture: evaluation of the relationship between the site of rupture and the cause of rupture in 15 dogs. Cornell Vet 1990; 80(3):267–272.
76. Ludwig LL, McLoughlin MA, Graves TK, et al. Surgical tracking of bile peritonitis in 24 dogs and 2 cats: a retrospective study (1987–1994). Vet Surg 1997; 26(2):90–98.
77. Mehler SJ, Mayhew PD, Drobatz KJ, et al. Variables associated with outcome in dogs undergoing extrahepatic biliary surgery: 60 cases (1988–2002). Vet Surg 2004; 33(6):644–649.

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78. Amsellum PM, Seim HB, MacPhail CM, et al. Long-term survival and risk factors associated with biliary surgery in dogs: 34 cases (1994–2004). J Am Vet Med Assoc 2006; 229(9):1451–1457.
79. Worth AJ, Tomlin SC. Post-traumatic paraureteral urinoma in a cat. J Small Anim Pract 2004; 45(8):413–416.
80. Moores AP, Bell AMD, Costello M. Urinoma (para-ureteral pseudocyst) as a consequence of trauma in a cat. J Small Anim Prac 2002; 43(5):213–216.
81. Bacon NJ, Anderson DM, Barnes EA, et al. Post-traumatic paraureteral urinoma (uriniferous pseudocyst) in a cat. Vet Comp Orthop Traumatol 2002; 15(2):123–126.
82. Montavon PM, Arnold A, von Segesser LK. Chronic peritoneal effusion secondary to partial caudal vena cava obstruction following pneumothorax in a dog. Vet Comp Orthop Traumatol 2007; 20:340–345.
83. Gaarder C, Kroepelien FC, Loekke R, et al. Ultrasound performed by radiologist-confirming the truth about FAST in trauma. J Trauma 2009; 67(2):323–329.
84. Nunes LW, Simmons S, Hallowell MJ, et al. Diagnostic performance of trauma US in identifying abdominal or pelvic free fluid and serious abdominal or pelvic injury. Acad Radiol 2001; 8: 128–136.
85. American College of Emergency Physicians Policy Statement: Emergency Ultrasound Guidelines. 2008. Available at http://www.acep.org/workarea/downloadasset.aspx?id=32878
86. Hoffman L, Pierce D, Puumala S. Clinical predictors of injuries not identified by focused abdominal sonogram for trauma (FAST) examinations. J Emerg Med 2009; 36(3):271–279.
87. Ong AW, McKenney MG, McKenney KA, et al. Predicting the need for laparotomy in pediatric trauma patients on the basis of ultrasound score. J Trauma 2003; 54(3):503–508.
88. Vinayak A, Krahwinkel DJ. Managing blunt trauma-induced hemoperitoneum in dogs and cats. Comp Cont Ed Pract Vet 2004; 26(4):276–290.
89. Clark CH, Woodley CH. The absorption of red blood cells after parental injection at various sites. Am J Vet Res 1959; 10: 1062–1066.
90. McGahan JP, Richards J, Fogata MC. Emergency ultrasound in trauma patients. Radiol Clin N Am 2004; 42:417–425.
91. Sigrist NE, Doherr MG, Spreng DE. Clinical findings and diagnostic value of post-traumatic thoracic radiographs in dogs and cats with blunt trauma. J Vet Emerg Crit Care 2004; 14:259–268.
92. Brockman DJ, Puerto DA. Pneumomediastinum and pneumothorax, In: King LG. ed. Textbook of Respiratory Diseases in Dogs and Cats. Philadelphia: WB Saunders Company; 2004, pp. 617–621.
93. Jackson CB, Drobatz KJ. Pulmonary contusions, In: King LG. ed. Textbook of Respiratory Diseases in Dogs and Cats. Philadelphia: WB Saunders Company; 2004, pp. 472–480.
94. Powell LL, Rozanski EA, Tidwell AS, et al. A retrospective analysis of pulmonary contusions secondary to motor vehicle accidents in 143 dogs: 1994–1997. J Vet Emerg Crit Care 1999; 9(3):127–136.
95. Krahwinkel DJ, Rohrbach BW, Hollis BA. Factors associated with survival in dogs and cats with pneumothorax. J Vet Emerg Crit Care 1999; 9:7–12.
96. Soffer D, McKenney MG, Cohn S, et al. A prospective evaluation of ultrasonography for the diagnosis of penetrating torso injury. J Trauma 2004; 56(5):953–959.
97. Udobi KF, Rodriguez A, Chiu WC, et al. Role of ultrasonography in penetrating abdominal trauma: a prospective clinical study. J Trauma 2001; 50(3):475–479.
98. Pavletic MM, Trout NJ. Bullet, bite, burn wounds in dogs and cats. Vet Clin North Am Sm Anim Pract 2006; 36(4):873–893.
99. Blaiva M, Kirkpatrick AW, Rodriguez-Galvez M, et al. Sonographic depiction of intraperitoneal free air. J Trauma 2009; 67(3):675.
100. Boysen SR, Tidwell AS, Pennick DG. Ultrasonographic findings in dogs and cats with gastrointestinal perforation. Vet Radiol Ultrasound 2003; 44(5):556–564.
101. Quantz JE, Miles MS, Reed AL, et al. Elevation of alanine transaminase and gallbladder wall abnormalities as biomarkers of anaphylaxis in canine hypersensitivity patients. J Vet Emerg Crit Care 2009; 19(6):536–544.
102. Rozycki GS, Feliciano DV, Ochsner MG, et al. The role of ultrasound in patients with possible penetrating cardiac wounds: a prospective multicenter study. J Trauma 1998; 46(4):543–552.
103. Ball CG, Williams BH, Wyrzykowski AD, et al. A caveat to the performance of pericardial ultrasound in patients with penetrating cardiac wounds. J Trauma 2009; 67(5):1123–1124.
104. Rozycki GS, Pennington SD, Feliciano DV. Surgeon-performed ultrasound in the critical care setting: its use as an extension of the physical examination to detect pleural effusion. J Trauma 2001; 50:636–642.
105. Crowe DT, Crane SW. Diagnostic abdominal paracentesis techniques: clinical evaluation in 129 dogs and cats. J Am Anim Hosp Assoc 1984; 20:223–230.
106. Crowe DT, Crane SW. Diagnostic paracentesis and lavage in the evaluation of abdominal injuries in dogs and cats: clinical and experimental investigations. J Am Vet Assoc 1976; 168:700–705.
107. Soderstrom CA, DuPriest RW, Crowley RA. Pitfalls of peritoneal lavage in blunt abdominal trauma. Surg Gynec Obstet 1980; 151:513–518.
108. McCullough PA. Acute kidney injury with iodinated contrast. Crit Care Med 2008; 36(4 suppl):S204–S211.
109. Rashid AH, Brieva JL, Stokes B. Incidence of contrast-induced nephropathy in intensive care patients undergoing computerised tomography and prevalence of risk factors. Anaesth Intensive Care 2009; 37(6):968–975.
110. McGillicuddy EA, Schuster KM, Kaplan LJ, et al. Contrast-induced nephropathy in elderly trauma patients. J Trauma 2010; 68(2):294–297.
111. Shackford SR, Rogers FB, Osler TM, et al. Focused abdominal sonograms for trauma: the learning curve of nonradiologist clinicians in detecting hemoperitoneum. J Trauma 1999; 46(4):553–564.
112. Scalea TM, Rodriguez A, Chiu WC, et al. Focused assessment with sonography for trauma (FAST): results from an international consensus conference. J Trauma 1999; 46:466–472.
113. Berry G, Armitage P. Mid-p confidence intervals: a brief review. Statistician 1995; 44(4):417–423.
114. McGahan JP, Richards J, Gillen M. The focused abdominal sonography for trauma scan: pearls and pitfalls. J Ultrasound Med 2002; 21:789–800.
115. d'Anjou M. Liver, In: Pennick D, d'Anjou M. eds. Atlas of Small Animal Ultrasonography. Ames, IA: Blackwell Publishing; 2008, pp. 222–223.
116. Friese RS, Malekzadeh S, Shafi S, et al. Abdominal ultrasound is an unreliable modality for the detection of hemoperitoneum in patients with pelvic fracture. J Trauma 2007; 63(1):97–102.
117. Tayal VS, Nielsen A, Jones AE, et al. Accuracy of trauma ultrasound in major pelvic injury. J Trauma 2006; 61(6):1453–1457.
118. Culp WT, Weisse C, Kellog ME, et al. Spontaneous hemoperitoneum in cats: 65 cases (1994–2006). J Am Vet Assoc 2010; 236(9):978–982.
119. Ledgerwood AM, Lucas CE. A review of studies on the effects of hemorrhagic shock and resuscitation on the coagulation profile. J Trauma 2003; 54:S68–S74.
120. Sixma JJ, Wester J. The hemostatic plug. Semin Hematol 1977; 14:265–299.
121. Revell M, Greaves I, Porter K. Endpoints for fluid resuscitation in hemorrhagic shock. J Trauma 2003; 54(5):S63–S67.
122. Sondeen JL, Coppes VG, Holcomb JB. Blood pressure at which rebleeding occurs after resuscitation in swine with aortic injury. J Trauma 2003; 54(5):S110–S117.
123. Chelly MR, Marguiles DR, Mandavia D, et al. The evolving role of FAST scan for the diagnosis of pericardial fluid. J Trauma 2004; 56:915–917.
124. Brooks A, Davies B, Smethhurst M, et al. Emergency ultrasound in the acute assessment of haemothorax. Emerg Med J 2004; 21:44–46.
125. Testerman GM. Surgeon-performed ultrasound in the diagnosis and management of pericardial tamponade in a 20-month-old blunt injured toddler. Tenn Med 2006; 9:937–941.

126. Stowater JL, Lamb CR. Ultrasonography of noncardiac thoracic diseases in small animals. J Am Vet Med Assoc 1989; 195:514–520.
127. Kealy JK, McAllister H. The thorax, In: Kealy KJ, McAllister H. eds. Diagnostic Radiology and Ultrasonography of the Dog and Cat. St Louis, MO: Elsevier Saunders; 2005, pp. 226–232.
128. Tidwell AS. Ultrasonography of the thorax (excluding the heart). Vet Clin North Am Pract 1998; 28:993–1015.
129. Reibig A, Kroegel C. Accuracy of transthoracic sonography in excluding post-interventional pneumothorax and hydrothorax: comparison to chest radiography. Eur J Radiol 2005; 53: 463–470.
130. Chan SS. Pneumothorax detection with thoracic US: more research is needed (letter). Radiology 2003; 227:905–906.
131. Lichtenstein D, Meziere G, Biderman P, et al. The ''lung point'': an ultrasound sign specific to pneumothorax. Intensive Care Med 2000; 26:1434–1440.
132. Sargsyan AE, Hamilton DR, Nicolau S, et al. Ultrasound evaluation of the magnitude of pneumothorax: a new concept. Am Surg 2001; 67:232–235.
133. Dulchavsky SA, Schwarz KL, Kirkpatrick AW, et al. Prospective evaluation of thoracic ultrasound in the detection of pneumothorax. J Trauma 2001; 50:201–205.
134. Rantanen NW. Diagnostic ultrasound: disease of the thorax. Vet Clin N Am Equine Pract 1986; 2:49–66.
135. Reef VB. Thoracic ultrasonography: non-cardiac imaging, In: Reef VB. ed. Equine Diagnostic Ultrasound. Philadelphia: WB Saunders Company; 1998, pp. 187–214.
136. Boy MG, Sweeney CR. Pneumothorax in horses: 40 cases (1980–1997). J Am Vet Med Assoc 2000; 216:1955–1959.
137. Slack JA, Thomas CB, Peek SF. Pneumothorax in dairy cattle: 30 cases (1990–2003). J Am Vet Med Assoc 2004; 225:732–735.
138. Jung C, Bostedt H. Thoracic ultrasonography in newborn calves and description of normal and pathological findings. Vet Radiol Ultrasound 2004; 45:331–335.
139. Reef VB, Boy MG, Reid CF, et al. Comparison between diagnostic ultrasonography and radiography in the evaluation of horses and cattle with thoracic disease: 56 cases (1984–1985). J Am Vet Med Assoc 1991; 198:2112–2118.
140. Kirkpatrick AW, Ng AK, Dulchavsky SA, et al. Sonographic diagnosis of a pneumothorax inapparent on plain radiography: confirmation by computerized tomography. J Trauma 2001; 50:750–752.
141. Soldati G, Iacconi P. The validity of the use of ultrasonography in the diagnosis of spontaneous and traumatic pneumothorax (letter). J Trauma 2001; 51:423.
142. Boulanger BR, Kearney PA, Tsuei B, et al. The routine use of sonography in penetrating torso injury is beneficial. J Trauma 2001; 51:320–325.
143. Lichtenstein DA, Meziere GA, Lagoueyte J, et al. A-lines and B-lines. Lung ultrasound as a bedside tool for predicting pulmonary artery occlusion pressure in the critically ill. Chest 2009; 136(4):1014–1020.
144. Lichtenstein DA, Lascols N, Prin S, et al. The ''lung pulse'': and early ultrasound sign in complete atelectasis. Intensive Care Med 2003; 29:2187–2192.
145. Lichtestein DA, Lascos N, Meziere GA, et al. Ultrasound diagnosis of alveolar consolidation in the critically ill. Intensive Care Med 2004; 30:276–281.
146. Ball CG, Kirkpatrick AW, Laupland KB, et al. Factors related to the failure of radiographic recognition of occult posttraumatic pneumothoraces. Am J Surg 2005; 189:541–546.
147. Harbrecht BG, Alarcron LH, Peitzman AB. Management of shock, In: Moore EE, Feliciano DV, Mattox KL. eds. Trauma, 5th edn. New York: McGraw-Hill; 2004, pp. 201–226.
148. Garofalo G, Busso M, Perotto F, et al. Ultrasound diagnosis of pneumothorax. Radiol Med (Torino) 2006; 111:516–525.
149. Blavias M, Lyon M, Duggal S. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. Acad Emerg Med 2005; 12: 844–849.
150. Ball CG, Kirkpatrick AW, Fox DL, et al. Are occult pneumothoraces truly occult or simply missed? J Trauma 2006; 60:294–298.
151. Gargani L, Lionetti V, Di Cristofano C, et al. Early detection of acute lung injury uncoupled to hypoxemia in pigs using ultrasound lung comets. Crit Care Med 2007; 35(12):2769–2774.
152. Peris A, Zagli G, Barbani F, et al. The value of lung ultrasound monitoring in H1N1 acute respiratory distress syndrome. Anaesthesia 2010; 65(3):294–297.
153. Lichtenstein D, Meziere G, Biderman P, et al. The comet-tail artifact: an ultrasound sign ruling out pneumothorax. Intensive Care Med 1999; 25:383–388.
154. Ball CG, Ranson KM, Rodrigeuz-Galvez M, et al. Sonographic depiction of posttraumatic alveolar-interstitial disease: the hand-held diagnosis of a pulmonary contusion. J Trauma 2009; 66(3):962.
155. Noble VE, Lamhaut L, Capp R, et al. Evaluation of a thoracic ultrasound training module for the detection of pneumothorax and pulmonary edema by prehospital physician care providers. BMC Med Educ 2009; 9:3–7.
156. Monti JD, Younggren B, Blankenship P. Ultrasound detection of pneumothorax with minimally trained sonographers: a preliminary study. J Special Oper Med 2009; 9:43–46.
157. Filly RA. Ultrasound: the stethoscope of the future, alas. Radiology 1988; 167:400.
158. Boone JA. Acquired heart disease, In: Boone JA. ed. Manual of Veterinary Echocardiography. Philadelphia: Lippincott, Williams, & Wilkins; 1998, pp. 355–370.
159. Kienle RD. Pericardial disease and cardiac neoplasia – pericardial effusion resulting from acquired disease – part 2, In: Kienle RD, Kittleson MD. eds. Small Animal Cardiovascular Medicine. London: Elselvier Health Sciences; 1998, pp. 413–432.
160. Boone JA. Evaluation of size, function, and hemodynamics, In: Boone JA. ed. Manual of Veterinary Echocardiography. Philadelphia: Lippincott, Williams, & Wilkins; 1998, pp. 159–161.
161. Gunst M, Ghaemmaghami V, Sperry J, et al. Accuracy of cardiac function and volume status estimates using the bedside echocardiographic assessment in trauma/critical care. J Trauma 2008; 65(3):509–516.
162. Yanagawa Y, Nishi K, Sakamoto T, et al. Early diagnosis of hypovolemic shock by sonographic measurement of inferior vena cava in trauma patients. J Trauma 2005; 58(4):825–829.

