ORIGINAL RESEARCH

FAST Performance in a Stationary versus In-Motion Military Ambulance Utilizing Handheld Ultrasound: A Randomized Controlled Study

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Keywords: ambulance; FAST; military medicine; prehospital; ultrasound

Abbreviations:
ACEP: American College of Emergency Physicians
eFAST: extended Focused Assessment with Sonography in Trauma
FAST: Focused Assessment with Sonography in Trauma
LUQ: left upper quadrant
PA: physician assistant
RUQ: right upper quadrant
US: ultrasound

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Abstract

Objective: On-scene prehospital conditions and patient instability may warrant a during-transport ultrasound (US) exam. The objective of this study was to assess the effect of ambulance turbulence on the performance of the Focused Assessment with Sonography in Trauma (FAST) with a handheld US device.

Methods: This was a randomized controlled trial in which participants were randomized to perform a FAST in either a stationary or an in-motion military ambulance. Participants were physicians and physician assistants (PAs) with previous FAST training. All exams were performed on an US phantom model. The primary outcome was FAST completion time, reported as a mean, in seconds. Secondary outcomes included image acquisition score (range of 0-24, reported as a mean), diagnostic accuracy (reported as sensitivity and specificity), and a post-participation survey with five-item Likert-type scales.

Results: Twenty-seven participants performed 27 FASTs, 14 in the stationary ambulance and 13 in the in-motion ambulance. All participants obtained the four requisite views of the FAST. A significant difference was detected in image acquisition scores in favor of the stationary ambulance group (19.4 versus 16.7 [95% CI for difference, 0.9-4.4]; P <.01). Significant differences in survey items between groups were related to obtaining and maintaining US images and the exam conditions. There was not a difference in FAST completion time between groups (98.5 seconds versus 78.7 seconds [95% CI for difference, -13.5 seconds to 53.1 seconds]; P = .23). Sensitivity and specificity of FAST in the stationary ambulance was 85.7% (95% CI, 67.3%-96.0%) and 96.4% (95% CI, 81.7%-99.9%) versus 96.2% (95% CI, 80.4%-99.9%) and 100.0% (95% CI, 86.8%-100.0%) in the in-motion ambulance group (P = .21).

Conclusion: Vehicular motion did not affect FAST completion time and diagnostic accuracy; however, it did reduce FAST image acquisition scores. The results suggest timely and diagnostically accurate FASTs may be completed by experienced sonographers during moderate levels of ambulance turbulence. Further investigation assessing the utility and limitations of newer handheld US devices in various prehospital conditions is warranted.

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Introduction

The Focused Assessment with Sonography in Trauma (FAST) is an ultrasound (US) exam with high specificity for hemoperitoneum and pericardial effusion that may provide valuable clinical information for guiding, and even changing, management decisions in the prehospital environment.[1–5] Trauma scenes in a military or unsecured environment can be hostile, necessitating threat suppression, treatment of life-threats, and rapid patient

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extrication followed by immediate transport.[6–8] Moreover, studies demonstrate decreased mortality in penetrating trauma patients transported by police and privately-owned vehicles compared to ground ambulance.[9,10] This underscores the potential benefit of the "scoop and run" model; however, this model requires any US exam to be performed during transport, as it may not be safe or feasible to perform an US exam on-scene or in the back of a stationary ambulance prior to transport.

Transport over rough terrain or unimproved roads may produce turbulence that complicates patient evaluation and treatment. While the feasibility of prehospital US use has been established, there has been limited research directly evaluating the effect of ambulance turbulence on the performance of US exams.[11–13] Additionally, prehospital research regarding handheld US devices is largely limited to older-generation devices.[4,5,13] Recent technological advancements yield handheld US devices with improved image quality, portability, and user-interfaces.[14–16] This study aims to provide data regarding during-transport US exams by assessing the effect of ambulance turbulence on FAST performance. The primary objective of this study was to compare clinician FAST completion time when completed on a stationary versus in-motion ground ambulance using a handheld US device.

Methods

Study Oversight and Design

This was a prospective, randomized controlled study approved by the United States Army Regional Health Command-Pacific's Institutional Review Board (Fort Lewis, Washington USA; protocol # 219082).

Subjects and Materials

Investigators conducted this study on Joint Base Lewis-McChord, Washington in November 2019. Inclusion criteria for study participants were the following: (1) United States military physician or physician assistant (PA); (2) prior FAST training; (3) older than 18 years of age; and (4) less than 55 years of age. The exclusion criterion was any physical limitation that would preclude adequate or safe performance of the FAST in an in-motion ambulance. Physicians and PAs already proficient with the FAST were sought to avoid confounding from a training intervention. Participants wore their duty uniform or civilian clothes with a military helmet (Advanced Combat Helmet, ArmorSource, LLC; Hebron, Ohio USA) without any additional body armor or field gear.

Participants utilized a handheld SonoSite iViz US device (FUJIFILM SonoSite, Inc.; Bothell, Washington USA) with the P21v phased array transducer (5-1 MHz) on the abdominal preset for all FASTs (Figure 1). A Blue Phantom "FAST Exam Real Time Ultrasound Training Model" (Item Number BP-FAST1800; CAE Blue Phantom, CAE Health Care; Sarasota, Florida USA; Figure 2) was utilized for simulated FAST. These models afforded life-like sonographic images that study investigators could manipulate to produce abnormal findings (hemoperitoneum and hemopericardium) in each of the four views of the FAST.

Study activities were conducted inside a military ambulance (model M997, AM General; South Bend, Indiana USA) with a single overhead light source, providing ideal lighting for visualizing the US screen (Figure 2 and Figure 3). The US model was placed on a military stretcher and loaded head-first on the ambulance's passenger side, on the bottom rack, enabling a right-hand dominant sonographer to face the direction of travel while scanning

Figure 1. Handheld SonoSite iViz with Phased Array Transducer (FUJIFILM SonoSite, Inc.; Bothell, Washington USA).

Figure 2. Participant Performing a FAST on Phantom Model (CAE Blue Phantom, CAE Health Care; Sarasota, Florida USA) Inside M997 Ambulance.
Abbreviation: FAST, Focused Assessment with Sonography in Trauma.

(Figure 2). The stationary ambulance had the engine shut off during testing to avoid exhaust exposure. Drivers of the in-motion ambulance drove on a 300-meter figure-of-eight course and were instructed not to exceed 10 miles per hour. The driver stopped the vehicle briefly after each lap to incorporate acceleration and deceleration conditions. An unimproved gravel road was selected that was relatively flat, and possessed numerous bumps and divots. The speed, terrain, and course provided a moderate amount of ambulance turbulence in the military ambulance without placing the participants at significant risk of injury. Higher speeds were tested on the course prior to data collection; however, the conditions it produced precluded safe FAST performance.

Study Protocol

Investigators (*CS, LM*) assessed eligibility of potential participants for the study. Subjects then underwent a three-minute orientation via PowerPoint (Microsoft Corporation; Redmond, Washington USA) on the phantom model's anatomy, showing them examples

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Figure 3. M997 Ambulance (AM General; South Bend, Indiana USA).
Note: Image obtained from: https://www.amgeneral.com/wp-content/uploads/2019/12/M997A3-Ambulance.pdf on February 13, 2020.

of the presence and absence of free-fluid in each view. This was necessary as the phantom model's anatomy differed slightly in its sonographic appearance in comparison to live human anatomy. Investigators briefly oriented participants to the SonoSite iViz with a focus on how to adjust gain and depth. Participants were instructed to perform all four views of the FAST in a time-efficient manner, in any order, with the goal of identifying the presence or absence of free-fluid (hemoperitoneum or hemopericardium).

Investigators randomized subjects into one of two groups using a random number sequence generator. Participants assigned to group one performed a single FAST in a stationary ambulance, while those in group two performed a single FAST in an in-motion ambulance.

Before testing, study investigators manufactured normal and abnormal findings for all views of the FAST on each of the phantom models. Two study investigators independently validated the diagnostic accuracy setup on each model before testing commenced. Models were set up with hemoperitoneum seen in the right upper quadrant (RUQ) and left upper quadrant (LUQ) with no free fluid seen in the suprapubic and cardiac views. Emergency US fellowship trained PAs (*AC, JM, BA*) timed all exams and evaluated them for image acquisition score and diagnostic accuracy.

Outcomes

The primary outcome for the study was FAST completion time measured in seconds. Time started when the transducer made contact with the model and ended after the participant vocalized their interpretation of the fourth view of the FAST or when they stated they were complete. The secondary outcomes included image acquisition score, diagnostic accuracy, and a post-participation survey with five-item Likert-type scales. Image acquisition score was assessed using a previously validated 24-point checklist for the FAST (Appendix A; available online only).[17] The checklist contains six items for each of the four components of the FAST with higher scores correlating to increased exam thoroughness in the appropriate images for evaluation of free fluid in the abdomen and around the heart. For diagnostic accuracy, participants were required to vocalize "free fluid" or "no free fluid" in each of the four FAST views. Diagnostic accuracy was assessed per view, not per exam, to yield more specific diagnostic data regarding the participants' FAST performance. Study investigators determined the participant's responses as diagnostically correct or incorrect by comparing them to the preset Blue Phantom FAST model conditions. All post-survey responses were on five-item Likert-type scales.

Statistical Analysis

G*Power analysis software (version 3.1; Dusseldorf, Denmark) was utilized for a pre-study sample size calculation. Power was set at 0.8 and the alpha at 0.05. Assessing to detect a 60 second difference between groups with a standard deviation of 45 seconds in each group yielded a sample size of 20 FASTs (10 in each group).

Statistical analyses were conducted with SPSS statistical software package (IBM SPSS Statistics for Windows, Version 24.0; Armonk, New York USA). Two-tailed t-tests were used to analyze continuous data, Fisher's exact test for categorical data, and Wilcoxon signed-rank tests for ordinal data. Continuous variables are reported as means with standard deviations (SD) and 95% confidence intervals (CIs) for difference, categorical data as sensitivity and specificity with 95% confidence intervals (CIs), and ordinal variables as medians with interquartile ranges (IQRs). Statistical significance was defined as $P < .05$.

Results

In November 2019, 27 clinicians participated in the study (Table 1). All 27 volunteered, zero were excluded, and zero withdrew. Emergency medicine physician residents comprised the greatest proportion of subjects. The median age of participants was 30 years and most participants had performed less than 50 FASTs prior to study activities. All participants completed a FAST for the study with 14 in the stationary ambulance group and 13 in the in-motion ambulance group.

There was not a significant difference in FAST completion time (98.5 seconds versus 78.7 seconds [95% CI for difference, -13.5 seconds to 53.1 seconds]; $P = .23$) or in diagnostic accuracy (85.7% sensitivity [95% CI, 67.3%-96.0%] and 96.4% specificity [95% CI, 81.7%-99.9%] versus 96.2% sensitivity [95% CI, 80.4%-99.9%] and 100.0% specificity [95% CI, 86.8%-100.0%] $P = .21$) between the stationary and in-motion ambulance groups, respectively (Table 2). In total, there was one false positive (pericardial window) and five false negatives (three in the RUQ, two in the LUQ), making for an overall sensitivity and specificity in the study of 90.5% [95% CI, 79.7%-96.9%] and 98.2% [95% CI, 90.2%-99.9%], respectively. A significant difference in image acquisition score in favor of the stationary ambulance group (19.4 versus 16.7 out of 24 [95% CI for difference, 0.9-4.4]; $P < .01$) was detected. Significant differences in survey items between groups were related to obtaining and maintaining US images and the exam conditions (Table 3).

Discussion

To the authors' knowledge, this was the first randomized study directly assessing the effect of ambulance turbulence on FAST performance with handheld US. No statistical difference was found in FAST completion time or diagnostic accuracy between stationary and in-motion ambulances. Image acquisition scores were higher in the stationary ambulance.

The authors were unable to find published studies with a primary outcome assessing US exam times between stationary platforms and those performed during transport. However, Brun, et al evaluated extended FAST (eFAST) times as a secondary

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Characteristics	Total n (%) 27 (100)	SG n (%) 14 (100)	IMG n (%) 13 (100)	Significant Difference between Groups? (P value)
Gender				No (P = .31)
Male	21 (77.8)	12 (85.7)	9 (69.2)	
Female	6 (22.2)	2 (14.3)	4 (30.7)	
Age				No (P = .26)
24-29	12 (44.4)	7 (50.0)	5 (38.5)	
30-35	9 (33.3)	5 (35.7)	4 (30.7)	
36+	6 (22.2)	2 (14.3)	4 (30.7)	
Clinician Type				No (P = .35)
Physician	17 (63.0)	10 (71.4)	7 (53.8)	
PA	10 (37.0)	4 (28.6)	6 (46.2)	
Number of FASTs Prior to Study				No (P = .41)
<25	13 (48.1)	8 (57.1)	5 (38.5)	
26-50	2 (7.4)	0 (0)	2 (15.4)	
51-75	3 (11.1)	2 (14.3)	1 (7.7)	
76-100	1 (3.7)	0 (0)	1 (7.7)	
>100	8 (29.6)	4 (28.6)	4 (30.7)	
Resident Status				No (P = .34)
No	9 (33.3)	3 (21.4)	6 (46.2)	
PGY-1	8 (29.6)	6 (42.9)	2 (15.4)	
PGY-2	5 (18.5)	3 (21.4)	2 (15.4)	
PGY-3	5 (18.5)	2 (14.3)	3 (23.1)	

Table 1. Participant Demographic Data
Abbreviations: FAST, Focused Assessment with Sonography in Trauma; IMG, in-motion group; PA, physician assistant; PGY, post-graduate year; SG, stationary group.

	Stationary Ambulance	In-Motion Ambulance	95% CI for Difference	*P* Value
FAST Time (mean, in seconds)	98.5 (SD = 38.7)	78.7 (SD = 45.3)	[-13.5 – 53.1]	.23[a]
Image Acquisition Score (mean, max score = 24)	19.4 (SD = 2.2)	16.7 (SD = 2.3)	[.9 – 4.4]	<.01[a]
Diagnostic Accuracy (sensitivity [95% CI], specificity [95% CI])	85.7% [67.3% – 96.0%] 96.4% [81.7% – 99.9%]	96.2% [80.4% – 99.9%] 100% [86.8% – 100%]	n/a	.21[b]

Table 2. Primary and Secondary Outcome Results
Abbreviation: FAST, Focused Assessment with Sonography in Trauma.
[a] T-Test.
[b] Fisher's exact test.

outcome in their study on the feasibility of prehospital US performed on-scene and during transport. They found no difference between on-scene versus during-transport eFAST times (3.5 minutes [210s] versus 3.9 minutes [234s], respectively).[12] Although the times averaged approximately two minutes faster, this study similarly found no difference in exam times between stationary and in-motion ambulance groups. The faster times may be due to this study's FAST exams not involving an evaluation of the thorax for pneumothorax or hemothorax like that of the eFAST exam completed in the Brun, et al study. Additionally, performing an US exam on a phantom model, on average, is likely faster than performing one on an actual patient for a variety of factors such as clothing, body habitus, and patient non-compliance. Brun, et al used a SonoSite TITAN laptop-style US machine that may be less than ideal for use in ambulances (as compared to a handheld device), given its minimal portability in a confined space and could have translated in an increase in exam time in their study. Furthermore, a laptop-style machine may also disadvantage a sonographer's performance if its screen and controls are not within arm's reach of the sonographer.

This study's exam times were closer to those seen in a study by Walcher, et al in which they employed handheld US units, specifically the PRIMEDIC HandyScan (Metrax GmbH; Rottweil, Germany), for prehospital FASTs in 230 trauma patients.[18] Their sonographers were both paramedics and emergency physicians; however, their prior FAST experience was not reported. The average FAST time in the study was 2.4 minutes (144s). These times are slower but comparable to this study, perhaps

	Stationary Ambulance	In-Motion Ambulance	*P* Value
Difficulty to Obtain and Maintain Images	4	3	.02
(Median, 1 – 5)[a]	IQR: 3–4.75	IQR: 2–3	
Exam Negatively Affected by Conditions	2	4	<.01
(Median, 1 – 5)[b]	IQR: 1.25–3	IQR: 4–4	
Confidence in Ultrasound Diagnosis	4	4	.68
(Median, 1 – 5)[c]	IQR: 4–4	IQR: 4–5	

Table 3. Post-Participation Survey Results
Note: Wilcoxon signed-rank test used to evaluate significance levels.
[a] 1 = very difficult, 2 = difficult, 3 = neutral, 4 = easy, 5 = very easy.
[b] 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.
[c] 1 = not confident at all, 2 = not confident, 3 = neutral, 4 = confident, 5 = extremely confident.

secondary to performing FASTs on actual trauma patients. Similar to this study's methods, they performed a four view FAST with handheld US. In contrast to this study, all FASTs were performed either on-scene or in the ambulance *prior* to transport.

Image acquisition scores in this study favored the stationary group; however, the increased score did not appear to have a significant impact on exam time or diagnostic accuracy. Ziesmann, et al previously validated the FAST checklist used in this study and found expert versus novice scores to be 17.2 versus 11.1 out of 24, respectively (an absolute difference of 6.1 points). Their checklist criteria closely aligns with FAST performance parameters from the American Institute of Ultrasound in Medicine (Laurel, Maryland USA) and the American College of Emergency Physicians (ACEP; Irving, Texas USA).[19] Both of the groups scored near the expert level (17.2) with 19.4 versus 16.7 out of 24 in the stationary and in-motion ambulance respectively, which may account for why the difference did not have a significant bearing on exam time or diagnostic accuracy in this study.

This study's diagnostic accuracy results did not demonstrate statistically significant differences between its groups (Table 2). The 95% CI for specificity is consistent with previously reported data and the 95% CI for sensitivity is within the upper limits of that data.[1,20] The FAST models were standardized, as noted in the methods section, with positive findings (free fluid) in the RUQ and LUQ. This served to replicate scanning conditions amongst the participants but does not mimic the prevalence or distribution of sonographic findings in the majority of trauma patients. The authors acknowledge that a difference in the model setup may alter diagnostic accuracy results.

The diagnostic accuracy data serve as a measure of comparison between the two groups and should not be extrapolated for the following reasons: (1) a phantom model was used and controlled the prevalence of findings; (2) diagnostic accuracy was assessed by view, not by the entire exam, given that there was not a large sample of exams with a variety of findings; and (3) the sample size was not powered specifically to assess diagnostic accuracy.

Regarding the post-participation survey data, there was no difference between groups in participant confidence in their diagnosis. Participants in the in-motion group expressed more difficulty in obtaining and maintaining their US images and were more likely to feel that their exam was negatively affected by the conditions. This did not translate to a difference in diagnostic accuracy between groups; however, on the other hand, image acquisition scores (or thoroughness of examinations) was significantly lower in the in-motion group. This finding is likely explained by the constant motion of the patient and movement of the transducer during in-motion FASTs that interfered with image acquisition and maintenance.

This study's findings cannot be extrapolated to the pneumothorax evaluation included in the eFAST. As established methods of pneumothorax evaluation by US rely upon observing the presence or absence of movement on the US screen (B-mode sliding lung sign, M-mode seashore sign, color doppler power slide), vehicle turbulence may have a more significant impact on image acquisition and image interpretation for this application. Further investigation of this should be considered; although, extraneous motion has not been reported as a limitation of *in-flight* aeromedical pneumothorax evaluation with US.[21–23]

Recommendations for using handheld US in ground ambulances include: (1) developing local protocols for appropriate use; (2) controlling overhead light and outside light, as bright conditions can limit US screen viewing; (3) using a portable and adjustable arm clamp/mount to hold the US screen to free up the non-scanning hand, which may increase sonographer safety; and (4) communicating with the ambulance driver to limit turbulence when performing an US exam (as is done for other during-transport tasks).

Limitations

This study has several notable limitations. This was a single-center study at an academic medical center of physicians and PAs with prior training on the FAST. Clearly, the results cannot be generalized to those without US training, and caution should be used to generalize the results to those who have had a significant time-gap in US use. The results cannot necessarily be generalized to non-physician and non-PA clinicians. However, similar results may be achievable with novice sonographers after a training intervention and performance of around 25-50 FASTs, which is a benchmark recommended by the ACEP for any given US application.[24] Previous research has shown emergency medical technicians can be trained in trauma sonography after a brief training intervention to achieve results comparable to physicians.[25–27]

Participants performed all FASTs on an US phantom model, not a live human model or an actual trauma patient. This limits generalizability as patient factors such as obesity, difficult sonographic windows, movement, pain, altered mentation, and several others may complicate FAST performance.

To homogenize US scanning conditions for the in-motion ambulance, drivers drove on a course in a figure-eight pattern, limiting speeds to 10mph. The authors believe they replicated realistic driving conditions on an unimproved road, but nevertheless, this limits generalizability to other prehospital driving conditions. Despite restricting vehicle speed to 10mph, the amount of turbulence in the back of the ambulance was moderate (authors' consensus). On occasion at turns, bumps, and divots, the sonographer had to halt scanning to brace themselves to prevent from falling over. Although no injuries were sustained during the study, the authors' opinion is that additional turbulence beyond what was observed and, without some sort of safety restraint, could pose a safety hazard and may create enough extraneous motion to preclude performance of an US exam. Investigation of safety-restraint equipment allowing for increased freedom of movement in ambulances should be considered.

Conclusions

Vehicular motion did not affect FAST completion time and diagnostic accuracy; however, it did reduce FAST image acquisition scores. The results suggest timely and diagnostically accurate FASTs may be completed by experienced sonographers during moderate levels of ambulance turbulence. Further investigation assessing the utility and limitations of newer-generation handheld US devices in various prehospital conditions is warranted.

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Supplementary Material

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