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Too fast, or not fast enough? The FAST exam in patients with non-compressible torso hemorrhage[☆]



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ABSTRACT

Background: Focused assessment with sonography for trauma (FAST) performance metrics are unknown in patients with non-compressible torso hemorrhage (NCTH).

Methods: Retrospective review of a dedicated NCTH database from four level 1 trauma centers (2008–2012). NCTH was defined as (1) named axial torso vessel disruption; (2) AIS chest or abdomen >2 with shock (base deficit < -4) or truncal operation in ≤90 min; or (3) pelvic fracture with ring disruption. Patients were grouped by cavity of hemorrhage source and by shock (SBP ≤ 90).

Results: 274 patients had a FAST prior to diagnosis of NCTH. FAST was positive in 51% of patients with abdominal/pelvic hemorrhage for a false negative rate (FNR) of 49%. FNR was higher for pelvic (61%) versus abdominal (43%) sources ($p = 0.02$). There was no difference between FAST negative or positive patients for ISS, shock, length of stay, or mortality (all $p = NS$). FNR was not improved among the subgroup of NCTH patients with shock ($p = NS$).

Conclusion: FAST identified abdominal/pelvic hemorrhage in approximately half of NCTH patients, and this was not improved among patients presenting with shock.

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Introduction

Non-compressible torso hemorrhage (NCTH) is now widely recognized as a leading cause of preventable morbidity and mortality in both military and civilian trauma centers.^{1–5} Surgeons assessing patients with suspected NCTH often rely on the focused assessment with sonography for trauma (FAST) as a rapid initial screening test. There are widely varying reports of the accuracy and reliability of the FAST exam. Although the FAST exam is primarily aimed at identifying patients with major abdominal bleeding, the performance metrics of FAST are not well described in a large cohort of patients with NCTH.

The objective of this study was to describe the performance metrics of FAST in a large cohort of patients with NCTH.

Material and methods

Data source

Our group previously compiled a dedicated NCTH database of four level 1 trauma centers from 2008 to 2012.⁶ This database was retrospectively reviewed to identify all patients who had a definitive (positive vs. negative) FAST exam prior to having NCTH identified in the abdominal or pelvic cavity. In keeping with our prior study, NCTH was defined as (1) named axial torso vessel disruption; (2) AIS chest or abdomen >2 with shock (base deficit < -4) or truncal operation in ≤90 min; or (3) pelvic fracture with ring disruption. Variables examined can be seen in [Table 1](#) and [Table 2](#).

Study design and study participants

All patients meeting the above criteria were included for

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Table 1
Results by anatomic cavity of injury.

	Abdomen	Pelvis	p
Total, n	119	71	–
FAST negative, n (%)	51 (43%)	43 (61%)	0.02
Male, n (%)	85 (71%)	52 (73%)	0.79
Blunt mechanism, n (%)	80 (67%)	55 (78%)	0.13
Shock, n (%)	64 (44%)	33 (52%)	0.35
In-hospital death, n (%)	33 (28%)	23 (32%)	0.50
Age, mean	35.7	39.1	0.17
ISS, mean	32.7	30.4	0.27
AIS Chest, mean	2.4	1.9	0.09
AIS Abdomen, mean	4.0	3.3	<0.01
ED initial SBP, mean	100.5	92.2	0.11
LOS, mean	20.5	21.8	0.78

Shock: Initial systolic blood pressure of ≤ 90 mmHg; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; SBP: Systolic Blood Pressure (mmHg); LOS: Length of Stay (days).

Table 2
Results stratified by FAST.

	False Negative	True Positive	p
Total	94	96	–
Abdomen, n (%)	51 (54%)	68 (71%)	0.02
Male, n (%)	67 (71%)	70 (73%)	0.80
Blunt mechanism, n (%)	78 (83%)	57 (59%)	<0.01
Shock, n (%)	42 (49%)	44 (51%)	0.82
In-hospital death, n (%)	25 (27%)	31 (32%)	0.39
Age, mean	40.8	33.2	<0.01
ISS, mean	31.7	31.9	0.94
AIS Chest, mean	2.5	2.0	0.04
AIS Abdomen, mean	3.5	4.0	<0.01
LOS, mean	19.6	22.4	0.54

Shock: Initial systolic blood pressure of ≤ 90 mmHg; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; SBP: Systolic Blood Pressure (mmHg); LOS: Length of Stay (days).

consideration. Patients were excluded if (1) FAST was not performed, (2) FAST results were indeterminate or unknown, (3) primary source of hemorrhage was unknown, or (4) primary source of hemorrhage was identified in the thoracic cavity. Fig. 1 depicts the flow diagram arriving at a final sample of patients with a definitive (positive vs. negative) FAST exam who went on to have NCTH identified in the abdominal or pelvic cavity. Patients were grouped by cavity of hemorrhage source (thoracic vs. abdominal vs. pelvic) and by shock (SBP ≤ 90 mmHg).

Statistical analysis

Intergroup comparisons were performed using Chi-square and Fisher’s exact testing for categorical variables. Continuous variables were analyzed with independent samples t-testing and one-way ANOVA. Statistical tests were two-tailed and significance was set at $p < 0.05$. Analysis was performed using SPSS version 21 (IBM; Armonk, NY, USA).

Results

During the 5-year study period, 678 patients with NCTH were identified. Of these, 274 patients underwent FAST examination prior to diagnosis of NCTH. Definitive diagnosis was made by operative exploration (50%), CT angiography (28%), or traditional angiography (19%). The source of NCTH was thoracic in 84 patients, abdominal in 119, and pelvic in 71. The FAST was positive in only 51% of patients with abdominal or pelvic hemorrhage for an overall

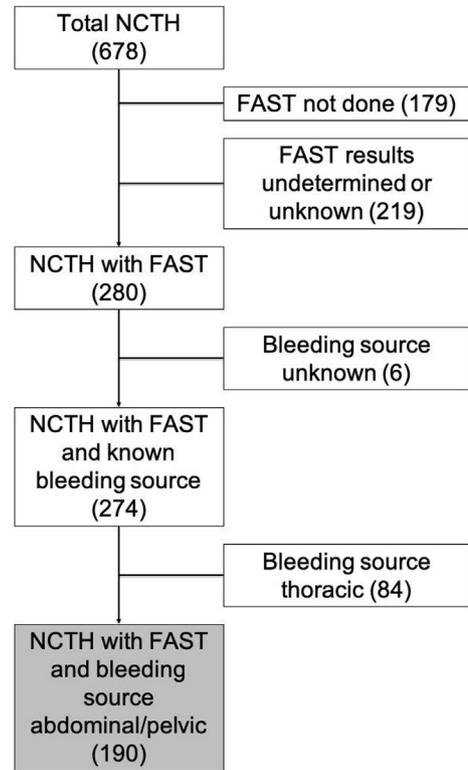


Fig. 1. Flow diagram of patient selection. Final sample noted in gray.

false negative rate (FNR) of 49% (sensitivity of 51%). The FNR was significantly higher for pelvic (61%) versus abdominal (43%) sources ($p = 0.02$) (Fig. 2).

There was no difference in age, gender, mechanism of injury, ISS, initial ED SBP, shock at presentation, or in-hospital mortality for patients with an abdominal vs. pelvic source of NCTH (all $p = NS$) (Table 1).

Furthermore, there was no difference between FAST negative or positive patients for gender, ISS, shock, length of stay, or mortality (all $p = NS$) (Table 2). However, mechanism of injury was blunt (as opposed to penetrating) in significantly more cases of false negatives (83%) vs. true positives (59%).

FAST performance metrics were not improved among the subgroup of NCTH patients with hemodynamic instability at presentation ($p = NS$). In addition, the FNR among those requiring laparotomy for hemorrhage control was 41% (abdominal) and 36% (pelvic).

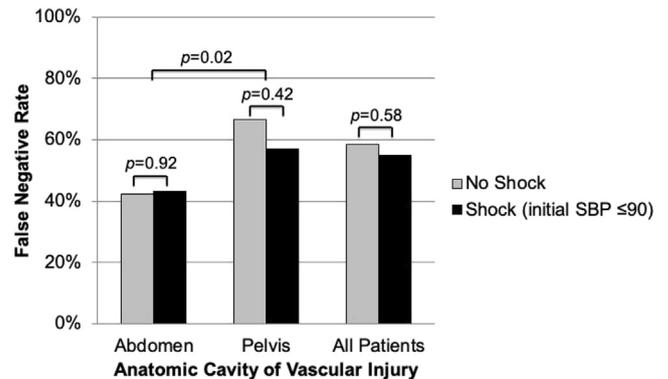


Fig. 2. False negative rate by anatomic cavity of vascular injury. Further stratified by shock at initial presentation.

FNR did differ depending on the specific vessel injured (Table 3). Central vessels carried the lowest FNR at 37%, which was significantly lower than perinephric (45%), pelvic (61%), or distal branches (64%) ($p = 0.014$).

Discussion

The objective of this study was to describe the performance metrics of FAST in a large cohort of patients with NCTH. Our key findings were that (1) FAST carried an FNR of 49% and sensitivity of 51%; (2) the FNR was significantly higher for pelvic (61%) versus abdominal (43%) sources of NCTH; (3) FNR was no better in patients with hemodynamic instability at presentation; and (4) FNR among those requiring laparotomy for hemorrhage control was 41% (abdominal) and 36% (pelvic).

Additionally, when we examined the FNR by vessel injured, we found that alarmingly high FNRs could be seen even with major vascular injuries. When central vessels were injured, FNRs were as high as 37%, and this rate only increased with injuries to perinephric vessels (45%), pelvic vessels (61%), or distal branches (64%). This is among the first reports of FNR stratified by specific vessel injury; however, prior studies have demonstrated a lack of correlation between presence of vascular injury and positive FAST, specifically in the setting of blunt trauma.⁷ Still other reports of patients with an initially negative FAST followed by a positive laparotomy have demonstrated high rates of splenic injury requiring splenectomy, liver laceration requiring packing, and mesenteric lacerations requiring repair/resection,⁸ not to mention the potential for missed injuries to the urinary system, diaphragm, adrenals, or any combination of the above.⁹ Given the potential clinical implications of missed hemorrhage, we recommend interpreting a negative FAST exam with caution if NCTH is suspected.

All of the patients in our database were positive for the outcome of interest (NCTH). This meant that each patient with a positive FAST had a “true positive” and each patient with a negative FAST had a “false negative”. Therefore, we were unable to capture false positives or true negatives, without which, we cannot comment on test characteristics such as specificity, positive predictive value, and negative predictive value.

This is the first study in the literature to specifically examine the performance of the FAST exam in the NCTH population. In other populations, numerous studies have highlighted the false negative rate as the key limitation of the FAST exam.^{7,9–32} In adults, studies have generally shown a sensitivity of 80%–88%, specificity of 98%–

100%, positive predictive value of 73%–83%, negative predictive value of 84%–99%, and an accuracy of 97%–99%.^{12–15}

However, these generalized reports of sensitivities in the 80% range (corresponding to an FNR of 20%) may be misleading in certain populations. For example, sensitivities as low as 28% have been reported in patients with pelvic fractures, an important subgroup of the NCTH population.²⁵ Another study found that in patients with splenic injury, sensitivity was as low as 28% if the patient presented with hemodynamic stability but 53% if the patient presented with hemodynamic instability.⁷ Further on the implications of hemodynamic stability, in patients with hypotension at presentation, sensitivities of 79% have been reported.⁸ Additionally, many studies fail to comment on the quandary of the pregnant patient with equivocal or negative FAST exam findings. Collectively, these reports on the limitations of the FAST exam are congruent with our findings.

In the context of the broader literature, we feel that three particular points are salient. First, the original description of the FAST exam by Rozycki et al. suggests that the intent of the exam was for positive FAST exams to guide management, but negative FAST exams (in the setting of high false negative rates) should not dissuade sound clinical judgment.¹³ Second, the FAST exam represents a snapshot of a single point in time, and repeated iterations might become warranted depending on then clinical condition of the patient. Finally, in light of this evidence, institutions may consider prospectively measuring their FAST exam false negative rates as a quality improvement measure to provide feedback to both clinicians and trauma systems.

Limitations

This study carries several notable limitations, largely due to its nature as a retrospective, *post-hoc* analysis of data collected for another study. First, we were bound by the operational definition of NCTH previously established by the NCTH Study Group. On one hand, this was advantageous to maintain consistency between studies and homogeneity of the patient sample. However, this is a research-driven definition of NCTH, and from a practical standpoint, clinicians may not be calculating AIS scores in the preoperative setting or know there is “named axial torso vessel disruption” before they operate.

Second, a sizeable proportion of patients had a FAST that was not done, unknown, or indeterminate. This may be reflective of clinical decision-making that is inherently difficult to capture in a

Table 3
False negative rate by vessel injured.

Injured Vessel	Negative	Positive	Total	False Negative Rate
Central	29	50	79	37%
Abdomen (not otherwise specified)	0	1	1	0%
Portal, hepatic, splenic, superior mesenteric vein	3	6	9	33%
IVC	6	11	17	35%
Celiac, hepatic, splenic, superior mesenteric, inferior mesenteric artery	15	27	42	36%
Aorta	5	5	10	50%
Perinephric	9	11	20	45%
Renal vein	0	3	3	0%
Renal artery	7	7	14	50%
Gonadal vein	2	1	3	67%
Pelvic	42	27	69	61%
Iliac vein	2	8	10	20%
Internal pudendal, obturator, or superior gluteal artery	7	4	11	64%
Iliac artery	33	15	48	69%
Distal Branches	14	8	22	64%

Abbreviations: IVC: inferior vena cava.

Distal branches include (n): inferior epigastric artery (4), mesenteric artery (3), gastroepiploic artery (3), lumbar artery (3), phrenic vessels (2), short gastric artery (1), omental artery (1), ovarian vein (1), superior epigastric artery (1), gastroduodenal artery (1), left gastric artery (1), and middle colic artery (1).

database. Nonetheless, this adds to the challenge of drawing generalizable conclusions from this study.

Third, because of the way our data only captured true positives and false negatives, we were unable to capture false positives or true negatives, without which, we cannot comment on specificity, positive predictive value, and negative predictive value.

Fourth, the NCTH database did not capture detail regarding who specifically performed or interpreted the FAST. Operator variability has been cited as a significant source of error, particularly in centers where trainees are performing FAST exams, even if those exam are interpreted by certified professionals.⁷ Bearing in mind that the accuracy of the FAST exam can vary depending on the examiner and the interpreter, we are unable to comment on the impact of this notable variable.

Conclusions

FAST carried a false negative rate as high as 50% in patients with NCTH. This was not significantly improved among NCTH patients presenting with hemodynamic instability. Even when central vessels were injured, false negative rates were as high as 37%, and this rate only increased with injuries to perinephric vessels (45%), pelvic vessels (61%), or distal branches (64%). Given the potential clinical implications of missed hemorrhage, the authors recommend interpreting a negative FAST exam with caution if NCTH is suspected.

Conflicts of interest

The authors have no conflicts of interest or financial disclosures which pertain to this study.

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