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Use of Point-of-Care Ultrasound in the Emergency Room and Intensive Care Unit - Abdomen Part I

Gregory Lisciandro, DVM, Dipl.ABVP, Dipl.ACVECC*

FASTVet.com and Hill Country Veterinary Specialists, Spicewood, TX, USA

KEYWORDS

• POCUS • AFAST • TFAST • Vet BLUE • Global FAST • Point-of-care ultrasound

KEY POINTS

- Traditionally difficult conditions that are often life-threatening may now be recognized by “seeing” the problem with evidence-based information using point-of-care ultrasound (POCUS).
- AFAST-TFAST-Vet BLUE are standardized POCUS formats achievable by non-radiologist/cardiologist sonographers that combined are called Global FAST used as an extension of the physical exam.
- Global FAST provides an unbiased set of 15 data imaging points serving as a first line imaging “screening” test of the abdomen and thorax.
- Global FAST should be strived for to prevent imaging interpretation errors (satisfaction of search, confirmation bias) that occur through “selective imaging.”
- Global FAST should be part of the initial examination of all patients so that preexisting and acquired conditions during patient care are better deciphered.

INTRODUCTION

Diagnostic ultrasound is a safe, radiation sparing, imaging modality that is available to veterinary imaging specialists and many small animal practices worldwide. The point-of-care ultrasound (POCUS) is safe, effective low risk and low impact diagnostic tool that has been monumental in changing the approach to diagnosing and serially assessing emergent and critical small animal patients.

Use of POCUS began in the 1990s with the development of focused assessment with sonography for trauma (FAST) by human trauma surgeons [1–4]. The use of FAST ultrasound in people documented proficiency of nonradiologist physicians for recognizing cavitary, retroperitoneal, and pericardial effusions (PCEs) [1–4]. In veterinary medicine, the initial FAST study was performed in dogs in 2004 [5]. The following year, the original veterinary FAST examination was modified by the author and named AFAST that also included a novel abdominal fluid scoring system (AFSS) along with the addition of a thoracic FAST protocol named TFAST [6,7]. These 2 formats were combined for Combo FAST, patient evaluation for a “global quad cavity” assessment of the abdominal and pleural cavities, the retroperitoneal, and pericardial spaces [8]. “T3” was applied to these acronyms

*Corresponding author. *E-mail address:* FastSavesLives@gmail.com

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ABBREVIATIONS

AFAST	abdominal FAST consisting of the DH, SR, CC, SIU, and HR5th bonus views
AFS	abdominal fluid score
AFSS	abdominal fluid scoring system
ALKP	alkaline phosphatase
ALT	alanine transaminase
AST	aspartate transaminase
AUS	abdominal ultrasound
AX	anaphylaxis
Bounce CVC	fluid responsive with 35%–50% change in maximum height
CC	cysto-colic
CT	computed tomography
CVC	caudal vena cava
CVP	central venous pressure
DH	diaphragmatico-hepatic
DPL	diagnostic peritoneal lavage
EPSS	enhanced peritoneal stripe sign
FAST	focused assessment with sonography for trauma
FAT CVC	fluid intolerant, distended with little change in maximum height
flat CVC	fluid starved, small with little change in maximum height
GIT	gastrointestinal tract
Global FAST	combination of AFAST, TFAST, and Vet BLUE as a single examination
HR5th	hepato-renal 5th bonus view
HV	hepatic veins
PCE	pericardial effusion
POCUS	point-of-care ultrasound
PTX	pneumothorax
R-CHF	right-sided congestive heart failure
SIU	spleno-intestino umbilical
SR	spleno-renal
TFAST	thoracic FAST consisting of bilaterally applied CTS, PCS, and single DH views
Vet BLUE	veterinary brief lung ultrasound

indicating their use for trauma, triage (nontrauma), and tracking (monitoring) [8–11]. With the detection of lung pathology at the TFAST chest tube site, a more comprehensive lung ultrasound screening test evolved named veterinary brief lung ultrasound (Vet BLUE) [8,11–16]. These 3 formats when combined and used as a single ultrasound examination are called Global FAST, and achievable ultrasound skill, and used routinely in trauma and nontrauma as "an extension of the physical examination" [8,14,17–24]. Each of these formats is more than "flashing" or "targeting" and thus separates these Global FAST formats from POCUS, that can employ the dangerous concept of "asking the clinical question, followed by targeted POCUS imaging, to answer the specific clinical question(s) in binary fashion" which can potentially lead to serious imaging interpretation errors [25]. Thus, this review will primarily focus on Global FAST and its 3 components, each having exact clarity to their views and objectives, while providing an unbiased set of 15-data imaging points of the abdomen and thorax, including heart and lung.

While performing the standardized formats of AFAST, target-organ approaches for soft tissue and vascular abnormalities, volume status by characterizing the caudal vena cava (CVC) and hepatic veins (HVs), estimating urinary bladder volume and urine output, TFAST and Vet BLUE when combined as an "extension of the physical examination" called Global FAST, a vast amount of clinical information may be gained in minutes without any additional views [6–8,17,18,20,24–46] (Table 1).

Add-on POCUS imaging may be used for additional clinical information such as a more detailed ultrasound approach to the heart, gastrointestinal tract (GIT), male and female reproductive tracts, volume estimation of the urinary bladder, locations of tubes and catheters, imaging a soft tissue swelling, the eye, the brain, or long and flat bones for fractures [29,31,34–42,47–63]. Just like the stethoscope, ultrasound belongs in the hands of all veterinary professionals; however, responsible use should be advocated with standardized formats and clear objectives [8]. This review will hopefully pique the interest of the reader to explore unlimited creative POCUS uses in patient care [8,64].

The AFAST is a rapid less than 3-minute ultrasound examination that describes views according to their target-organs to detect soft tissue abnormalities and detect and score the presence or absence of peritoneal effusion. Semiquantitating fluid volume can guide decisions regarding fluid resuscitation, including blood transfusion(s).

The AFAST examination can be performed with the patient standing, although right lateral recumbency is preferred, to allow imaging of the gallbladder, spleen, and CVC, and to perform abdominocentesis if fluid is present [65–67]. The 4 standardized AFAST views that make up its AFSS are the diaphragmatic-hepatic (DH) view, the spleno-renal (SR) view, the cysto-colic (CC) view, and the spleno-intestino umbilical (SIU) view in this order. The final SIU view is purposely the

TABLE 1
What Global FAST can do

What AFAST® can do	What TFAST® can do	What Vet BLUE® can do
AFAST® is a standardized abdominal FAST protocol	TFAST® is a standardized thoracic FAST protocol	Vet BLUE® is a proactive lung ultrasound examination
• Can detect free fluid in the peritoneal cavity and retroperitoneal space	• Can detect pleural effusion and pericardial effusion (PCE) by following the TFAST® rules	• Can detect alveolar-interstitial syndrome (“water, blood, or pus”) through the observation of B-lines also called lung rockets • Can detect forms of consolidation called shred sign (air broncho-gram), tissue sign (hepatization), nodule sign (soft tissue), wedge sign (lung infarction, pulmonary thromboembolism)
• Can semiquantitate using its abdominal fluid scoring system (AFSS) and its “weak positive (1/2)” vs “strong positive (1)” abdominal fluid score (AFS) and then categorize “small volume ($<$3)” and “large volume ($\geq$3)” principle	• *PCE rules o DH view—racetrack sign ○ Short axis right PCS view-s—bull’s eye ○ Long axis 4 chamber ○ Hammerhead view left short axis • *Pleural effusion ○ DH view wafting of lung ○ Left and right PCS views—slide cranial and caudal to heart in its “pouches” * Image the heart in its entirety	• B-lines scored as highest number over a single intercostal space at each respective Vet BLUE® view as “dry” (0) or “wet” scored as “weak positive (1,2,3)” and “strong positive ($>$3,∞)”
• Can screen for obvious soft tissue abnormalities using its “target-organ approach”	• Can detect pneumothorax and characterize its degree using the “Lung Point” location using the “TFAST® One-thirds Rule” of Upper 1/3, Middle 1/3, Lower 1/3 as a semiquantification for degree and as a tracking tool	• Can rule in and rule out left-sided congestive heart failure (CHF) and follow using TXR more sparingly
• Can predict the anticipated degree of anemia in hemoperitoneum cases through the application of its AFSS	• Can screen for poor intravascular volume status, decreased contractility and right-sided and left-sided cardiac problems using the TFAST® echocardiography views	• Can guide loop diuretic therapy by using the Vet BLUE® B-line scoring system and its “weak positive (1, 2, 3)” and “strong positive ($>$3,∞)” model and its inherent scoring system combining lung region scores with their distribution
• Can predict the anticipated degree of volume loss in nonhemorrhagic ascites through the application of its abdominal fluid scoring system	• Can screen for obvious soft tissue abnormalities of the heart using its target-organ approach including chamber abnormalities and intracardiac and pericardial masses and thrombi. Can be used to detect pulmonary pathology along the pulmonary-diaphragmatic interface	• Can assess severity of alveolar-interstitial edema (AIS, and lung contusions and hemorrhage by combining the B-line scoring system and its “weak positive (1, 2, 3)” and “strong positive ($>$3,∞)” model and its inherent scoring system combining lung region scores with their distribution

(*continued on next page*)

TABLE 1
(*continued*)

What AFAST® can do	What TFAST® can do	What Vet BLUE® can do
• Can be used to estimate urinary bladder volume and thus over time urine output	• Can assess intravascular volume status via characterization of the CVC ("FAT, flat, bounce") and its associated HVs ("tree trunk sign") ○ "FAT"—fluid intolerant, high Central Venous Pressure (CVP) ○ "flat"—fluid starved or hypovolemic, low CVP ○ "bounce"—fluid responsive—heart can handle fluid resuscitation	• Can screen for various respiratory conditions using its regional, pattern-based approach and its visual lung language including CHF, all forms of noncardiogenic pulmonary edema, pneumonias (bacterial, aspiration, other), nodular disease (neoplastic, fungal, verminous, bacterial), and lung infarction/pulmonary-thromboembolism
• Can be used to detect pleural and PCE through the DH view		
• Can be used to detect pulmonary pathology along the pulmonary-diaphragmatic interface		
• Can assess volume status via characterization of the CVC ("FAT, flat, bounce") and its associated HVs ("tree trunk sign") See TFAST®		
• Other add-ons ○ Gastro-intestinal motility ○ Placement of esophagostomy and gastrotomy tubes ○ Placement of urinary catheters		
*AFAST® serves as a screening test to help detect free fluid and soft tissue abnormalities to better direct resuscitation and diagnostic efforts. It is not meant to replace a complete AUS, AXR, CT, or MRI	*TFAST® serves as a screening test to help detect free fluid and soft tissue abnormalities related to the thorax including heart and lung to better direct resuscitation and diagnostic efforts. It is not meant to replace complete echocardiography, TXR, CT, or MRI	*Vet BLUE® serves as a screening test to help detect respiratory abnormalities to better direct resuscitation and diagnostic efforts. It is not meant to replace TXR, CT, or MRI

most gravity-dependent in right lateral recumbency, completes the total abdominal fluid score (AFS), and is where abdominocentesis is often performed in the presence of ascites. The hepato-renal 5th bonus view (HR5th), performed from the *right* side of the patient while standing, is advantageous as the small intestine falls away from and allows visualization of its target-organs the right kidney and adjacent right liver. The first 4 AFAST views (DH, SR, CC, and SIU), but not the HR5th view, make up the AFAST-assigned AFSS and the AFS (0–4) [6,8,68–70]. The DH view uniquely images the abdominal and pleural cavities including heart and lung; and the SR and HR5th views uniquely image the retroperitoneal space [11,22–24,26,65,66]. AFAST probe maneuvers follow fanning, rocking cranially, and returning to the starting point for the DH, SR, and HR5th bonus views; and fanning and sliding caudally to the trigone and urethra at the CC view; and fanning through the SIU pouch and the mid-abdomen at the SIU view (Table 2).

The AFSS, which is valid only in lateral recumbency, has been modified to include a "weak positive (1/2)"

TABLE 2
AFAST and its target-organ approach for soft tissue abnormalities

AFAST® target-organ approach for soft tissue abnormalities	
DH view—the probe is placed immediately caudal to the xiphoid, "fanned" through the liver and gallbladder, "rocked cranially" to evaluate the heart and its "cardiac bump," followed by the lung and pleural cavity, then "returned to the starting point" while imaging the CVC as it traverses the diaphragm *Note:* AFAST imaging is standardized in longitudinal planes while fanning; and following the 50% rule for its target-organs of the left and right kidneys, and the urinary bladder as no more than 50% of the screen. Only 3 probe maneuvers are used—fanning, rocking, and sliding	Gallbladder wall abnormalities • Edema • Masses • Rupture Gallbladder lumen abnormalities • Sludge • Mucocele • Calculi Biliary tract distension Liver parenchymal abnormalities • Masses and cysts • Heterogenous echogenicity CVC • Distension • Thrombi • Dirofilaria • Masses Pleural effusion PCE Echocardiography (left heart lies against the diaphragm) Lung abnormalities • B-lines • Signs of consolidation (shred, tissue, nodule, wedge)
**SR and HR5th views*—the probe is placed immediately caudal to the costal arch where it meets the sublumbar muscles, "fanned" through the left kidney, "rocked cranially" to evaluate the spleen, then "returned to the starting point" of the left kidney *Dependent on right or left lateral recumbency and is the least gravity dependent view *Note:* AFAST imaging is standardized in longitudinal planes while fanning; and following the 50% rule for its target-organs of the left and right kidneys, and the urinary bladder as no more than 50% of the screen. Only 3 probe maneuvers are used—fanning, rocking, and sliding	Retroperitoneal abnormalities • Fluid • Masses Renal parenchyma • Renal pelvic dilation—pyelectasis and hydronephrosis • Cysts—cortical and perinephric • Masses • Cortical infarction • Dioctophyme renale Ureters • Distension • Calculi Splenic abnormalities (see focused spleen) Vascular (great vessels, renal vessels) • Thrombus • Masses Pneumoperitoneum

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TABLE 2
(*continued*)

AFAST® target-organ approach for soft tissue abnormalities	
CC view—the probe is placed immediately dorso-lateral to midline over the caudal abdomen with the bladder apex centered, then "fanned" through the urinary bladder including ventrally through its "pouch," then "slid caudally" into the trigone and urethra, then "returned to the starting point" of the urinary bladder *Note:* AFAST imaging is standardized in longitudinal planes while fanning; and following the 50% rule for its target-organs of the left and right kidneys, and the urinary bladder as no more than 50% of the screen. Only 3 probe maneuvers are used—fanning, rocking, and sliding	Bladder wall abnormalities • Masses Bladder lumen • Sediment • Calculi • Thrombus Urogenital abnormalities • Prostatic disease • Uterine disease
SIU views—the probe is placed at the level of or immediately dorso-lateral to the umbilicus, "fanned" through the small intestine and spleen making sure the scanning plane passes through the "umbilical pouch," "rocked cranially" and then "returned to the starting point" *Note:* AFAST imaging is standardized in longitudinal planes while fanning; and following the 50% rule for its target-organs of the left and right kidneys, and the urinary bladder as no more than 50% of the screen. Only 3 probe maneuvers are used—fanning, rocking, and sliding	Mid-abdominal masses • Spleen • Mesenteric lymph nodes • Other Small intestine • Motility—ileus and distension • Corrugation • Plication • Intussusception • Shadowing foreign bodies • Masses
Focused spleen—the probe is used by "sliding and fanning," "sliding and fanning" following the spleen cranially and caudally, noting that the spleen courses from lower umbilical area to the left kidney making right lateral recumbency and scanning from the patient's left side when standing or sternal, advantageous	Splenic parenchymal abnormalities • Masses and cysts • Infarction • Torsion • Heterogenous echogenicity ○ Splenomegaly, Dark Swiss Cheese—R/O torsion ○ Splenomegaly, Bright Swiss Cheese—R/O lymphoma
**HR5th view*—the probe is placed caudal to the costal arch and sublumbar muscles similar to the SR view or over the 10th–12th intercostal spaces, "fanned" through the right kidney and adjacent right liver *Dependent on right or left lateral recumbency, is not part of the abdominal fluid system, and is most often performed in standing	Retroperitoneal abnormalities • Fluid • Masses Renal parenchyma • Renal pelvic dilation—pyelectasis and hydronephrosis • Cysts—cortical and perinephric • Masses • Infarction Ureteral distension Liver abnormalities Vascular (great vessels, renal and portal vessels) • Thrombus • Masses • Shunts • Volume status

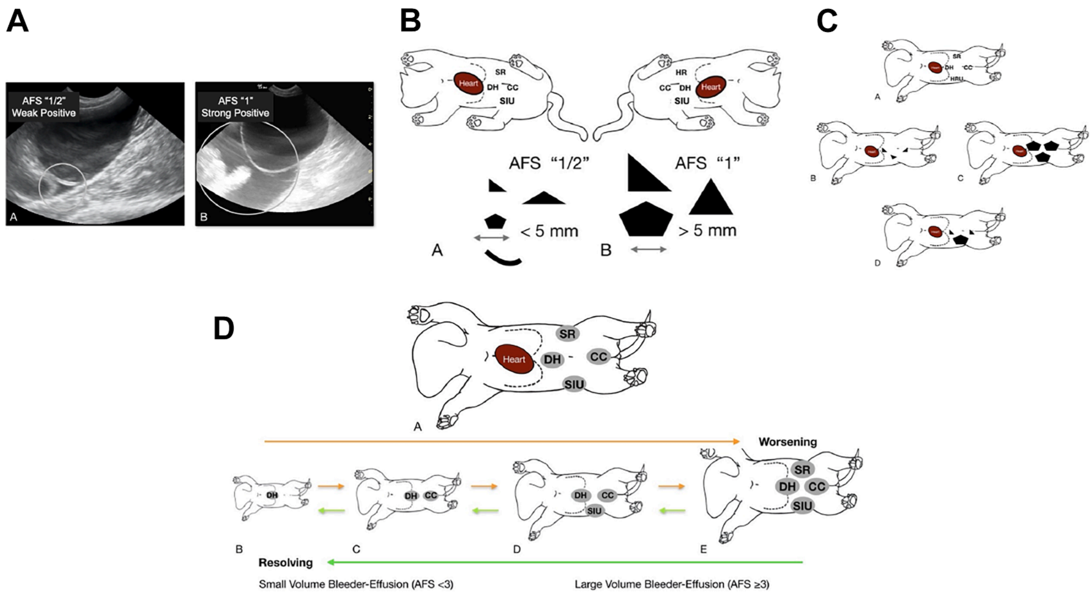

FIG. 1 (**A–D**) The AFAST-applied fluid scoring system (AFSS) and its modification. (*Reprinted with permission from* Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition, edited by Gregory R. Lisciandro, published by John Wiley & Sons, Inc, 2021. And Dr. Gregory Lisciandro, DVM, Dipl. ABVP, Dipl. ACVECC, Hill Country Veterinary Specialists and FASTVet.com. Copyright 2012, 2014, 2019, 2021.)

and "strong positive (1)" system to better categorize "small volume" versus "large volume" that better predicts degree of anemia and volume depletion for transfusion and volume resuscitation decisions (Fig. 1) [6,8,13,24,33,68–71]. The sonographer should record the AFS at each respective view because where the patient is positive or negative may have some relevance as to the source of hemorrhage or sepsis dependent on the case. When fluid is safely accessible by centestsis, it should be sampled and tested for packed cell volume, total protein, and cytology rather than characterization based on its gross appearance alone.

Under normal conditions, many juvenile dogs and cats up to 9 months of age can have small volume of peritoneal effusion. AFAST examination of healthy adult dogs and cats has commonly observed small stripes of "free fluid" along the diaphragm at the DH view [68–71]. Thus, AFS should always be placed in the clinical context of a patient's signalment, history, and physical examination findings. Moreover, performing a serial AFAST with fluid scoring is always a fallback option in suspect cases of being abnormal. As standard of care, all patients should have a serial AFAST/Global FAST (4-hour postadmission or sooner if questionable or unstable, and then during patient rounds, rechecks, as needed until the clinician is certain that AFAST may be discontinued) following fluid resuscitation and restoration of intravascular volume, as often patients image much differently despite clinical improvement [6–8,72]. The AFAST examination, combined with serial assessment of the AFS and correlation with the patient's hemodynamic status and history can aid in decision-making in hemorrhagic regarding whether medical management with transfusion versus performing an exploratory laparotomy to control hemorrhage is warranted. In the author's experience and in a recent study in postoperative dogs with pyometra, when noncoagulopathic dogs and cats stop bleeding, intra-abdominal hemorrhage is resorbed almost completely (AFS 1) to completely (AFS 0) within 48 hours [6,7,13,73]. In nonhemorrhagic effusions, that is, septic abdomen, similarly medical versus surgical management decisions may be made. A clinical diagnostic algorithm is provided (Fig. 2). Moreover, this same study was consistent with a previous study regarding iatrogenic postoperative pneumoperitoneum and ultrasound may perform better than radiography [27,73–75].

The standing position is recommended because it requires less restraint [65–67]. If AFAST detects no effusion, then moving the patient to lateral recumbency is unnecessary; however, if AFS-positive, then moving the patient to either lateral recumbency, and then waiting 3 minutes (the author's "3-minute rule") should be

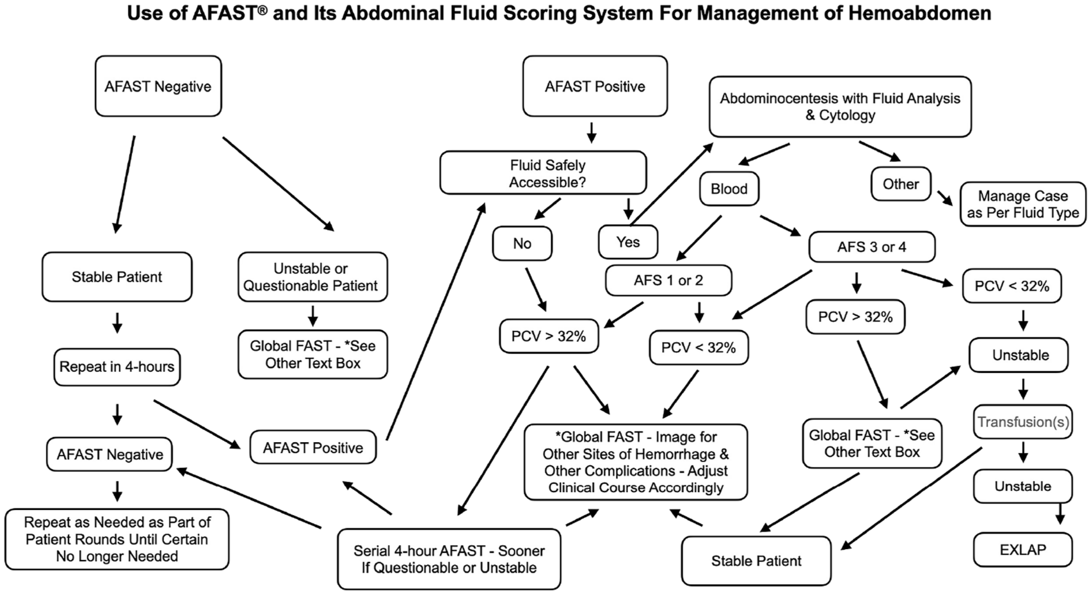

FIG. 2 Clinical diagnostic algorithm using the AFAST-assigned abdominal fluid scoring system for hemoperitoneum. (*Reprinted with permission from* Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition, edited by Gregory R. Lisciandro, published by John Wiley & Sons, Inc, 2021. And Dr. Gregory Lisciandro, DVM, Dipl. ABVP, Dipl. ACVECC, Hill Country Veterinary Specialists and FASTVet.com. Copyright 2012, 2014, 2019, 2021.)

followed to allow the fluid to redistribute to obtain a valid AFS [65–67].

Nontrauma, bleeding mass

The most common cause of nontraumatic hemoabdomen is hemorrhage from an abdominal or retroperitoneal mass. Global FAST can be utilized to rapidly stage the patient and for pulmonary metastasis check that then leads to thoracic radiography or a computed tomography (CT) scan for further metastatic evaluation [17,19,76,77]. Moreover, Global FAST is used to look for potential diagnostic sampling sites for fluid acquisition and cytopathological/histopathological evaluation [17,19]. However, the author first described a unique complication of "anaphylactic, heparin-related, medically treated hemoperitoneum (AX-hemoperitoneum)" in dogs [78–80]. Thus, nontraumatic canine hemoperitoneum must include this rule out because taking such a dog to surgery will likely lead to a fatal outcome.

Nontrauma, anaphylactic canine hemoabdomen

POCUS has allowed veterinarians to document nontraumatic hemoabdomen secondary to anaphylaxis (AX) in dogs, coined as "anaphylactic (AX)-related, medically treated, heparin-induced, hemoabdomen" [78,79]. However, it should be duly noted that a Global FAST approach should always be used to integrate findings in the abdomen and thorax to avoid imaging interpretation errors that can lead to major clinical mismanagement, that is, mistaking a "cardiac gallbladder" for an "anaphylactic gallbladder" and vice versa (Fig. 3) [25,81]. This fascinating complication is unique to canines because of their shock organs being the liver and GIT, where the greatest concentration of mast cells is located. During canine AX, degranulation of mast cell leads to systemic dispersal of heparin, histamine, phospholipases, tryptase, and others that are inflammatory and vasoactive, leading to acute hepatic venous congestion with hepatomegaly, followed by oozing of blood through the hepatic capsule, with an acquired reversible coagulopathy [80,82]. Fluid is most commonly present at the DH view with no other documented sites of bleeding other than the abdominal cavity on Global FAST examination, that is, no retroperitoneal, pericardial, or pleural effusion [78–80,83]. Care should be exercised during patient handling to avoid excessive abdominal pressure that could lead to rupture of the engorged, friable

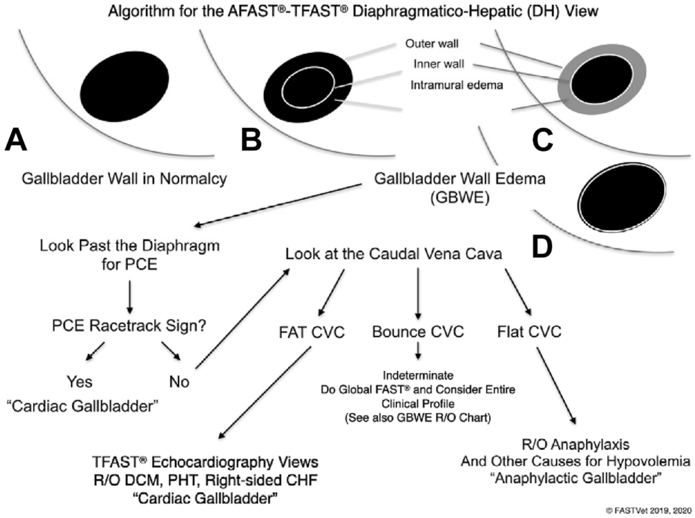

FIG. 3 Algorithm for determining "cardiac gallbladder" versus "anaphylactic gallbladder." (*Reprinted with permission from* Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition, edited by Gregory R. Lisciandro, published by John Wiley & Sons, Inc, 2021. And Dr. Gregory Lisciandro, DVM, Dipl. ABVP, Dipl. ACVECC, Hill Country Veterinary Specialists and FASTVet.com. Copyright 2012, 2014, 2019, 2021.)

liver; and degree of coagulation abnormalities does not predict the presence of AX-related hemoperitoneum [84,85].

Nontraumatic AX-related, medically treated hemoabdomen should be suspected in any dogs with history of acute collapse, often accompanied by gastrointestinal signs, with or without a witnessed insect sting or more rarely pit viper envenomation [80,82]. Laboratory abnormalities observed with this syndrome include hemoconcentration, elevated serum alanine transaminase (ALT) and aspartate transaminase (AST) with normal alkaline phosphatase (ALKP) [79,80,82–86]. AFAST often shows striation of the gallbladder wall consistent with intramural gallbladder edema (GBWE), a collapsed CVC consistent with hypovolemia, and a positive AFS that may be qualified as "small volume" or "large volume" that helps predict the anticipated degree of anemia and is followed with serial AFAST/Global FAST [6,8,13,65,66,78–80].

Other anecdotal unpublished causes of canine AX-related hemoabdomen include vaccine-reactions, medications, and mast cell tumor degranulation. Treatment for anaphylaxis includes administration of crystalloid fluids, histamine-receptor antagonists, glucocorticoids, and epinephrine and fresh frozen plasma if ongoing hypotension or coagulopathies are observed [79,80,82–87].

Sonographers should be aware that GBWE, also called the "gallbladder halo sign," is not pathognomonic for canine AX [25,66]. PCE, other right-sided cardiac conditions and generalized systolic failure that lead to hepatic venous congestion also cause GBWE with PCE being the most common. GBWE from cardiac causes has been referred to as a "cardiac gallbladder" and in one study was found in 14% of right-sided congestive heart failure dogs, and is less common, but also possible in cats [25,81]. Moreover, PCE dogs can have a similar presentation as AX including with gastrointestinal signs [26,88,89]. Several other causes of GBWE include cholecystitis, pancreatitis, hypoalbuminemia, and third spacing, right-sided volume overload from fluid resuscitation, immune-mediated hemolytic anemia, post blood product transfusion(s), and some drugs, that is, dexmedetomidine (Table 3) [22,92]. Unlike AX and PCE, other cause of GBWE typically do not present with a history of a clinically normal dog followed by acute onset of weakness or collapse. Moreover, AX is a life-threatening form of hypovolemic and distributive shock, so GBWE should be correlated with the individual patient's history, clinical signs, and laboratory abnormalities.

As a generalization, AX-hemoperitoneum has the following presenting history and findings: (1) a clinically normal dog with acute weakness/collapse often

TABLE 3
Rule outs for gallbladder wall edema

Rule outs for the finding of gallbladder wall edema (GBWE) in dogs		
Cause	Expected Characterization of CVC and HVs	Suspected Pathophysiology
[a]Canine anaphylaxis (AX) [82]	"flat" hypovolemic CVC	Acute portal venous infusion of histamine causing venous constriction resulting in acute marked hepatic venous congestion (and increased ALT, AST) [80,82]
[a]Pericardial effusion (PCE) [26]	"FAT" hypervolemic CVC and distended HVs ("tree trunk sign") [78,81]	Backflow of venous blood flow to the right heart resulting in severe hepatic venous congestion [26,66]
[a]Right-sided CHF in absence of PCE [26]	"FAT" hypervolemic CVC and distended HVs ("tree trunk sign") [78,81]	Backflow of venous blood flow to the right heart resulting in severe hepatic venous congestion [26]
Cholecystitis	Variable	Direct inflammation
Pancreatitis	Variable	Direct inflammation
Sepsis [90]	Variable	Direct inflammation (normal ALT as a general rule) [90]
Acute hemorrhagic gastroenteritis syndrome [91]	Variable	Direct inflammation (variable ALT as a general rule) [91]
Hypoproteinemia with third spacing	Variable	Vascular leak due to low oncotic pressure
Immune-mediated hemolytic anemia	Variable	Likely immune-mediated and volume overload associated with anemia
Post-transfusion	Variable to "FAT" hypervolemic	Likely immune-mediated and volume overload associated with increased oncotic pressure
Alpha-2 agonists, that is, dexmedetomidine [92]	"FAT" hypervolemic CVC and distended HVs ("tree trunk sign")	Result of arterial constriction and venous pooling [92]

[a] May present similarly with clinically-normal dog that experiences acute weakness, collapse.

associated with gastrointestinal signs, (2) hemoconcentration (packed cell volume [PCV] >52%), (3) elevated ALT and AST with ALKP unaffected (Ryan Smith, Personal Communication), GBWE, a "flat" CVC, and an absent splenic mass at the SIU view and during the focused spleen with no other sites of effusion [78–83,86]. Moreover, the source of hemorrhage is oozing/diapedesis of blood through the liver's capsule from acute severe hepatic venous congestion due to the massive portal infusion of histamine with venoconstriction and then not uncommonly the reversible acquired coagulopathy from AX-related inflammatory and vasoactive factors including heparin called the second episode of AX. As a result, the DH view is most commonly positive during AFAST [78–83,86].

Postsurgical abdominal effusion

To the author's knowledge, few studies exist that have evaluated the presence of intra-abdominal free fluid postoperatively without known or apparent surgical complications such as postoperative bleeding, peritonitis, or vascular abnormalities. In recent study of 22 dogs surgically treated by ovariohysterectomy without any abdominal lavage, sequential focused abdominal ultrasound (AUS) examinations ("AFAST" and fluid scored)" was performed at 3-time points preoperatively and postoperatively. The study reported that a small volume of peritoneal effusion, AFS 2, was present in 41% of cases up to 6 days postoperatively [73]. The most common positive "AFAST" locations in the canine pyometra study were the CC and SR views, presumably due to localized small volume hemorrhage at the uterine stump (CC) and left ovarian pedicle (SR), respectively [93]. It should be noted that although the authors cited AFAST and AFS by Lisciandro and colleagues, the reported AFAST protocol differed as positioning was in dorsal and not lateral recumbency [93].

Lavage fluid can be problematic when used and not removed from the abdominal cavity prior to surgical closure because it tends to persist for up to 5 days postoperatively and maybe longer, confounding AFS interpretation (author experience) and this observation is supported by an ultrasound study pre-FAST [34]. Thus, the author recommends to "dry" the abdomen of lavage fluid prior to surgical closure. Diagnostic peritoneal lavage (DPL) is no longer performed due to the difficulty in interpreting subsequent imaging and pathologic causes from the DPL-introduced fluid and likely air.

The AFAST abdominal fluid scoring system for nonhemorrhagic effusions

The AFSS can be applied to any type of abdominal effusion including sterile and septic peritonitis, transudates, and modified transudates. Serial assessment using AFAST can be used to characterize progression or worsening of abdominal fluid and correlate findings with a patient's clinical response to therapy. For example, a dog or cat with sterile (or septic) peritonitis secondary to pancreatitis may be monitored using the AFAST-applied AFSS. If on day 1, the patient is a low-scoring AFS 1 and then followed serially and found to be an AFS 0 on day 2, the AFS supports an improvement in clinical course. In contrast, if on day 2 the AFS has increased to an AFS of 3, then the patient is likely worsening. When larger volumes of fluid are safely accessible, sampling and testing via abdominocentesis are indicated because ultrasound cannot reliably characterize type of fluid based on echogenicity.

AFAST compared to radiography and computed tomography

To the author's knowledge, there are limited studies that compare FAST ultrasound formats with standard radiography and CT. In the author's original AFAST study, serosal detail was normal in 24% of dogs with positive AFS and was decreased in 33% of dogs that were AFS-negative [6]. Another study of 13 dogs and 2 cats with both blunt and penetrating trauma that differed published methodology [94,95]. The median time from presentation to FAST examinations by ER clinicians, radiologists then start of CT was 54, 84, and 99 minutes, respectively. "AFAST" had moderate to excellent correlation with CT for peritoneal effusion ($N = 5$); and fair to moderate correlation for pleural effusion ($N = 3$). There was poor correlation with the reported "TFAST" methodology compared with CT for detection of pneumothorax; however, 5/15 of those enrolled had incomplete "TFAST" examinations consisting of imaging only one hemithorax [94]. In between these time intervals, some patients had sedation including dexmedetomidine (an agent that causes hepatic venous congestion, gallbladder wall edema, and ascites) invasive centestsis events, and fluid resuscitation that could have affected comparative imaging findings [92]. Moreover, degrees of effusion and pneumothorax (PTX) were not reported. The small numbers of PE, PCE, and PTX detected as well as incomplete studies with invasive interventions could have confounded findings that limit the study's validity [95].

A second comparative study of 16 animals with blunt (8 dogs and 8 cats) and additional penetrating trauma (3/16) compared FAST ultrasound performed in 11 of the 16 animals to whole-body CT [96]. There is no reported interval between "AFAST–TFAST" imaging, and CT, which could have affected results as patients were presumably fluid resuscitated and may have had other invasive centestsis procedures, although this is unclear. The CT findings found 3 patients with pleural effusion not detected on "TFAST"; and 1 with peritoneal effusion not detected on "AFAST", however, the volume of effusion and results of cavitary ultrasound prior to CT were not reported [5,97]. In a second comparative "AFAST" and "TFAST" to CT study by the same group, the interval between FAST ultrasound and CT was up to 24 hours. Moreover, 16 of the 21 patients were sedated and 5 of the 21 had general anesthesia that included dexmedetomidine [92]; and 52% received contrast medium. These sedation/anesthesia interventions including the use of dexmedetomidine, plus fluid resuscitation, and likely centestsis events could also have changed findings between the FAST ultrasound preempting CT [94,96,97]. These 3 studies are examples for why the terms AFAST, TFAST, Vet BLUE, and Global FAST were service marked for education purposes to protect their integrity as standardized formats with exact clarity to each format's views.

Final AFAST comments

Evaluation of abdominal radiographic serosal detail or CT is largely subjective and lacks qualitative descriptors to note degrees of PTX and peritoneal or pleural effusion. By using standardized AFAST and its applied AFSS, the sonographer can "see and score" ascites with evidence-based information rather than "flashing" or performing targeted abdominal and thoracic that describes the presence or absence of fluid without serially scoring fluid volume [96–98]. Unclear abnormalities on AFAST ultrasound that may affect clinical management should have additional imaging considered such as radiography, more advanced ultrasound studies, that is, complete detailed AUS and/or echocardiography, CT, or MRI.

Other clinical uses of the AFAST

In addition to screening for the presence of effusions (abdominal, retroperitoneal, pericardial, and pleural) and soft tissue abnormalities of its target-organs with a focused spleen component, serial AFAST may be used to estimate urine output using the AFAST CC view formula, urine volume estimation = length × height × width measured in centimeters × 0.625 equals volume in milliliters [46]; and intravascular volume status by characterizing the CVC and HVs during fluid resuscitation (DH view) of emergent and critically ill patients [81,99–109]. Other AFAST uses with no additional views, include detecting diaphragmatic hernia [28], assessing the stomach (empty nothing per os [NPO patients] vs imaging its contents and distension at the DH view) [36], detecting gastrointestinal foreign bodies/obstruction, gastrointestinal motility (fetal and adults) [24,31,32,37,50,110], pneumoperitoneum (AFAST SR view in right lateral; superior to radiography) [27,73–75], and determining location of urinary and abdominal drainage catheters, gastric tubes, endotracheal tube placement, and more [10,35,111,112].

Soft tissue abnormalities of target-organs

See Table 2. All abnormalities should have calipers placed and images and cine clips archived.

Intravascular volume assessment

The use of central catheters for central venous pressure measurement to guide responsiveness to fluid therapy

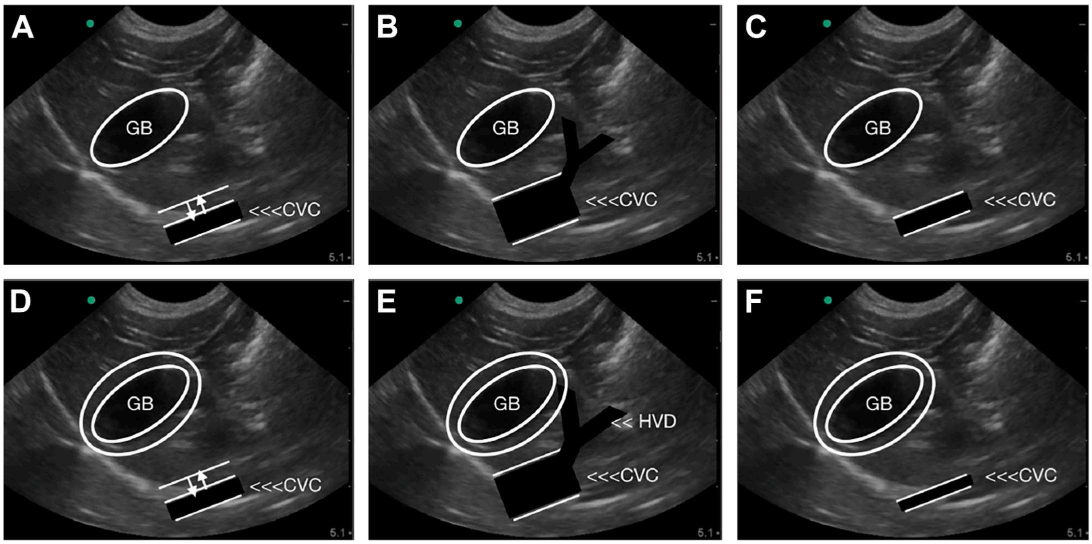

FIG. 4 (**A**–**F**) Maximum caudal vena caval height measurements for "bounce," "flat," and "FAT" in dogs and cats. In the top row, the CVC and HVs are shown as (**A**) "bounce" with a 35% to 50% change in maximum height, called "fluid responsive CVC," (**B**) a distended "FAT" CVC with a less than 10% change in maximum height and HV distension, the "tree trunk sign," called "fluid intolerant CVC," and (**C**) "flat" with a less than 10% change in maximum height, called "fluid starved CVC." The bottom row shows GBWE and the same 3 scenarios of the CVC maximum heights for a "FAT" CVC have been derived by the author as ≥0.5 cm cats; ≥1.0 cm small dogs less than 9 kg; ≥1.5 cm medium to large dogs greater than 9 kg. (*Reprinted with permission from* Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition, edited by Gregory R. Lisciandro, published by John Wiley & Sons, Inc, 2021. And Dr. Gregory Lisciandro, DVM, Dipl. ABVP, Dipl. ACVECC, Hill Country Veterinary Specialists and FASTVet.com. Copyright 2012, 2014, 2019, 2021.)

is no longer performed in people and has been replaced by characterization of the inferior vena cava at the level of the diaphragm [113–115]. For small animal patients, intravascular volume status is evaluated by observing the dynamic changes in height of the CVC (distensibility index) through cardiac and respiratory cycles, or more simply by assessing the CVC and HVs over a few seconds, freezing the screen and moving frame by frame through captured images. The CVC and its associated HVs view may be characterized by the "eyeball method" as "FAT (fluid intolerant)," "flat (hypovolemic)," and "bounce (fluid responsive)" (Fig. 4). Distended HVs have been referred to as the "tree trunk sign" (see Fig. 4) [17,24,33,81,99,116]. Maximum CVC height measurement as a double check for a "FAT" CVC have been published by the author as cats greater than 0.5 cm, small dogs greater than 1.0 cm, and large dogs greater than 1.5 cm [24,33,81,100,102,113–115]. Other CVC assessments and measurements at other locations have been described in dogs; however, it seems most logical that the CVC will be most reflective of intravascular volume as close to the right heart as possible, where the CVC traverses the diaphragm at the DH view, an easy CVC image to acquire [17,24,33,66,116].

Free air, pneumoperitoneum

The "enhanced peritoneal stripe sign (EPSS)" is the added brightness (hyperechoic) of the peritoneal lining by free air found at the least gravity-dependent view dependent on patient positioning (Fig. 5) [27]. Postoperative laparotomy cases normally have free air that can last up to 25 days, thus are a good model to practice the technique [27,73].The study by Kim and colleagues was performed in dorsal recumbency, which is never recommended for AFAST or any component of the Global FAST, with general anesthesia and intraoperative monitoring as an exception. The study was able to detect as little as 0.2 mL of an air with 93% sensitivity and specificity [27]. The preferred AFAST location in right lateral recumbency would be the SR view as air rises. Pneumoperitoneum findings in nonsurgical cases should be placed into clinical context alerting the clinician a differential of causes that includes ruptured viscus organs, forms of gas producing peritonitis (ie, ruptured abscess such as hepatic,

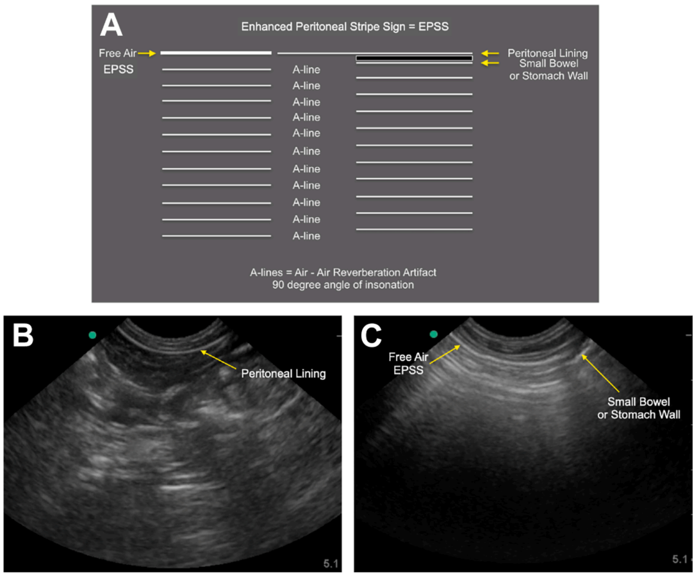

FIG. 5 The detection of "free air" and pneumoperitoneum at the AFAST SR view when the patient is positioned in right lateral recumbency. In (**A**) is a drawing that shows that both "Free Air" and air in the GI tract will shadow with air reverberation (A-lines) through the far field. The difference is that the "free air" boldens the peritoneal lining called the "EPSS" whereas the GI tract has a wall with layering referred to as the "Black Gap" by the author. In (**B**), the peritoneal lining is shown. In (**C**), the contrast between the "EPSS" and GI tract is shown. (*Reprinted with permission from* Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition, edited by Gregory R. Lisciandro, published by John Wiley & Sons, Inc, 2021. And Dr. Gregory Lisciandro, DVM, Dipl. ABVP, Dipl. ACVECC, Hill Country Veterinary Specialists and FASTVet.com. Copyright 2012, 2014, 2019, 2021.)

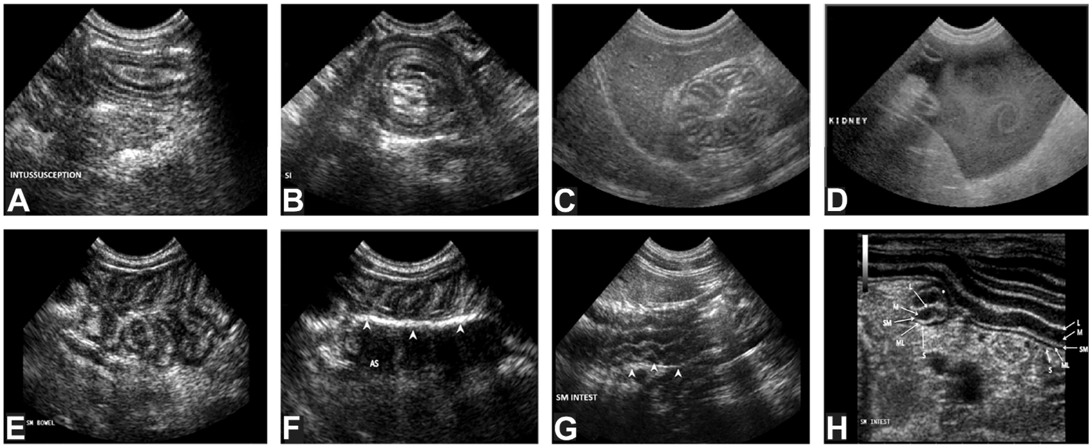

FIG. 6 A series of GIT images that can be seen during AFAST. In (**A** and **B**) are examples of intussusceptions, the “bull’s eye” or “ring sign” appearance not to be confused with an empty stomach in (**C**) and ascarids in (**D**). In (**E** and **F**) are examples of plication from a linear foreign body not to be confused with corrugation from enteritis in (**G**). Normal layering is shown in (**H**). (Reprinted with permission from Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition, edited by Gregory R. Lisciandro, published by John Wiley & Sons, Inc, 2021.)

splenic, and prostatic abscesses), penetrating peritoneal wounds, and others. The confounder for the “EPSS” is GIT that when immediately opposed to the peritoneal lining also shadows through the far field. The difference is the lack of the “black gap” of the sonographic layering of GIT that would *not* be present with true pneumoperitoneum [24,27,71].

Gastrointestinal motility and obstruction

The AFAST SIU view may be used for evaluating the GIT for motility. Fasted dogs (>12–24 hours) will normally have ileus and are best evaluated less than 6 hours of fasting [31,32]. Normal expected peristaltic contractions per minute have been published. The stomach and proximal duodenum contract 4 to 5 minute^{-1}, while the distal duodenum and jejunum contract 1 to 5 minute^{-1} [31,32,48,49]. Luminal measurements of the jejunum greater than 1.5 cm should raise the suspicion for small bowel obstruction, particularly in the absence of normal peristalsis [50,110]. Intussusceptions may be recognized by concentric sonographic multilayering with a bull’s eye or target effect [32]. Some fundamental small intestinal findings are shown (Fig. 6).

Comparisons to other imaging modalities

There are few studies that have compared FAST and POCUS to other imaging modalities. Regarding the abdominal cavity and ascites, correlation has been good for answering the simple binary question of the presence or absence of fluid [94–97]. The AFAST fluid scoring system (AFSS) has not been compared as a semiquantitative approach to degree of free fluid to findings on radiography and CT; and to the author’s knowledge such fluid scoring systems do not exist for radiography and CT.

SUMMARY

The Global FAST approach as “an extension of the physical examination” is having a vital impact in small animal veterinary medicine. The mindset of Global FAST over POCUS “flashing” and “selective imaging” is important to prevent imaging interpretation errors. Documentation of baseline and serial findings on goal-directed templates help track patients and can determine preexisting conditions. The greatest potential of Global FAST and its unbiased set of 15 data imaging points of the abdomen, and thorax including heart and lung, lies in its ability to capture conditions earlier in their course and conditions traditionally missed without use of ultrasound, with the potential for cure. The Global FAST examination is performed more expediently without the delay of traditional complete ultrasound studies and radiography including CT that may be delayed due to patient instability or resources. The use of Global FAST imaging allows the clinician to better pick the “next best” diagnostic test and more accurately treat patients by “seeing” their problems, thus, carrying potential for keeping patients alive for gold standard testing and treatment. The Global FAST approach and POCUS have "awakened a sleepy giant" already contributing to widespread advancement in patient care and untold uses still exist on the horizon.

CLINICS CARE POINTS

- AFAST is a rapid point-of-care imaging test that can detect soft tissue abnormalities of its target organs, many of which are only suspected or missed on plain radiography; and characterization of the caudal vena cava and hepatic veins for volume status, lung and cardiac pathology along the cardiac-diaphragmatic and pulmonary-diaphragmatic interface.
- AFAST is a rapid point-of-care imaging test that can detect "free fluid" as ascites, pleural and pericardial effusion, and retroperitoneal fluid that should be sampled and tested when safely accessible.
- The AFAST-assigned abdominal fluid scoring system semiquantitates intra-abdominal fluid and can further categorize as "small volume" versus "large volume" principles for clinical decision-making including fluid resuscitation (blood transfusion, crystalloids, colloids) and surgical intervention(s).
- Many add-on skills may be applied to the 5 AFAST views including its urinary bladder volume estimation formula that over time provides noninvasive urine output estimation, the detection of pneumoperitoneum, gastrointestinal motility and distension, location of catheters, presence of thrombosis, and more.
- AFAST is an ultrasound screening that is not meant to replace plain radiography, a more complete detailed abdominal ultrasound, echocardiography, computed tomography, or MRI.

DISCLOSURE

Dr G. Lisciandro is the co-owner of Hill Country Veterinary Specialists and FASTVet.com, a private company that provides veterinary ultrasound training to veterinarians and veterinary professionals with loaned equipment from several ultrasound companies without sales commissions. The terms AFAST, TFAST, Vet BLUE, and Global FAST are service marked for educational purposes and are proprietary to FASTVet.com and Hill Country Veterinary Specialists through Lisciandro Enterprises, PLLC, Spicewood, Texas. His spouse, Dr S. Lisciandro, DVM, DACVIM (SAIM) is a co-owner of Hill Country Veterinary Specialists and FASTVet.com.

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