Accuracy, reliability, and utility of the extended focused assessment with sonography in trauma examination in the setting of thoracic gunshot wounds

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BACKGROUND: The extended focused assessment with sonography in trauma (eFAST) examination includes additional thoracic views beyond the standard focused assessment with sonography in trauma examination. Its validation has predominantly been conducted in blunt trauma cases. Our aim was to evaluate the eFAST examination in a targeted population with penetrating thoracic trauma.

METHODS: Patients with thoracic gunshot wounds who underwent eFAST between 2017 and 2021 were included from a local trauma registry. Performance metrics for each component of eFAST in each window and pathological condition were analyzed across the entire population, as well as within two cohorts: survived and deceased patients. Chest tube placement rates were compared within true-positive and false-negative (FN) eFAST results for subgroups with pneumothorax or hemothorax.

RESULTS: A total of 288 patients were included (male, 91% male; Injury Severity Score ≥15, 48%; and died, 17%). Thirty-nine percent required chest tube, and 18% required urgent thoracic surgical intervention. Although specificity was high (91–100%) for all components, the sensitivity was less than 50% for all thoracic views, except for "no cardiac motion" (100% sensitivity). Sensitivity for pericardial fluid was 47%; for pneumothorax, 22%; for hemothorax, 36%; and for peritoneal fluid, 51% in the total population. Comparing survived versus deceased cohort, the eFAST sensitivity was higher among deaths for all components. The majority of patients (>70%) with a FN eFAST for pneumothorax or hemothorax received chest tube.

CONCLUSION: The eFAST examination showed highly variable performance metrics among patients with penetrating thoracic trauma, with all thoracic components demonstrating high specificity but low overall sensitivity. Urgent interventions were frequently received in patients with FN studies. (*J Trauma Acute Care Surg.* 2025;00: 00–00. Copyright © 2025 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic and Epidemiological; Level IV.

KEY WORDS: eFAST; gunshot wound; penetrating; trauma; reliability.

Trauma is a major cause of death globally, with many fatalities potentially preventable through earlier lifesaving procedures.[1,2] The Advanced Trauma Life Support guidelines emphasize the need for rapid injury assessment to implement these interventions.[3] Limitations of physical examination and the risk of missing critical injuries have led physicians to rely on diagnostic imaging tools in the trauma bay. While computed tomography (CT) has become the standard definitive imaging modality for thoracoabdominal trauma, it has several limitations in the emergent setting, including the need to transport unstable patients, ionizing radiation, high costs, and potential complications from contrast use.[4] In contrast, chest x-rays are quicker but have lower sensitivity for critical conditions like pneumothorax compared with CT scans.[5]

Focused abdominal sonography for trauma (FAST), introduced by Rozycki et al.[6] in 1995, has become a standard component of the Advanced Trauma Life Support primary survey, enabling assessment of life-threatening injuries during resuscitation. Focused abdominal sonography for trauma is an ultrasound protocol designed to identify intraperitoneal and pericardial fluid, with extensive research validating its effectiveness in trauma patients.[7] In 2004, FAST was expanded to include additional thoracic views and sonographic evaluation of the chest, now known as extended focused assessment with sonography in trauma (eFAST). With these thoracic views, the eFAST examination evaluates conditions such as pneumothorax and hemothorax, which can be immediately life-threatening if not promptly identified and managed.[8]

Kirkpatrick et al.[8] were among the first to describe the eFAST examination for detecting pneumothorax in patients with blunt and penetrating trauma. Their study reported that eFAST demonstrated higher sensitivity (49% vs. 21%) compared with traditional chest radiography for detecting occult pneumothoraxes (initially missed on clinical evaluation and chest x-ray but later identified with CT scan).[8] Brooks et al.[9] also evaluated eFAST for assessing hemothorax, reporting a sensitivity of 92%

Submitted: August 13, 2024, Revised: December 23, 2024, Accepted: January 6, 2025, Published online: March 3, 2025.

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This study was presented at the 83rd AAST Annual Meeting, September 11–14, 2024, in Las Vegas, Nevada.

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

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DOI: 10.1097/TA.0000000000004583

and a specificity of 100% for blunt trauma, and 100% for both sensitivity and specificity in penetrating trauma. Overall, the sensitivity of eFAST in diagnosing traumatic pneumothorax ranges from 47% to 98.1% across various studies. Some authors argue that eFAST should replace chest x-rays for screening stable patients after blunt thoracic trauma, given that eFAST approaches 100% sensitivity and specificity in detecting pneumo- and hemothorax.[8,10–13]

Although the efficacy of eFAST has been well studied in abdominal and blunt thoracic trauma, data on its effectiveness and performance metrics for penetrating chest trauma are limited.[14–16] While blunt chest trauma involves a wide distribution of force, penetrating trauma causes direct tissue disruption along the path of the projectile, posing a significant risk for pneumothorax, hemothorax, and cardiac tamponade. It has been reported that a significant portion of penetrating chest trauma cases can be effectively managed with simple chest tube drainage. Ultrasound can be valuable for rapidly determining the need for intervention and for identifying the source of hemorrhage in unstable patients.[17] We therefore sought to evaluate the real-world performance of the eFAST examination in patients with thoracic gunshot wounds and assess its impact on clinical interventions. We hypothesized that eFAST has high specificity and sensitivity for all pathologies in abdominal, cardiac, and thoracic windows and eFAST does not negatively impact necessary chest tube placement in pneumothorax or hemothorax in patients with thoracic gunshot wounds.

PATIENTS AND METHODS

Inclusion Criteria and Data Collection

In this retrospective cohort study, we included all patients with thoracic gunshot wounds admitted to our American College of Surgeons Adult Level I Trauma Center from January 2017 to December 2021. Thoracic trauma was defined anatomically as injuries located inferior to the clavicles anteriorly, superior to the costal margin inferiorly, and extending to the superior aspect of the scapula posteriorly. Among them, patients who underwent eFAST were enrolled in the study. Patients who were dead on arrival were excluded from the analysis, as they typically receive immediate life-saving interventions rather than eFAST. In contrast, patients who arrived with signs of life but later deteriorated during trauma evaluation were included. Data collected included patient demographics (age and sex), injury characteristics (Injury Severity Score [ISS] and body region Abbreviated Injury Scale [AIS]), index emergency department (ED) vital signs, imaging findings (CT scan and chest x-ray), interventions (chest tube placement and surgical procedures including thoracotomy, sternotomy, laparotomy, and laparoscopy), duration of stay (hospital length of stay [LOS], intensive care unit LOS, and ventilation days), and in-hospital mortality.

Extended FAST results were collected, including assessments through abdominal, cardiac, and thoracic windows for peritoneal fluid, pericardial fluid, and pleural fluid. Pleural fluid was initially detected by ultrasound and classified as hemothorax based on chest tube output or confirmed through surgical exploration. Pneumothorax was classified by the absence of sliding. Extended FAST results were collected through chart review based on the assessments made at the time of the examination. The analysis did not involve a reevaluation of the images for accuracy. Definitive diagnoses of positive or negative pericardial fluid and peritoneal free fluid were based on surgery, CT, and observation. For hemothorax and pneumothorax, definitive diagnoses were determined through surgery, x-ray, CT, chest tube findings, and observation, serving as the benchmarks against which eFAST results were compared. Data were collected from chart review and from review of our prospectively collected monthly quality improvement review of all identified false-negative (FN) and false-positive eFAST examinations.

In this study, a true-positive (TP) eFAST was defined as a positive result confirmed by surgical exploration, fluid on chest tube, x-ray, or CT. A false-positive eFAST was a positive result with no evidence of injury based on x-ray, CT, fluid on chest tube, or surgical exploration. A true-negative eFAST was a negative result confirmed by negative x-ray, CT, or continued negative clinical observation. A FN eFAST was a negative result with evidence of fluid on chest tube or injury based on x-ray, CT, or surgical exploration. Discrepancies between eFAST and definitive diagnoses were closely examined to understand the accuracy and reliability of the eFAST in our clinical setting.

At our teaching hospital, eFAST examinations were performed by emergency medicine residents or fellows, supervised by an attending or senior resident. The training level ranged from first year to chief residents, and results were determined at the time of the examination. Supervision ensured consistent accuracy despite no formal minimum training requirement. Extended FAST examinations were performed using dedicated Sonosite ultrasound machines located in each trauma bay. The examinations were performed using either a linear or curved array probe based on the sonographer's preference, with depth of penetration set to 4 to 6 cm and adjusted based on body habitus to provide maximal visualization of the pleura to chest wall interface.

Outcomes and Analysis

Patients were divided into two groups based on in-hospital mortality status: survived or deceased. Patient demographics, ED vital signs, moderate to severe injuries within each body region, procedures, and LOS were compared within the survived and deceased cohort. Performance metrics, including TPs, true negatives, false positives, and FNs, were first determined for each pathology. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were then calculated based on these metrics for the total population, as well as for the survived and deceased groups. Four subgroups of patients were identified for further analysis: those with a definitive diagnosis of pneumothorax who survived, those with a definitive diagnosis of pneumothorax who were deceased, those with a definitive diagnosis of hemothorax who survived, and those with a definitive diagnosis of hemothorax who were deceased. Within each subgroup, patients were further classified based on eFAST results into two cohorts: TP and FN. Chest tube placement in the ED was compared between these two cohorts within each group. Baseline characteristics, including sex, ISS ≥15, and moderate to severe injuries (AIS score, ≥3) in regions such as the head or neck, face, chest, abdomen or pelvis, extremities, and external areas, were compared with ensure comparable baseline characteristics and injury profiles.

The primary outcome was the sensitivity and specificity of each eFAST component, including cardiac, thoracic, and abdominal windows. The secondary outcome was the impact of eFAST result on chest tube placement as a life-preserving intervention. Continuous variables are presented as median (interquartile range). Categorical variables are presented as number (percentage). Patient demographics, clinical and injury variables, intervention, and outcomes were compared between groups with Fisher's exact test, Pearson χ^2, and Mann-Whitney U test as appropriate. All data were analyzed using SPSS version 28.0 (IBM Corporation, Armonk, NY), and Statistical significance was defined as $p < 0.05$. This study was determined to be exempt from review by the institutional review board. Conflict of interest disclosures are provided (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/E294). The STROBE guideline was used to ensure proper reporting of background, methods, results, and discussion (Supplemental Digital Content, Supplementary Data 2, http://links.lww.com/TA/E293).[18]

RESULTS

Three hundred fifty-three patients who had thoracic injury by gunshot and admitted at level 1 trauma center in Los Angeles between 2017 and 2021 were identified. Of them, 288 (82%) patients underwent eFAST, thus enrolled; 238 (83%) survived, and 50 (17%) died during the hospitalization (Fig. 1).

The median age in the total population was 28, and majority (91%) were male. No significant difference was observed in age median ($p = 0.989$) and gender (0.589) within survived and deceased cohorts. Hypotension (systolic blood pressure, <90 mm Hg) on admission and low Glasgow Coma Scale (GCS; GCS score, <9) on admission were significantly more frequent in deceased patients (10.9% vs. 52%, $p < 0.001$, and 2.9% vs. 64%, $p < 0.001$, respectively). Deceased patients had significantly higher frequency of an ISS (≥15) compared with those who survived (38% vs. 98%, respectively; $p < 0.001$). Frequency of moderate to severe injuries (AIS score, ≥3) in the head/neck (1.7% vs. 22%, $p < 0.001$), thorax (55% vs. 90%, $p < 0.001$), abdomen/pelvis (22.3% vs. 58%, $p < 0.001$), and external regions (0.8% vs. 8%, $p = 0.009$) was higher in deceased patients compared with survived cohort.

Surgical procedures including left thoracotomy (1.3% vs. 38%, $p < 0.001$), clamshell thoracotomy (0.4% vs. 34%, $p < 0.001$), and laparotomy (20.6% vs. 38%, $p = 0.008$) were more commonly performed on deceased patients, and right thoracotomy ($p = 1.000$), sternotomy ($p = 0.150$), and laparoscopy ($p = 1.000$) rates were comparable within the two cohorts. The median hospital LOS (6 vs. 1, $p < 0.001$) and ventilation days

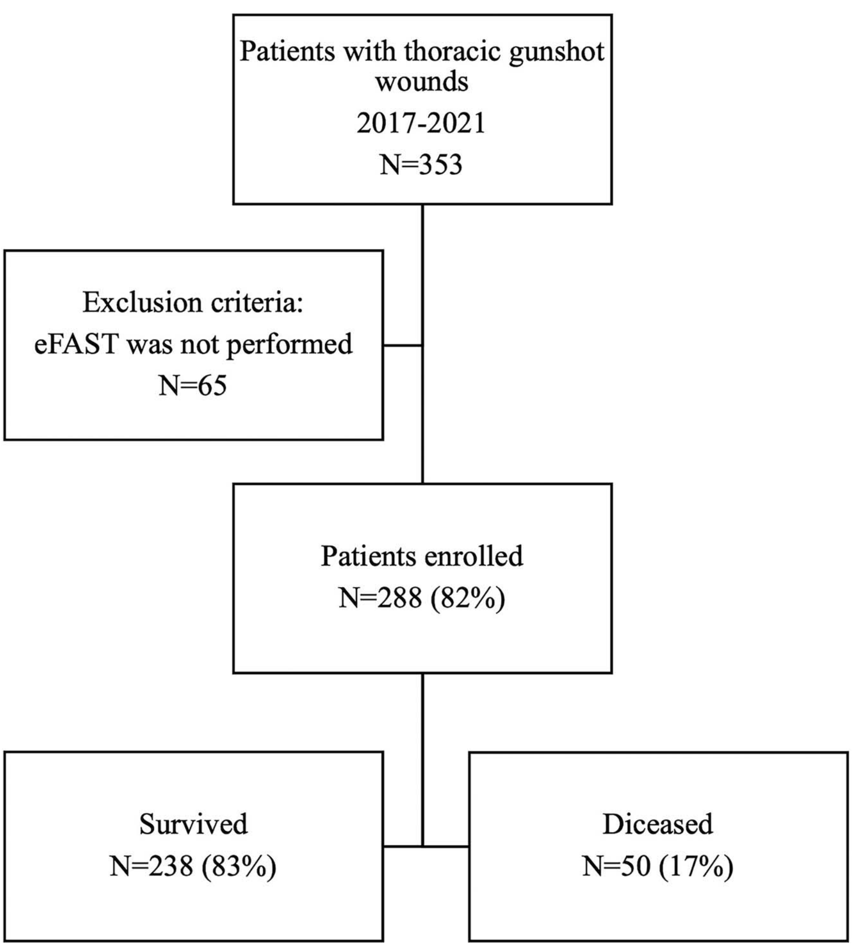

Figure 1. Flowchart depicting patient inclusion, exclusion criteria, and cohort formation.

TABLE 1. Patient Demographics, Injury Characteristics, Procedures, and LOS Compared Within the Survived and Deceased Cohort

	Total N = 288	Survived n = 238	Deceased n = 50	*p*
Age, median (IQR), y	28 (23–36)	28 (23–37)	29.5 (25–34)	0.989
Sex, male	262 (91.0)	215 (90.3)	47 (94.0)	0.589
ED vitals				
SBP <90 mm Hg	52 (18.1)	26 (10.9)	26 (52.0)	**<0.001**
GCS <9	39 (13.5)	7 (2.9)	32 (64.0)	**<0.001**
ISS ≥15	138 (48.1)	89 (37.6)	49 (98.0)	**<0.001**
AIS ≥3				
Head/neck	15 (5.2)	4 (1.7)	11 (22.0)	**<0.001**
Face	1 (0.3)	1 (0.4)	0 (0.0)	1.000
Thorax	176 (61.1)	131 (55.0)	45 (90.0)	**<0.001**
Abdomen/pelvis	82 (28.5)	53 (22.3)	29 (58.0)	**<0.001**
Extremity	32 (11.1)	26 (10.9)	6 (12.0)	0.826
External	6 (2.1)	2 (0.8)	4 (8.0)	**0.009**
Procedures				
Left thoracotomy	22 (7.6)	3 (1.3)	19 (38.0)	**<0.001**
Right thoracotomy	11 (3.8)	9 (3.8)	2 (4.0)	1.000
Clamshell thoracotomy	18 (6.3)	1 (0.4)	17 (34.0)	**<0.001**
Sternotomy	15 (5.2)	10 (4.2)	5 (10.0)	0.150
Laparotomy	68 (23.6)	49 (20.6)	19 (38.0)	**0.008**
Laparoscopy	4 (1.7)	0 (0.0)	4 (1.4)	1.000
LOS				
Hospital LOS, median (IQR)	4 (2–10)	6 (2–12)	1 (1–2)	**<0.001**
ICU LOS, median (IQR)	4 (2–7)	4 (2–6.5)	2 (1–9.5)	0.134
Ventilation days, median (IQR)	2.5 (2–5)	3.5 (2–5)	1 (1–2)	**0.002**

Statistically significant p-values shown in bold font.
Results are reported as number (percentage within column), unless otherwise specified.
IQR, interquartile range; SBP, systolic blood pressure; ICU, intensive care unit.

(3.5 vs. 1, $p = 0.002$) were significantly longer in survived cohort, although length of intensive care unit stay was comparable within the two groups (4 vs. 2, $p = 0.134$) (Table 1).

Table 2 presents the performance metrics for pathologies evaluated by eFAST examination.

Abdominal Windows

For peritoneal fluid detection in the three traditional abdominal windows (right upper quadrant, left upper quadrant, and suprapubic regions), high specificity was observed for both the survived group (97.8%) and the deceased group (100%). Sensitivity was notably high for the deceased group (83.3%) but lower in the survived cohort (38.3%). The overall accuracy was 82.8% for the survived group and 91.3% for the deceased group. The overall PPV was noted to be high at 91.5%, while the NPV was slightly lower at 82.7%, with both metrics higher in deceased patients versus survivors.

Cardiac Window

For the detection of no cardiac motion in the cardiac window, no false positives or FNs were observed, and all metrics were 100% in both the survived and deceased cohorts for this pathology. For pericardial fluid detection, high specificity was observed in both the survived (99.6%) and the deceased cohort (91.2%). Sensitivity was relatively lower in the survived (30.0%) and deceased cohort (66.7%). The overall accuracy of pericardial fluid detection was high in both groups, with 96.6% in the survived cohort and 86% in the deceased cohort. Accuracy was higher in the survived group. The overall PPV and NPV were 100% for cardiac motion but were significantly lower at 69.2% and 96.3% for pericardial fluid. The PPV was noted to be high at 91.5%, while the NPV was slightly lower at 82.7%.

Thoracic Window

In the thoracic window for the detection of pneumothorax, high specificity was observed, with 98.5% in the survived cohort and 96% in the deceased cohort. Sensitivity was the lowest

TABLE 2. Diagnostic Performance of eFAST in Each Pathology in Total Population, Survived, and Deceased

Metrics in Abdominal Window Finding	Total N = 288	Survived n = 238	Deceased n = 50	*p*
Abdominal windows				
Peritoneal fluid				
Sensitivity (%)	51.2	38.3	83.3	**<0.001**
Specificity (%)	98	97.8	100.0	1.000
PPV (%)	91.5	85.2	100.0	0.126
NPV (%)	82.7	82.5	84.6	1.000
Accuracy (%)	84.2	82.8	91.3	0.187
Cardiac window				
No cardiac motion				
Sensitivity (%)	100.0	N/A	100.0	N/A
Specificity (%)	100.0	100.0	100.0	N/A
PPV (%)	100.0	N/A	100.0	N/A
NPV (%)	100.0	100.0	100.0	N/A
Accuracy (%)	100.0	100.0	100.0	N/A
Pericardial fluid*				
Sensitivity (%)	47.4	30.0	66.7	0.179
Specificity (%)	98.5	99.6	91.2	**0.007**
PPV (%)	69.2	75.0	66.7	1.000
NPV (%)	96.3	97.0	91.2	0.120
Accuracy (%)	95.0	96.6	86.0	**0.011**
Thoracic window**				
Pneumothorax				
Sensitivity (%)	22.2	19.2	46.2	**0.039**
Specificity (%)	98.1	98.5	96.0	0.404
PPV (%)	89.7	90.9	85.7	1.000
NPV (%)	63.2	61.1	77.4	0.110
Accuracy (%)	65.9	63.9	78.9	0.096
Hemothorax				
Sensitivity (%)	35.9	35.2	39.1	0.720
Specificity (%)	100.0	100.0	100.0	N/A
PPV (%)	100.0	100.0	100.0	N/A
NPV (%)	63.3	65.0	51.7	0.216
Accuracy (%)	69.6	70.6	63.2	0.448

*Extended FAST finding for pericardial fluid was not available in seven patients; therefore, the total population in pericardial fluid metric is 281, with 43 deaths affecting accuracy measurement.
**Extended FAST finding for thoracic window was not available in 12 deceased patients; therefore, the total population in this window is 276, with 38 death.
N/A, not available.

TABLE 3. Baseline, Injury Characteristics, and Rate of ED Chest Tube Placement in Patients With Definitive Pneumothorax Diagnosis (n = 85)

	Survived n = 74			Deceased n = 11		
	TP n = 18	FN n = 56	*p*	TP n = 5	FN n = 6	*p*
Sex male	17 (94.4)	53 (94.6)	1.000	4 (80.0)	5 (83.3)	1.000
ISS ≥15	11 (61.1)	33 (60.0)	0.933	5 (100.0)	6 (100.0)	N/A
Body region AIS ≥3						
Head/Neck	0 (0.0)	0 (0.0)	N/A	2 (40.0)	2 (33.3)	1.000
Face	0 (0.0)	1 (1.8)	1.000	0 (0.0)	0 (0.0)	N/A
Chest	16 (88.9)	54 (96.4)	0.247	5 (100.0)	6 (100.0)	1.000
Abdomen/pelvis	5 (27.8)	17 (30.4)	0.835	2 (40.0)	2 (33.3)	1.000
Extremity	3 (16.7)	4 (7.1)	0.350	0 (0.0)	0 (0.0)	N/A
External	0 (0.0)	1 (1.8)	1.000	0 (0.0)	0 (0.0)	N/A
Chest tube placement	18 (**100.0**)	42 (**75.0**)	**0.016**	5 (100.0)	6 (100.0)	N/A

Values that were statistically significant differences in bold font.
Results are reported as number (percentage within column) in all variables.
N/A, not available.

among all pathologies, at 19.2% in the survived group and 46.2% in the deceased group. Sensitivity was higher in deceased patients. Overall accuracy was 63.9% in the survived group and 87.9% in the deceased group. The overall PPV for pneumothorax was noted to be high at 89.7%, while the NPV was lower at 63.2%, with no significant differences in deceased patients versus survivors. For hemothorax, the PPV was 100% and NPV was 63.3%, and again, there was no significant difference between groups.

In summary, results of eFAST metrics indicated that, while specificity ranged from 91% to 100% across all components, sensitivity for thoracic views was generally low, except for "no cardiac motion" on the cardiac window, which had 100% sensitivity. Sensitivity for pericardial fluid was 47%, for hemothorax was 36%, and for peritoneal fluid was 51%; pneumothorax had the lowest sensitivity at 22%. Comparing survivors versus deaths, the eFAST sensitivity was higher among deaths versus survivors for all components.

Chest Tube Placement

Comparing the TP and FN cohorts among the subpopulations of deceased patients with pneumothorax (n = 11, FN = 54%) and those with hemothorax (n = 16, FN = 56%), it was found that all patients in the FN cohort, as well as all TP patients, underwent chest tube placement. Therefore, an analysis of differences between these cohorts was not applicable.

However, among the subpopulations of survived patients with pneumothorax (n = 74, FN = 75.6%) or hemothorax (n = 82, FN = 59.7%), the FN cohorts received the intervention in ED significantly less frequently than the TP cohort. In the survived pneumothorax group, chest tube placement rates were 100% in the TP cohort and 75% in the FN cohort ($p = 0.016$). For the survived hemothorax group, the rates were 93.9% in the TP cohort and 75.5% in the FN cohort ($p = 0.030$) (Tables 3 and 4).

TABLE 4. Baseline, Injury Characteristics, and Rate of ED Chest Tube Placement in Patients With Definitive Hemothorax Diagnosis (n = 98)

	Survived n = 82			Deceased n = 16		
	TP n = 33	FN n = 49	*p*	TP n = 7	FN n = 9	*p*
Sex, male	29 (87.9)	49 (100.0)	0.023	6 (85.7)	8 (88.9)	1.000
ISS ≥15	23 (69.7)	30 (62.5)	0.635	7 (100.0)	9 (100.0)	N/A
Body region AIS ≥3						
Head/neck	0 (0.0)	1 (2.0)	1.000	2 (28.6)	2 (22.2)	1.000
Face	0 (0.0)	1 (2.0)	1.000	0 (0.0)	0 (0.0)	N/A
Chest	33 (100.0)	47 (95.9)	0.513	7 (100.0)	9 (100.0)	N/A
Abdomen/pelvis	12 (36.4)	15 (30.6)	0.587	2 (28.6)	6 (66.7)	0.315
Extremity	3 (9.1)	3 (6.1)	0.681	0 (0.0)	2 (22.2)	0.475
External	0 (0.0)	1 (2.0)	1.000	0 (0.0)	1 (11.1)	1.000
Chest tube placement	31 (**93.9**)	37 (**75.5**)	**0.030**	7 (100.0)	9 (100.0)	N/A

Values that were statistically significant differences in bold font.
Results are reported as number (percentage within column) in all variables.
N/A, not available.

DISCUSSION

The objective of this retrospective cohort study from the real-world utilization of eFAST at an academic level 1 trauma center was to describe the performance metrics of eFAST in a large cohort of patients with penetrating torso trauma, specifically gunshot wounds. Key findings showed that eFAST had high specificity across components but variable sensitivity. The cardiac window was highly reliable for detecting no cardiac motion, while the thoracic window exhibited high specificity for pneumothorax but had the lowest sensitivity among all pathologies. The abdominal windows also showed high specificity for detecting peritoneal fluid, although with lower sensitivity. Sensitivity was generally higher in deceased than survivors. Chest tube placement rates were significantly different between TP and FN cohorts among survivors.

High specificity and low sensitivity indicate that, while eFAST identifies life-threatening pathologies for rapid intervention, it should not be the sole basis for clinical decisions or replace chest x-ray or CT. Instead, negative results should be confirmed by findings from all available imaging modalities or interventions based on injury mechanism and/or clinical gestalt.

Several studies have assessed FAST in detecting peritoneal fluid in penetrating trauma. Boulanger et al.[19] reported FAST sensitivity of 67% and specificity of 98% for abdominal fluid in penetrating torso injuries. Brooks et al.[20] prospectively evaluated FAST sensitivity for intraperitoneal fluid in 10 patients with penetrating injury to either thoracoabdominal or loin area and reported 33% sensitivity and 86% specificity, which was notably lower than sensitivity (100%) and specificity (99%) in blunt traumas. Furthermore, Soffer et al.[21] prospectively evaluated FAST metrics in detecting intraperitoneal and pericardial fluid in 177 victims of penetrating torso trauma and reported 48% sensitivity and 98% specificity. In addition, they evaluated metrics by mechanism of injury and reported sensitivity and specificity of 49% and 98% for gunshot wounds (n = 84), respectively.[21] A systematic review by Quin and Sinert[22] summarized FAST sensitivity and specificity in penetrating torso trauma and reported that FAST in penetrating trauma is highly specific (94.1–100%) but not highly sensitive (28.1–100%). Although abdominal window metrics were not the primary focus of our study, we included them to provide a more complete assessment of eFAST and to compare peritoneal fluid detection with similar studies in penetrating thoracoabdominal trauma, offering further insight into our findings. Our study focusing on penetrating gunshot wound chest trauma revealed varying sensitivity for peritoneal fluid detection, with 38.3% in surviving patients and 83.3% in deceased patients, resulting in an overall sensitivity of 51.2%, which falls between the findings of previous studies.

In terms of thoracic trauma and hemothorax, several studies have evaluated eFAST in comparison with other modalities including CT scan and chest x-ray. Brooks et al.[9] evaluated thoracic ultrasound in 61 trauma patients, predominantly with blunt trauma, and found a sensitivity of 92% and a specificity of 100% for detecting hemothorax. Similarly, the study by Sisley et al.[23] on blunt and penetrating torso trauma reported a sensitivity of 97.5% and specificity of 99.7% for ultrasound in detecting hemothorax, compared with 92.5% sensitivity and 99.7% specificity for chest radiography. Ma et al.[24] found that ultrasound was on par with chest radiographs in identifying hemothorax, with reported sensitivities ranging from 81% to 96%. In supine patients, detecting blood on an x-ray requires up to 1,000 mL to be visible. Trauma patients are typically admitted to the trauma unit in a supine position. Unlike chest x-rays, ultrasound can identify much smaller volumes of blood, around 100 mL.[9,24] Because of this limitation, along with subsequent studies demonstrating ultrasound's consistent superiority in sensitivity for detecting hemothorax, it has been concluded that eFAST may be a more reliable method than chest x-ray for identifying hemothorax.[25]

Regarding thoracic trauma and pneumothorax, ultrasound has been identified as a reliable diagnostic tool. Dulchavsky et al.[26] evaluated the eFAST technique for pneumothorax and reported a sensitivity of 95%, superior to that of chest x-ray. Similarly, Knudtson et al.[27] reported a sensitivity of 92.3% and a specificity of 99.6%. Kirkpatrick et al.[8] assessed eFAST and chest x-ray for pneumothorax detection using CT as the reference standard, finding eFAST sensitivity at 48.8% versus 20.9% for chest x-ray. Chan et al.[28] reviewed 13 studies comparing chest ultrasound and supine chest x-ray, concluding that ultrasound is more reliable in trauma, with a sensitivity of 91% versus 47%. Collectively, these findings indicate that eFAST is a reliable tool for diagnosing pneumothorax, demonstrating superior accuracy compared with chest x-ray.[29] On the other hand, Santorelli et al.[30] reported a lower sensitivity for chest ultrasound at 65%, compared with 78% for chest x-ray in a population with 85% blunt trauma rates.

Although eFAST has been reported to be a reliable tool in assessing pneumothorax and hemothorax in the aforementioned studies, most of the literature have focused on either blunt trauma or a mixed population of penetrating and blunt trauma. To the best of our knowledge, only one study has previously explored the utility of eFAST in penetrating trauma. For instance, Bouzid et al.[16] conducted a prospective single center study on patients with stab wounds to either thorax or abdomen and reported that eFAST is not sensitive enough to detect pneumothorax (77% [54–92%]) or hemoperitoneum (75% [35–97%]) but performs better in detection of hemothorax (97% [74–99%]), suggesting that a CT scan may not be required in an event of hemothorax detected on eFAST.[16]

Our study demonstrated high specificity but relatively low sensitivity in detecting pneumothorax (22.2%) and hemothorax (35.9%). Overall, sensitivities were lower than specificities across all pathologies. These findings align with the study of Bouzid et al.[16] regarding low sensitivity but contrast with their results for hemothorax. However, the study of Bouzid et al.[16] focused on stab wounds, while our study included gunshot wounds. The type of penetrating injury can influence the nature and detectability of injuries, as gunshot wounds may create more complex and diffuse damage compared with stab wounds, affecting eFAST's sensitivity.

Both the study of Bouzid et al.[16] and our research indicate that eFAST lacks sufficient sensitivity for reliably detecting pneumothorax in cases of penetrating chest trauma, in contrast to previous blunt injury studies. This discrepancy, as well as reports in previous literature on low sensitivity of eFAST in detection of peritoneal fluid in penetrating trauma, may be attributed to the distinct nature of penetrating trauma and sheds light on the potential differences in the diagnostic performance of eFAST between blunt and penetrating injuries. These findings underscore the importance of considering the mechanism of injury in evaluations and the need for further investigations.

We also evaluated and compared eFAST metrics in survivors and deceased cohorts. This stratification helps reduce the wide range of sensitivity seen in eFAST metrics. Notably, deceased group had higher rates of SBP <90 mm Hg, GCS score of <9, ISS of ≥15, and higher rates of moderate to severe injuries of thorax and abdomen. Our analysis revealed that deceased patients demonstrated significantly higher sensitivity for detecting both peritoneal fluid in the abdominal window and pneumothorax, suggesting that eFAST may be particularly effective in identifying life-threatening injuries in those with more severe trauma. On the other hand, the higher accuracy for detecting pericardial effusion in surviving patients suggests that timely identification can facilitate immediate lifesaving procedures in the ED. While eFAST effectively detects peritoneal fluid, the need for surgical transfer may delay intervention and impact survival outcomes.

A notable strength of our study is its evaluation of the relationship between FN eFAST results and rates of chest tube insertion. We observed that FN eFAST results were associated with a significantly lower rate of chest tube insertion compared with TPs in patients with pneumothorax and hemothorax who survived. This aspect of eFAST results' impact on interventions has not been extensively studied. A retrospective study by Sauter et al.[14] in Switzerland found similar findings in blunt trauma patients. They reported that pneumothoraxes identified by eFAST required treatment in 88.9% of cases, while those missed by eFAST needed treatment in only 30.2% of cases ($p < 0.001$).[14] These findings indicate that an FN eFAST result may delay necessary interventions, potentially impacting patient outcomes. Importantly, while 75% of patients in the FN group still required chest tube insertions, this may suggest that FN results can lead to critical delays in care. Overall, this observation underscores the importance of addressing FN eFAST results to ensure timely and effective interventions.

In patients with penetrating chest trauma, our findings suggest that the absence of cardiac motion in the cardiac window of eFAST is highly reliable, with both 100% sensitivity and specificity, indicating the need for immediate ED thoracotomy if no motion is detected. However, pericardial effusion, along with the abdominal and thoracic windows, had lower sensitivity, especially in surviving patients, although positive results remained highly specific (over 90%). This suggests that patients with positive findings should be promptly transferred to the operating room or receive emergent chest tube intervention. Given the lower sensitivity, negative results must be interpreted cautiously, with clinical judgment, including assessment of abdominal tenderness and respiratory status, remaining crucial. Stable patients should undergo serial examinations and additional imaging, such as chest x-rays or CT scans, to rule out missed injuries.

Several limitations should be noted. This study was conducted at a single level 1 trauma center, which may limit the generalizability of the findings to other settings. In addition, the retrospective nature of the study may introduce biases related to data collection and documentation. The evaluation of eFAST results and subsequent chest tube placement timing and urgency cannot be fully determined from retrospective records in some cases, and the placement of possibly unnecessary chest tubes based on eFAST results can also not be definitively determined. No universal protocol was used to guide chest tube placement, which was at the discretion of the attending trauma surgeon and emergency medicine attending. Another limitation of our study is that it did not account for the variability in eFAST performance based on the operator, which ranged from first-year emergency medicine residents to fellows, all under the supervision of senior residents or attending physicians in a teaching trauma center. This variability could influence the reliability of the test, as prior studies have emphasized that operator experience significantly impacts eFAST accuracy, particularly in environments where trainees perform the scans, even if the final interpretation is made by experienced professionals.[31] This variability may help explain the differences in thoracic pathology sensitivity in eFAST between our study and others. For instance, Sisley et al.[23] conducted a prospective study where all operators were experienced surgeon-sonographers with training in ultrasound, including practical and written assessments, and experience with patients exhibiting known pathological conditions such as pleural effusions. Similarly, Kirkpatrick et al.[8] restricted eFAST examinations to attending trauma surgeons before using other diagnostic tools. In contrast, retrospective studies, like the study of Bouzid et al.,[16] did not specify the operator's role. Given these factors, we are unable to fully assess how this variability might have influenced our results. Finally, some of our analyses may be underpowered to detect a clinically significant difference because of the small sample size of the deceased cohort. Therefore, these findings should be interpreted with these limitations in mind. Nevertheless, our findings offer valuable insights into real-world practice at a teaching level I trauma center.

Future multicenter prospective studies are essential to validate our findings in larger, more diverse populations. These studies should account for the operator's expertise, consider various mechanisms of penetrating injuries, and control for confounding factors such as body mass index and preexisting conditions, alongside standardized machine settings. In addition, future advancements in eFAST will require continued evaluation of its metrics, as emerging technologies and AI applications in ultrasound may affect its reliability and clinical applicability.[32]

CONCLUSION

These findings suggest that eFAST effectively rules out certain injuries but may not reliably detect all pneumothorax and hemothorax instances in penetrating trauma. Extended FAST reliably identifies critical pathologies like cardiac motion, making positive results valuable. However, negative results are not highly reliable for ruling out major thoracic pathologies and should be complemented with physical examinations, imaging, and surgery for comprehensive care.

AUTHORSHIP

M.A., M. Sozzi, M. Schellenberg, K.M., K.I., and M.J.M. contributed in the conception and study design. M.A., N.N., and M.J.M. contributed in the literature review. M.A. and M. Sozzi. contributed in the data acquisition. M.A., M.S., and M.J.M. contributed in the data analysis and interpretation. M.A., N.N., M. Sozzi, M. Schellenberg, K.M., K.I., and M.J.M.

contributed in the drafting of the manuscript. M.A., N.N., M. Sozzi, M. Schellenberg, K.M., K.I., and M.J.M. contributed in the critical revision.

DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E294).

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