Focused Assessment with Sonography in Trauma for Assessing the Injury in the Military Settings: A Meta-Analysis

Qi et al. FAST for Injury in Military Settings

Xingshun Qi1,2, Jing Tian1, Rui Sun1, He Zhang1, Jinsong Han1, Hai Jin1, Hui Lu1

1Military Medical Research Group, General Hospital of Northern Theater Command (formerly General Hospital of Shenyang Military Area), Shenyang, Liaoning Province, China
2Meta-Analysis Interest Group, Department of Gastroenterology, General Hospital of Northern Theater Command (formerly General Hospital of Shenyang Military Area), Shenyang, China

Address for Correspondence: Hui Lu and Xingshun Qi, Military Medical Research Group, General Hospital of Northern Theater Command (formerly General Hospital of Shenyang Military Area), Shenyang, Liaoning Province, China
e-mail: northerntheater@126.com - xingshunqi@126.com

Received: 20 August 2019
Accepted: 1 October 2019

DOI: 10.4274/balkanmedj.galenos.2019.2019.8.79

Cite this article as:

Background: Non-invasive, rapid, and precise assessment of injury in the military settings is extremely important but difficult. Focused Assessment with Sonography in Trauma (FAST) has been increasingly employed for assessing the location and severity of injury and guiding further treatment decision.

Aims: However, the evidence regarding utility of FAST in the military settings is scattered. We conducted a meta-analysis to evaluate the diagnostic performance of FAST for assessing injury in the military settings.

Study Design: Meta-analysis study.

Methods: We identified all relevant papers via the PubMed, EMBASE, and Cochrane Library databases. We evaluated the quality of included studies by the QUADAS-2 tool. We pooled the area under curve (AUC), sensitivity, specificity, positive and negative likelihood ratio, and diagnostic odds ratio as the effect sizes. We evaluated the heterogeneity by P value and I².

Results: Six papers were included. The AUC of FAST for assessing the injury was 0.85. The pooled sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, and diagnostic odds ratio were 0.66, 0.98, 33.1, 0.34, and 97, respectively. The heterogeneity among studies was statistically significant (P=0.006, I²=78%).
**Conclusion:** FAST is potentially valuable for assessing the injury in the military settings. Due to its high specificity, FAST may be appropriate to rule in significant injury. However, due to its poor sensitivity, the ability of FAST to rule out injury cannot be relied upon.

**Keywords:** Injury, trauma, ultrasound, combat, military medicine

In the military settings, rapid and precise assessment and management of injury should be warranted to avoid the progression of injury and death, but is very difficult because the injury is usually complicated and severe and source of diagnostic instruments is limited. Historically, abdominal penetrating wounds should have an exploratory laparotomy as soon as possible. During the World Wars I and II, all soldiers with abdominal gunshot wounds went for a routine laparotomy. Since Shaftan has for the first time questioned its nature of over-treatment, numerous studies, including the Vietnam wound analysis, have supported the possibility of “negative laparotomy”, “unnecessary laparotomy”, and “non-therapeutic laparotomy”. However, how to non-invasively identify the “negative or unnecessary laparotomy” is not easy. Nowadays, military radiological techniques have been increasingly employed to assess the location and severity of injury. Focused Assessment with Sonography in Trauma (FAST), a hand-held point-of-care ultrasound, seems to be the most frequently used front-line imaging modality. Additionally, the implementation of FAST examination does not need specialized radiologists who are often lacking in the role military facilities. More importantly, FAST can effectively classify the causalities into three major types, which are useful for guiding further treatment decision: 1) negative injury: those needing further clinical observations; 2) suspected injury: those needing further imaging observations; and 3) positive injury: those needing immediate surgery. However, the evidence regarding utility of FAST in the military settings is scattered and inconclusive. Herein, we collected all available evidence and combined the relevant data to explore the diagnostic accuracy of FAST for assessing the injury in the military settings.

**Methods**
This work was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses statement. Our study has been registered in the PROSPERO. The registration number was CRD42019134305.

**Search Strategy**
PubMed, EMBASE, and Cochrane Library databases were searched for relevant papers since the inception of these databases. The last search date was June 2, 2019. The search items were as follows: (Focused Assessment with Sonography in Trauma) AND ((Combat) OR (War) OR (Military)) AND ((Injury) OR (Trauma)). Publication language and date are not restricted. All papers regarding diagnostic performance of FAST for assessing the injury in the military settings were potentially eligible. Papers would be excluded if 1) they were duplicates, case reports, comments, editorials, reviews, or conference meeting reports, 2) they did not employ FAST, or 3) they did not evaluate the diagnostic accuracy of FAST nor extract the sensitivity or specific data.

**Data Extraction**
The data were extracted by the first author as follows: first author, journal, publication year, sources of patients/causalities, period of enrollment, FAST machine and view areas, reference standards for assessment of injury, characteristics of trauma, and number of patients/causalities undergoing FAST and those with positive and negative injury via FAST and reference standards. If there was any uncertainty, he would discuss with others and reach a consensus.
**Study Quality Assessment**
The Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool was employed to assess the methodological quality of included studies. It assesses the risk of bias by answering the signaling questions in the four domains (Patient Selection, Index Test, Reference Standard, and Flow and Timing) and the applicability concerns by answering the questions in the first three of the four domains. Studies with more “low risk of bias” and “high applicability concern” would be of higher quality. Review Manager version 5.3 (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) was employed to draw the schematic diagram. The study quality was evaluated by the first author; if there is any difficulty, a consensus will be reached through a discussion with other authors.

**Data Analysis**
True positive, false positive, true negative, and false negative values were extracted from the original papers into a table. The “midas” module in the Stata/SE 14.0 for Windows (SataCorp LP, TX USA) was employed to perform all meta-analyses. Area under curve (AUC), sensitivity, specificity, positive and negative likelihood ratio, diagnostic odds ratio, and post-test probability were calculated. Their 95% confidence intervals (95%CIs) were calculated, if any. Heterogeneity was evaluated by chi-square and inconsistency tests. P value and I^2 were calculated. If P value was less than 0.1 and/or I^2 was more than 50%, the heterogeneity would be statistically significant. Heterogeneity was also visually evaluated by the Galbraith plot. Meta-regression analysis was performed, if possible. Neither meta-regression nor publication bias analysis was not performed due to a relatively small number of included studies.

**Results**

**Study Selection**
Among the 39 papers retrieved, a total of 6 papers were finally included (Figure 1). Study characteristics were shown in Table 1. They were published between 2005 and 2019. The data were reported from Iraq, Afghanistan, South Africa, and Saudi Arabia. The FAST machine was different among studies. Four regions, including pericardial, perihepatic, perisplenic, and pelvic views, were detected via the FAST. Reference standards for assessing the injury include CT, follow-up observation, and/or surgery. The sample size ranged from 15 to 396.

**Study Quality**
Study quality was shown in Figure 2. As for the signaling question “Was a consecutive or random sample of patients enrolled?” in the “Patient Selection” domain, one study had an answer of “No” because it mentioned “During the initial assessment of casualties in this study, FAST was performed on 396 of 468 (85.0%) casualties” and “A total of 403 of 468 (86.1%) casualties in the study group had abdominal/pelvic CT”. As for the signaling question “Did the study avoid inappropriate exclusions?” in the “Patient Selection” domain, one study had an answer of “No” because it mentioned “Reports were unavailable in 2 cases”. As for the signaling question “Were the reference standard results interpreted without knowledge of the results of the index tests?” in the “Reference Standard” domain, all included studies had an answer of “No” because the reference standard tests were performed after FAST in all studies.

**Meta-analyses**
The AUC of FAST for assessing the injury was 0.85 (95%CI=0.82-0.88) (Figure 3). The pooled sensitivity was 0.66 (95%CI=0.55-0.76) and specificity was 0.98 (95%CI=0.93-0.99) (Figure 4). The positive likelihood ratio was 33.1 (95%CI=10.0-109.1) and negative likelihood ratio was 0.34 (95%CI=0.25-0.47) (Figure 5).
The diagnostic odds ratio was 97 (95%CI=29-322) (Figure 6).
If FAST is positive, the post-test probability should be estimated as 97%; if FAST is negative, the post-test probability should be estimated as 26% (Figure 7).

**Heterogeneity**
The heterogeneity among studies was statistically significant (P=0.006, I²=78% [95%CI=51%-100%]).
Galbraith plot with true positive rate as an effect indicator suggested all studies within the 95%CI.
Galbraith plot with true negative rate as an effect indicator suggested the study by Waheed et al. was not within the 95%CI.

**Discussion**
To the best of our knowledge, our study should be the first meta-analysis to explore the role of FAST in assessing the injury in the military settings. Several previous systematic reviews and meta-analyses regarding application of FAST should be fully acknowledged 22-24, and their features are compared with our study. First, our study, rather than previous work, focused on the military settings. It should be noted that the severity and complexity of injury and accessibility of diagnostic equipments and therapeutic modalities are greatly different between civilian and military settings. Second, the Quinn’s paper performed a systematic literature review 22, but not combined the data by the means of meta-analysis. Third, among the Stengel’s papers, one focused on the patients with blunt abdominal trauma 23, and another on the patients with blunt thoracoabdominal trauma 24. The Quinn’s paper focused on the patients with penetrating torso trauma 22. By comparison, our present study did not limit the type of injury. Fourth, the Stengel’s study regarding blunt abdominal trauma identified 4 papers 23, the Stengel’s study regarding blunt abdominal trauma identified 34 papers 23, and the Quinn’s study regarding penetrating torso trauma identified 8 papers 22. By comparison, our present study identified 6 papers.

Our study found that FAST had a moderate diagnostic accuracy with an AUC of 0.85 and a very high specificity (i.e., true negative rate) of 0.98 but a relatively low sensitivity (i.e., true positive rate) of 0.66. These findings suggested that the performance of FAST for identifying patients with severe injuries might be moderate on the basis of an undesired sensitivity value, and some patients with truly severe injuries might be missed by FAST. But its performance for identifying patients who did not have severe injury might be very high and only few patients were misdiagnosed with severe injury. This might be translated into our clinical practice. In details, if FAST indicates a positive finding, we are confident that it is positive. In other words, we can rule in the injuries that we are looking for, if FAST shows a positive finding. Certainly, the heterogeneity of available studies should not be neglected to precisely recognize the potential limitation of the results.

According to the QUADAS-2 tool for assessing the risk of bias 15, the reference standard domain was at a high risk of bias for all included studies. However, considering the order of tests, invasiveness of reference standard (i.e., surgery), and nature of study population in real-world practice (i.e., injuries who need immediate management in the military settings), it was impossible to interpret the reference standard results without knowledge of the results of the index tests. FAST is an easy-to-access and non-invasive index test and firstly performed for the causalities. Then, CT, follow-up observation, and/or surgery, which are considered as the reference standards, are performed to further identify the severity of injury.

There was a statistically significant heterogeneity among studies. This can be explained by the difference in the characteristics of study population. In the Tummers’s study, only the young children aged less than 18 years old were selected 19. By comparison, in the Waheed’s studies, only the adults
aged more than 14 years old were included \(^{20}\). In other studies, the age was not limited. The mechanisms of injury might be another source of heterogeneity. In the Tummers’s and Waheed’s studies, only blunt abdominal injury was selected \(^{19-20}\). By comparison, in the other studies, the mechanisms of injury were not clearly restricted. For examples, in the Smith’s study, more injured patients had explosive injury and gunshot wounds \(^{18}\); in the Beck-Razi’s and Brook’s studies, patients had blunt and penetrating injury \(^{16-17}\).

Our study had several limitations. First, the number of included studies is relatively small. Thus, the meta-regression, publication bias, and subgroup analyses are hardly performed. Additionally, the current results should be confirmed in large-scale studies. Second, there is a difference in the age and source of target population, mechanisms of injury, and reference standards among studies. Therefore, the conclusions need to be validated in different settings. Third, we evaluated all injuries in the military settings, rather than focused on the combat-related injured soldiers alone. There were 3 studies conducted in the hospitals where most of injured civilians were admitted. One was from Level 1 hospital in Lebanon, one from the Red Cross War Memorial Hospital in Cape Town, and another from the Level 1 hospital in Saudi Arabia. Fourth, the type of trauma is not limited. So the results cannot be used for any specific injury. Fifth, only one primary author was involved in initially literature search and data extraction. This behavior is potentially inadequate.

Based on this meta-analysis, FAST has a moderate diagnostic performance for assessing the severity of injury in the military settings. Despite FAST can rarely misdiagnose with truly positive injury and accurately cover the cases with truly negative injury, it can miss some cases with truly positive injury. How to improve the utility of FAST for identifying more cases with truly severe injury should be explored in future.

References

1. Loria FL. Historical perspective of penetrating wounds of the abdomen. *Int Abstr Surg* 1948;87:521-549.
11. Ramoutsaki IA, Giannacos EN, Livadas GN. Birth of battlefield radiology: Greco-Turkish War of
**Figure 1.** Flowchart of study inclusion.
### Figure 2. Diagram of study quality assessment.

<table>
<thead>
<tr>
<th>Study</th>
<th>Risk of Bias</th>
<th>Applicability Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patient Selection</td>
<td>Index Test</td>
</tr>
<tr>
<td>Beck-Razi 2007</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Brooks 2005</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Carter 2019</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Smith 2015</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Tummers 2016</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Waheed 2018</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

- High
- Low
- Unclear
Figure 3. Summary receiver operating characteristic (ROC) plot of FAST for assessing injury.
AUC: area under curve; SENS: sensitivity; SPEC: specificity.
Figure 4. Summary sensitivity and specificity of FAST for assessing injury.

Figure 5. Summary positive likelihood ratio and negative likelihood ratio of FAST for assessing injury.
Figure 6. Summary diagnostic odds ratio of FAST for assessing injury.
Figure 7. Post-test probability of FAST for assessing injury.