นิพนธ์ต้นฉบับ . Original Article

การตรวจอัลตราซาวด์และความแม่นยำของการแปลผลการตรวจอัลตราซาวด์ช่องท้องในผู้ป่วยที่ได้รับอุบัติเหตุโดยนักปฏิบัติการฉุกเฉิน การแพทย์

ปิยฉัตร ศศิภัทรพงศ์
กลุ่มงานเวชศาสตร์ฉุกเฉิน *โรงพยาบาลขอนแก่น*

Focused Assessment with Sonography for Trauma Examinations Acquisition and Diagnostic Accuracy of Interpretation by Paramedics

Piyachat Sasipattarapong,
Department of Emergency Medicine, Khon Kaen Hospital, Khon Kaen, Thailand, 40000

Received: 7 June 2022/ Revised: 14 September 2022 / Accepted: 5 October 2022

Abstract

หลักการและวัตถุประสงค์: การตรวจอัลตราซาวด์ช่องท้องในผู้ป่วยที่ได้รับอุบัติเหตุ (FAST) ส่งผลให้การดูแลผู้ป่วยดีขึ้นในหลายประเทศ อย่างไรก็ตามข้อมูลความแม่นยำของการตรวจ FAST โดยนักปฏิบัติการฉุกเฉินการแพทย์ในประเทศกำลังพัฒนายังมีจำนวนจำกัด การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาการตรวจ FAST และความแม่นยำของการแปลผลการตรวจ FAST โดยนักปฏิบัติการฉุกเฉินการแพทย์

วิธีการศึกษา: เป็นการศึกษาไปข้างหน้าในผู้ป่วยอุบัติเหตุที่ได้รับการตรวจ FAST ในห้องฉุกเฉิน นักปฏิบัติการฉุกเฉินการแพทย์ที่ปฏิบัติงาน ณ ห้องฉุกเฉินโรงพยาบาลขอนแก่นได้รับการเรียนการสอนภาคทฤษฎีเป็นเวลา 2 ชั่วโมงและการสอนภาคปฏิบัติเป็นเวลา 2 ชั่วโมงตามด้วยการสอนภาคทฤษฎีผ่านสื่อวิดีโอสำหรับทบทวนความรู้โดยแพทย์ฉุกเฉินผู้เชี่ยวชาญด้านอัลตราซาวด์ จากนั้นประเมินความแม่นยำในการแปลผล FAST โดยนักปฏิบัติการฉุกเฉินการแพทย์ รวมถึงความสามารถในการตรวจอัลตราซาวด์ในผู้ป่วยจำลอง

ผลการศึกษา: นักปฏิบัติการฉุกเฉินการแพทย์ทั้งหมด 10 รายเข้าร่วมการศึกษา นักปฏิบัติการฉุกเฉินการแพทย์ทำการแปลผลอัลตราซาวด์จากผู้ป่วย 200 ราย ค่าความไว ค่าความจำเพาะ ค่าพยากรณ์ผลบวก และค่าพยากรณ์ผลลบในการแปลผล FAST เมื่อเปรียบเทียบกับผลการตรวจอัลตราซาวด์โดยแพทย์ฉุกเฉินผู้เชี่ยวชาญด้านอัลตราซาวด์เท่ากับร้อยละ 91.9 (95%CI, 78.1-98.3), 89.6 (95%CI, 83.8-93.8), 66.7 (95%CI, 55.8-76.0) และ 98.0 (95%CI, 94.3-99.3) ตามลำดับ ความแม่นยำเท่ากับร้อยละ 90.0 นักปฏิบัติการฉุกเฉินการแพทย์ทุกรายสามารถทำการตรวจอัลตราซาวด์ร้อยละ 100

สรุป: นักปฏิบัติการฉุกเฉินการแพทย์สามารถสามารถแปลผลอัลตราซาวด์ด้วยความแม่นยำที่สูงและสามารถทำการตรวจ FAST ในผู้ป่วยจำลองหลังได้รับการสอนเป็นเวลา 4 ชั่วโมง

คำสำคัญ: ความแม่นยำในการวินิจฉัย, นักปฏิบัติการฉุกเฉินการแพทย์, การตรวจอัลตราซาวด์ช่องท้องในผู้ป่วยที่ได้รับอุบัติเหตุ, อัลตราซาวด์

Corresponding author: p.sasipattarapong@gmail.com

Abstract

Background and Objective: Prehospital Focused Assessment with Sonography for Trauma (FAST) training has resulted in improved trauma patient outcomes in multiple countries. Previous studies demonstrated good accuracy. However, data regarding the diagnostic performance among paramedics in developing countries is sparse. This study's purpose was to examine the diagnostic accuracy of paramedic FAST exam interpretation and the success rate of image acquisition.

Materials and methods: This was a prospective observational study of trauma patients who received a FAST examination performed in the emergency department. Paramedics who worked at a tertiary emergency department in Khon Kaen hospital were included in this study. A 2-hour didactic lecture and 2-hour hands-on practice, followed by internet-based didactic session for review were provided by ultrasound-trained emergency physician. The diagnostic indices for FAST interpretation were calculated. Paramedics were also tested on image acquisition skills on a standardized patient using a standardized assessment tool.

Results: In total, 10 paramedics voluntarily participated and underwent FAST training. FAST exams from 200 patients performed in the emergency department were evaluated by paramedics. The paramedics were mostly ultrasound-naïve. The sensitivity, specificity, positive predictive value, and negative predictive value for image interpretation by paramedics compared to FAST results by ultrasound-trained emergency physician were 91.9% (95% CI, 78.1 - 98.3), 89.6% (95% CI, 83.8 - 93.8), 66.7% (95% CI, 55.8 - 76.0), and 98.0% (95% CI, 94.3 - 99.3), respectively. The overall accuracy was 90.0%. All of the paramedics were able to successfully complete 100% of the views of the FAST and achieved a practical standard considered by the ultrasound-trained emergency physician.

Conclusions: This study determined that paramedics were able to interpret FAST exams with a high degree of accuracy and perform FAST in a simulated environment following a four-hour training course.

Keywords: diagnostic accuracy, paramedic, FAST, ultrasonography

Introduction

Abdominal injury is one major cause of death after severe trauma.[1] A Physical examination, however, is not likely to reliably detect abdominal bleeding requiring immediate surgical care.[2] Focused assessment with sonography for trauma (FAST) ultrasound (US) has become an important diagnostic tool in emergency departments (ED) internationally and is part of the Advanced Trauma Life Support protocol.[3] Prior to the use of FAST, detecting abdominal injury was a clinical challenge in the prehospital setting.[4] Recently, it has been demonstrated that the detection of hemoperitoneum and pericardial effusion in traumatized patients can be achieved using FAST in the prehospital setting with good sensitivity and specificity.[5,6] Studies have shown that emergency medicine service (EMS) providers can perform a reliable FAST evaluation after a short training program.[7] In Thailand, paramedic curriculum (a four-year course) was developed for less than 10 years. However, the use of FAST US by paramedics is a relatively new application in Thailand. To the best of our knowledge, the diagnostic performance of FAST when used by graduate paramedics in Thailand has not been previously established. Determining the accuracy of FAST US by paramedics is necessary before implementing FAST US into large prehospital systems. The aim of this study is to evaluate the accuracy of FAST interpretation by paramedics for detection of free fluid in the peritoneal cavity and pericardial space and the ability to perform FAST exams in a simulated environment.

Methods

This was a prospective observational study conducted on paramedics. This study was conducted at ED of Khon Kaen hospital, Thailand. Khon Kaen hospital is a tertiary care hospital with an annual ED census of approximately 130,000 patients, of which 29,000 (22%) are trauma patients with more than 9,000 trauma admissions. An annual EMS run volume is 3,500, of which 900 (26%) are trauma patients. EMS service provides urgent prehospital treatment, stabilization for serious illness and injuries, and transport to definitive care in its respective communities. Eleven graduate paramedics worked at this ED.

Participant selection

In February 2022, following Ethics approval provided by the Ethics Committee of Khon Kaen hospital, paramedics at the ED at Khon Kaen hospital were enrolled in this study. Written informed consent was obtained from each paramedic participating in the study. The participants completed a 4-hour, FAST training program instructed by an emergency physician (EP), who is a specialist in the field of Emergency US. US-trained EP was an EP who had completed emergency US fellowship with 6 years of experience in emergency US teaching. We used a GE Venue Go US machine with a 5-1 MHz low frequency convex transducer in this study. FAST examinations from patients visiting to the ED at Khon Kaen hospital between October 1, 2021 and February 28, 2022 were recorded from trauma patients who had received a FAST US. Indications for each study were determined based on the clinical suspicion of the clinician performing the US.

Sample size calculation

We performed a sample size calculation for sensitivity and specificity analysis based on the method described by Daniel Wayne.[12] The sample size was calculated based on the prevalence of abdominal injury cases encounterd at Khon Kaen hospital which was 0.167, an absolute precision of 0.15, and a standard normal value of 1.96. The alpha of the test was set at 0.05. To detect an 84% sensitivity[7], the study requires at least 198 subjects.

Study protocol

All preexisting FAST examinations were performed by attending EPs or emergency medicine residents. All US views were recorded using 6-second video clips and stored in the computer. The entire examination was saved, de-identified, and compiled into a file for the purpose of subsequent review by the US-trained EP and interpretation by paramedics independently. All FAST examinations were reviewed for the presence or absence of hemopericardium and peritoneal fluid by the US-trained EP. Interpretation by the US-trained EP was used as a gold standard in this study. FAST results were recorded as positive or negative in each case. Only complete FAST examinations recorded in B mode (2D) videos were

included in the study. A complete examination was defined as including video clips of each window obtaining from 1) subcostal pericardial window 2) hepatorenal space (Morrison's pouch) 3) perisplenic space 4) pelvic transverse window, and 5) pelvic sagittal window. Exclusion criteria included examinations for which patient identifying information was incomplete, or when FAST exams were not recorded in all five FAST views, when still images rather than videos were recorded, and when no videos were recorded in B-mode format (e.g., only color Doppler format was recorded). Patient's age, sex, body mass index, arrival vital signs, mechanism of injury, abdominal computed tomography (CT) results, and intraoperative findings were obtained from chart review.

All paramedics were trained to perform FAST US through a 2-hour didactic lecture and 2-hour hands-on practice by the US-trained EP as shown in Table 1. Similar training curriculum has been effective among physicians, medical students, and paramedics.[8,9] Reading materials were given and were available as free downloads online. The hands-on session was a practice using a standardized patient as a live normal model and a mannequin with hemoperitoneum and hemopericardium as a model with positive findings. Pocket flashcards containing tips for performing the FAST scan, reference images for positioning the probe, and examples of normal and positive images were provided for review (Figure 1). In addition, all participants were given access to an e-learning curriculum which is online instructional 30-minute video link for review.

Table 1 Training Format of Paramedic FAST Ultrasound Course

Didactic lecture:	120 minutes
Physics and image orientation	30 minutes
FAST exam	40 minutes
Case review of each quadrant	30 minutes
Common pitfalls	20 minutes
Hands-on training	120 minutes
E-learning for review	30 minutes

FAST = Focused Assessment with Sonography for Trauma

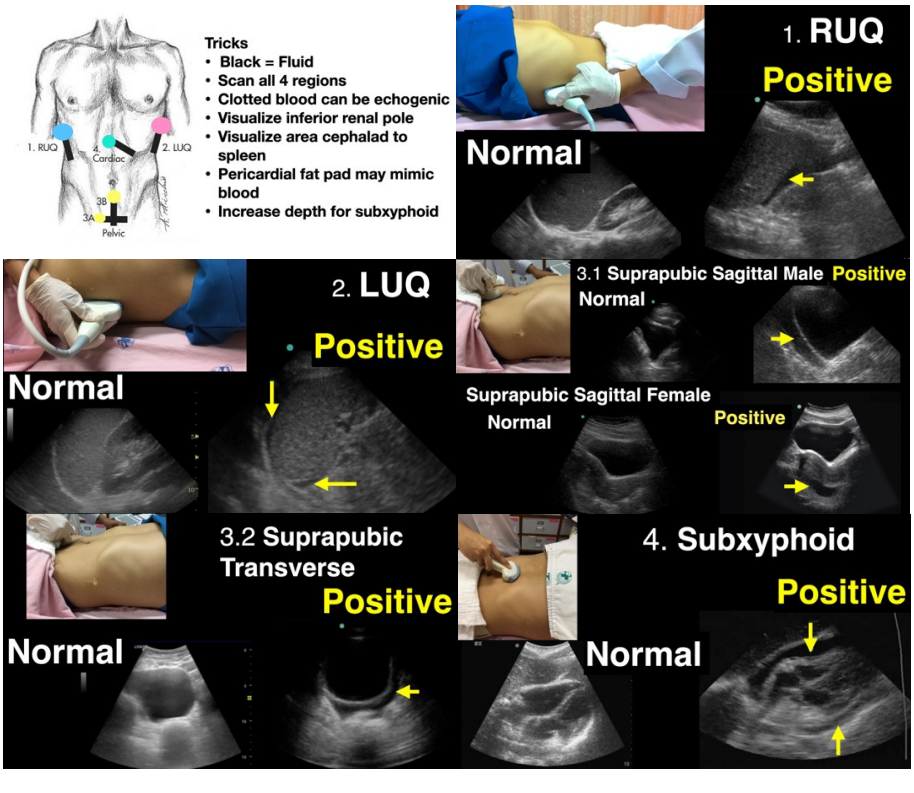

Figure 1 Pocket flashcards that were provided to the participants for quick review

Following the training period, the paramedics were assessed with a two-part examination. Part 1 assessed the paramedics' ability to detect the presence or absence of a hemoperitoneum and a hemopericardium using prerecorded FAST US video clips, which were shown on a laptop. All prerecorded FAST US video clips from 200 patients were divided into 10 folders for 10 trained paramedics. Each examination from each patient consisted of 1) subcostal pericardial window 2) hepatorenal space (Morrison's pouch) 3) perisplenic space 4) pelvic transverse window, and 5) pelvic sagittal window. Paramedics were blinded to the results of FAST US interpretation by the US-trained EP, other test results, clinical parameters, and further treatment plan. They were evaluated for image interpretation. Testing was distributed with real-time monitoring by a proctor to ensure independent work. Paramedics interpreted each examination as positive or negative in each case. The examination was interpreted as positive if the free fluid was seen in at least one view. If all views are negative, this was interpreted as a negative FAST. Interpretations were used to determine test characteristics. We determined the accuracy of FAST interpretation by paramedics using FAST interpretation by the US-trained EP as a gold standard. Part 2 assessed the FAST US acquisition skill. The paramedics undertook an objective structured clinical examination (OSCE) with the US-trained EP, marked according to a pre-defined checklist. All participants were required to conduct a FAST examination on a standardized patient immediately after the training session. Participants were assessed on image acquisition skill. Evaluation was done in standardized forms for all regions. They were examined on preparation, the transducer selection and orientation, technique, and achieved image quality (depth, angle and gain). A pre-defined checklist was created using a guideline from the Academy of Emergency US and American Institute of US in Medicine.[10,11]

Outcome Measures

The primary outcome for the study was the diagnostic accuracy of the FAST interpretation. Each paramedic interpreted video clips shown on a laptop computer within one week after the training session. We determined the accuracy of FAST interpretation by paramedics using FAST interpretation by the US-trained EP as a gold standard.

The secondary outcome of this study was to determine if paramedics could perform FAST scans after a training session. The paramedics undertook an OSCE with the US-trained EP, marked according to a pre-defined checklist. All participants were required to conduct a FAST examination on a standardized patient immediately after the training session. Participants were required to obtain adequate views in each of the 4 regions of the FAST examination. Paramedics were considered passing the test if they completed all components of the checklist.

Data analysis

All data analyses were completed using STATA version 10.0. The sensitivity, specificity, overall accuracy, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+) and negative likelihood ratio (LR-) of FAST as interpreted by paramedics were calculated along with corresponding 95% confidence intervals (CI).

Results

A total of 11 paramedics from EMS were voluntarily recruited. However, one did not complete the training. The remaining 10 paramedics were enrolled in the present study. There were 3 women and 7 men with an average age of 29.4±6.5 years. Regarding work experience, 4 (40.0%) had 1-2 years of EMS experience, 4 (40.0%) had 5 years of EMS experience, and 2 (20.0%) had 8 months of EMS experience. Moreover, of those, 8 (80.0%) had no previous FAST US training during paramedic program. Two (20.0%) reported receiving a 3-hour FAST US training on standardized patients during paramedic program 2 years prior to participating in this study. However, they never performed FAST US after the training.

FAST exams performed between October 1, 2021 and February 28, 2022 from a total of 200 patients in the ED were included in this study. Table 2 summarizes the demographic characteristics of patients that received FAST US and numbers of CT and operation performed. FAST US was positive in 37 (18.5%), and negative in 163 (81.5%) patients. The mean ages of the patients in the positive FAST and

negative FAST groups were 37.4 ± 16.5 and 39.4 ± 19.3 years, respectively. Males constituted 82.0% of the patients. The leading mechanism of injury (n=194, 97%) was due to blunt trauma. Systolic blood pressure, diastolic blood pressure and heart rate showed statistical significances (p< 0.05) between the 2 groups. Twelve patients (32.4%) in the positive FAST group underwent exploratory laparotomy, while none in the negative FAST group underwent exploratory laparotomy. Of 37 FAST positive cases, 32 (86.5%) underwent abdominal CT, while four (10.8%) were taken directly to emergency *exploratory laparotomy without* undergoing *CT* and one (2.7%) died before further imaging or operation was performed. Of 163 FAST negative cases, one (0.6%) underwent CT and CT showed no hemoperitoneum without evidence of intraabdominal solid organ injury in this patient.

Table 2 Baseline characteristics and numbers of abdominal CT and operation performed in patients received FAST US

Characteristics	Positive FAST (n=37)	Negative FAST (n=163)	Total (n=200)	p value
Age (years), mean ± SD	37.4±16.5	39.4±19.3	39.0±18.8	0.560
Gender				0.431
Male, n (%)	32 (86.5)	132 (81.0)	164 (82.0)	
Body Mass Index (mean ± SD)	22.2±3.0	22.3±4.3	22.3±4.1	0.908
Mechanism of injury, n (%)				1
Blunt trauma	36 (97.3)	158 (96.9)	194 (97.0)	
Penetrating trauma	1 (2.7)	5 (3.1)	6 (3.0)	
Cause of injury, n (%)				0.064
Traffic injury	32 (86.5)	117 (71.8)	149 (74.5)	
Non-traffic injury	5 (13.5)	46 (28.2)	51 (25.5)	
Arrival vital signs (mean±SD)				
- Systolic blood pressure (mmHg)	114.7±32.4	130.6±22.2	127.7±25.0	0.001*
- Diastolic blood pressure (mmHg)	75.1±19.0	81.4±15.5	80.3±16.3	0.035*
- Heart rate (beats per minute)	103.2±28.5	90.9±17.2	93.2±20.3	0.015*
- Respiratory rate (breaths per minute)	22.1±4.0	20.1±6.6	20.4±6.3	0.078
Abdominal CT performed, n (%)	32 (86.5)	1 (0.6)	33 (16.5)	<0.001*
Operation performed, n (%)	12 (32.4)	Nil	12 (6.0)	<0.001*

FAST = Focused Assessment with Sonography for Trauma, n= number, SD = Standard Deviation, mmHg = millimeter of mercury, CT = computed tomography *Statistical significant

In total, 10 paramedics assessed FAST US video clip images from a total of 200 patients for the presence or absence of hemoperitoneum and hemopericardium. In this study, we calculated the diagnostic performances on the basis of the interpretation of FAST prerecorded video cases by paramedics compared to FAST interpreted by the US-trained EP as a gold standard, as shown in Table 3. Our results showed a sensitivity of 91.9% (95%CI; 78.1 - 98.3), specificity of 89.6% (95%CI; 83.8-93.8), PPV of 66.7% (95%CI; 55.8-76.0), NPV of 98.0% (95%CI; 94.3-99.3), LR+ of 8.81 (95%CI; 5.56-13.96), and LR- of 0.09 (95%CI; 0.03-0.27). The paramedics demonstrated an overall accuracy in FAST US interpretation of 90.0% (95%CI; 85.0 - 93.8). The data are summarized in Table 3.

Table 3 Diagnostic Accuracy of FAST exams interpretation by paramedics

Parameter	Results
Sensitivity, % (95% CI)	91.9 (78.1 - 98.3)
Specificity, % (95% CI)	89.6 (83.8 - 93.8)
Overall Accuracy, % (95% CI)	90.0 (85.0 - 93.8)
Positive predictive value, % (95% CI)	66.7 (55.8 - 76.0)
Negative predictive value, % (95% CI)	98.0 (94.3 - 99.3)
Positive likelihood ratios, (95% CI)	8.81 (5.56 - 13.96)
Negative likelihood ratios, (95% CI)	0.09 (0.03 - 0.27)

CI = confidence interval

On image acquisition testing, paramedics obtained all 4 views of FAST examination completely with a success rate of 100%. Each of the candidates was able to achieve all appropriate views with sufficient quality on standardized patients.

The results of FAST interpreted by the US-trained EP were all true positives for 37 patients as confirmed by one of the following: abdominal CT only (n=23), abdominal CT and laparotomy (n=9), emergency laparotomy only (n=3), abdominal paracentesis (n=1), and autopsy (n=1).

Discussion

To our knowledge, this study was the first study to assess the diagnostic accuracy of FAST ultrasonography among paramedics in Thailand. After a short training, we found that paramedics could accurately interpret FAST examination. They accurately identified the presence or absence of free fluid on the FAST examination 90.0% of the time, with a sensitivity of 91.9% and a specificity of 89.6% in detecting a positive FAST exam. Several studies showed various sensitivities and specificities regarding the diagnostic accuracy of FAST US among paramedics. In the previous literature, the accuracy measures were reported, sensitivity ranged from 67%– 97.5%, and specificity ranged from 56%–97%.[8] The results of our study suggest that the accuracy of FAST interpretation by paramedics trained in FAST, is comparable to, and are not lower than, those from previous studies. The paramedics were trained for four hours. Most of them had no prior experience with FAST US. Unluer et al. observed FAST from paramedics performed on patients admitted to the ED following trauma after four hours of didactic and four hours of hands-on training. Sensitivity was 84.6% and specificity was 97.4% for the detection of hemoperitoneum when compared with radiologist US and abdominal CT.[7] Another study by Buaprasert et al which was similar to our setting, observed extended-FAST from final-year paramedic students after 2 hours of didactic training session and 1 hour of hands-on workshop. The outcome revealed a sensitivity of 85.7% and a specificity of 81.6% on the basis of the interpretation of extended-FAST prerecorded video cases, and 41 (87.2%) participants passed the OSCE exam on image acquisition performed on a mannequin model.[13] This study pointed out extended-FAST exam performed by healthcare personnel other than doctors from a middle-income country who were unfamiliar with scanning US was effective. Waterman et al found that after 1 hour of didactic training, aeromedical critical care paramedics have shown an accuracy of 85.6% in FAST examinations using a mannequin.[14] We found that our results well correlated with this study as well.

We found that all paramedics could successfully perform FAST examination on standardized patients with a success rate of 100% which was as high as that found by a previous study. Considering the relatively brief training program, we consider this to be a promising result. Boniface et al demonstrated a similar finding: that 51 US paramedics with no prior US experience used US to obtain FAST US images on a live volunteer under remote guidance from experienced EPs during the FAST examination after a 20-minute lecture, and found that paramedics were able to successfully obtain 100% of the views of the FAST. Even though in our study, paramedics were not provided any real-time feedback, paramedics in our study had a much longer training session.[15] Heegaard et al demonstrated that paramedics were unable to obtain adequate images in 7.7% (8/104) of the patients in the ambulance after receiving a 6-hour training program in US with ongoing refresher education.[16] The success rate in our study was higher than that in the study by Heegaard et al.[16] It might have been because paramedics in our study performed US on a

standardized patient in a classroom setting as opposed prehospital environment. Technical and mechanical difficulties of a real trauma at the scene may affect the ability of paramedics to obtain US in his study.

Of the patients requiring FAST in this study, the majority of the patients were male (82.0%), which is consistent with a previous study that reported a male preponderance (80.5%).[17] The major causes of injury in the present study were traffic injuries (74.5%), consistent with a study by Prathep et al.[17] Most of the trauma patients with positive FAST were managed nonoperatively, but exploratory laparotomy was needed in 12 cases (32.4%), a result consistent with other research studies.[18,19]

Our study had some limitations. Firstly, generalizability of the results is limited by the fact that this study was conducted at a single center with a single crew of paramedics. We had a relatively small number of paramedics, limiting the ability to apply these data to the broader population. Secondly, the ability to apply our data to the prehospital use of US for paramedics is limited. Paramedics did not perform FAST US on real trauma patients in the prehospital setting but instead they performed FAST US on a standardized patient in a classroom setting and conducted an interpretation of recorded video. This process does not account for the additional factors at the real trauma scene. As a result, it cannot be considered to represent the accuracy and the success rate of image acquisition when it is carried out on real patients in actual prehospital clinical practice. Further studies should include examinations in more realistic situations and evaluation of the impact of US on patient outcomes. Thirdly, examination was performed within one week after the training session; hence, additional research is needed considering the long-term knowledge and skill retention.

Conclusion

In conclusion, this study determined that paramedics were able to interpret FAST exams with a high degree of accuracy and perform FAST in a simulated environment following a short 4 hour-training session. This has the potential to help paramedics to make an early diagnosis of abdominal injury, which in turn should lead to early treatment decision and enhance patient survival. Further studies are needed to determine the optimal use of US in the prehospital setting by paramedics and whether it can impact patient outcomes.

Acknowledgments

The author expresses sincere gratitude to Dr. Narudee Srisang, Dr. Weerasak Phongphuttha, Dr. Ratrawee Pattanarattanamolee, emergency physicians from the Department of Emergency Medicine, Khon Kaen Hospital, for their advice, and IDS Medical Systems Thailand for supporting the GE ultrasound machine in the present study.

References

1. Demetriades D, Murray J, Charalambides K, Alo K, Velmahos G, Rhee P, et al. Trauma fatalities: time and location of hospital deaths. J Am Coll Surg 2004;198(1):20–6.
2. Blaivas M, Sierzenski P, Theodoro D. Significant hemoperitoneum in blunt trauma victims with normal vital signs and clinical examination. Am J Emerg Med 2002;20(3):218–21.
3. Helm M, Kulla M, Lampl L. Advanced Trauma Life Support®. Anaesthesist 2007;56(11):1142–6.
4. Clarke JR, Trooskin SZ, Doshi PJ, Greenwald L, Mode CJ. Time to laparotomy for intra-abdominal bleeding from trauma does affect survival for delays up to 90 minutes. J Trauma Acute Care Surg 2002;52(3):420–5.
5. El Sayed MJ, Zaghrini E. Prehospital Emergency Ultrasound: A review of current clinical applications, challenges, and future implications. Emerg Med Int 2013;2013:531674.
6. Yates JG, Baylous D. Aeromedical ultrasound: the evaluation of point-of-care ultrasound during helicopter transport. Air Med J 2017;36(3):110–5.
7. Unluer EE, Yavasi O, Kara PH, Kilic TY, Vandenberk N, Kayayurt K, et al. Paramedic performed focused assesment with sonography in trauma (fast) in the emergency department. Turk J Trauma Emerg Surg 2011;17(2):113–6.
8. Meadley B, Olaussen A, Delorenzo A, Roder N, Martin C, St. Clair T, et al. Educational standards for training paramedics in ultrasound: a scoping review. BMC Emerg Med 2017;17(1):18.

9. Press GM, Miller SK, Hassan IA, Blankenship R, del Junco D, Camp E, et al. Evaluation of a training curriculum for prehospital trauma ultrasound. J Emerg Med. 2013;45(6):856–64.
10. Lewiss RE, Pearl M, Nomura JT, Baty G, Bengiamin R, Duprey K, et al. CORD-AEUS: consensus document for the emergency ultrasound milestone project. Acad Emerg Med. 2013; 20(7):740–5.
11. American Institute of Ultrasound in Medicine; American College of Emergency Physicians. AIUM practice guideline for the performance of the focused assessment with sonography for trauma (FAST) examination. J Ultrasound Med. 2014; 33(11):2047–56.
12. Daniel W Wayne. Biostatistics: A Foundation of Analysis in the Health Sciences. 6th ed. New York: John Wiley&Sons; 1995:180.
13. Buaprasert P, Sri-On J, Sukhuntee J, Asawajaroenkul R, Buanhong O, Khiaodee T, et al. Diagnostic accuracy of extended focused assessment with sonography for trauma performed by paramedic students: a simulation-based pilot study. Open Access Emerg Med 2021;13:249–56.
14. Waterman B, Aarsen KV, Lewell M, Tien H, Myslik F, Peddle M, et al. Abdominal ultrasound image acquisition and interpretation by novice practitioners after minimal training on a simulated patient model. Can J Emerg Med. 2020;22(S2):S62–6.
15. Boniface KS, Shokoohi H, Smith ER, Scantlebury K. Tele-ultrasound and paramedics: real-time remote physician guidance of the Focused Assessment With Sonography for Trauma examination. Am J Emerg Med. 2011;29(5):477–81.
16. Heegaard W, Hildebrandt D, Spear D, Chason K, Nelson B, Ho J. Prehospital ultrasound by paramedics: results of field trial. Acad Emerg Med 2010;17(6):624–30.
17. Prathep S, Sriplung H, Phuenpathom N, Zunt J, Hirunpat S, Vavilala MS. Characteristics and outcomes of thai patients hospitalized with severe traumatic brain injury between 2009 and 2011. J Med Assoc Thai 2017;100(8):7.
18. Raza M, Abbas Y, Devi V, Prasad KVS, Rizk KN, Nair PP. Non-operative management of abdominal trauma – a 10 years review. World J Emerg Surg 2013;8:14.
19. Leppäniemi A. Nonoperative management of solid abdominal organ injuries: From past to present. Scand J Surg 2019;108(2):95–100.

SMJ