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Bridging the Experience Gap in Trauma: Diagnostic Performance of Tele-Guided eFAST Compared with Expert-Performed eFAST

Travmada Deneyim Açığını Kapatmak: Tele-Rehberli eFAST'ın Uzman Tarafından Gerçekleştirilen eFAST ile Karşılaştırmalı Tanısal Performansı

Suha Serin, Bahadir Caglar

Department of Emergency Medicine, Faculty of Medicine, Balikesir University, Balikesir, Turkey

Abstract

Aim: Extended Focused Assessment with Sonography for Trauma (eFAST) is a standard bedside protocol in trauma care, but its dependence on operator expertise limits prehospital use. Tele-ultrasound may allow inexperienced operators to acquire images under real-time expert guidance. This study evaluated the diagnostic performance and technical feasibility of tele-guided eFAST acquired by paramedics without previous ultrasound experience in real trauma patients.

Material and Method: In this prospective paired diagnostic comparison study, trauma patients underwent clinically indicated eFAST in an emergency department. Each patient first underwent expert-performed eFAST, the study reference examination. Three paramedics without previous ultrasound experience then acquired a second eFAST after an eight-hour training programme (four hours theoretical, four hours practical). Image acquisition was performed by the paramedics, whereas final interpretation was made by a remotely located emergency physician blinded to the expert findings.

Results: Of 194 patients assessed, 47 were excluded (hemodynamic instability, n=23; penetrating injury, n=4; connection-related failure, n=14; examination not completed per protocol, n=6), leaving 147 who completed both examinations (Figure 1). A technically adequate connection was established in 91.6% (153/167) of attempted cases. Region-specific sensitivity ranged from 75.0% to 100.0% and specificity from 93.1% to 98.6%. Patient-level sensitivity was 90.3% (95% CI 80.1–96.4) and specificity 74.1% (95% CI 63.5–83.0), with 22 false-positive and six false-negative results.

Conclusion: In a controlled emergency department environment, tele-guided eFAST showed high region-specific performance compared with expert-performed eFAST, but patient-level specificity was lower and connectivity failures occurred. These findings require external validation in different EMS systems and in actual prehospital environments before widespread implementation can be recommended.

Keywords: Telemedicine, ultrasonography, emergency medical technicians, wounds and injuries

Öz

Amaç: Travma için Genişletilmiş Odaklanmış Ultrasonografik Değerlendirme (Extended Focused Assessment with Sonography for Trauma, eFAST), travma bakımında standart bir hasta başı protokoldür; ancak operatör deneyimine bağımlı olması hastane öncesi kullanımını sınırlandırmaktadır. Tele-ultrason, deneyimsiz uygulayıcıların gerçek zamanlı uzman rehberliği altında görüntü elde etmesine olanak sağlayabilir. Bu çalışmada, gerçek travma hastalarında ultrasonografi deneyimi bulunmayan paramedikler tarafından görüntüleri elde edilen tele-rehberli eFAST'ın tanısal performansı ve teknik uygulanabilirliği değerlendirildi.

Gereç ve Yöntem: Bu prospektif eşleştirilmiş tanısal karşılaştırma çalışmasına acil serviste klinik olarak eFAST endikasyonu konulan travma hastaları dahil edildi. Her hastaya önce çalışma referans incelemesi olarak kullanılan uzman tarafından gerçekleştirilen eFAST uygulandı. Daha önce ultrasonografi deneyimi bulunmayan üç paramedik, sekiz saatlik eğitim programı (dört saat teorik, dört saat pratik) sonrasında ikinci eFAST incelemesinin görüntülerini elde etti. Prob manipülasyonu ve görüntü elde edilmesi paramedikler tarafından gerçekleştirilirken nihai yorum, uzman eFAST bulgularına kör olan uzaktaki bir acil tıp uzmanı tarafından yapıldı.

Bulgular: Değerlendirilen 194 hastanın 47'si dışlandı (hemodinamik instabilite, n=23; penetran yaralanma, n=4; bağlantı kaynaklı başarısızlık, n=14; protokole göre tamamlanamayan inceleme, n=6) ve 147 hasta her iki incelemeyi tamamladı (Şekil 1). Yeterli teknik bağlantı, deneme yapılan olguların %91,6'sında (153/167) sağlandı. Bölgesel duyarlılık %75,0-%100,0, özgüllük ise %93,1-%98,6 arasında değişti. Hasta düzeyinde duyarlılık %90,3 (%95 GA 80,1-96,4), özgüllük %74,1 (%95 GA 63,5-83,0) olup 22 yanlış pozitif ve altı yanlış negatif sonuç saptandı.

Sonuç: Kontrollü acil servis ortamında tele-rehberli eFAST, uzman tarafından gerçekleştirilen eFAST ile karşılaştırıldığında yüksek bölgesel performans gösterdi; ancak hasta düzeyindeki özgüllük daha düşüktü ve bağlantı sorunları gözlendi. Bu bulguların yaygın kullanım önerilmeden önce farklı acil sağlık sistemlerinde ve gerçek hastane öncesi ortamlarda dış geçerliliğinin gösterilmesi gereklidir.

Anahtar Kelimeler: Teletıp, ultrasonografi, paramedikler, yaralar ve yaralanmalar

Corresponding *(İletişim)*: Bahadir Çağlar, Department of Emergency Medicine, Faculty of Medicine, Balikesir University, Balikesir, Turkey
E-mail *(E-posta)*: mail@bahadircaglar.com
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INTRODUCTION

Point-of-care ultrasound (POCUS) has become an essential bedside diagnostic tool in emergency medicine, critical care, and trauma management. Advances in portable ultrasound technology allow clinicians to obtain rapid, repeatable, non-invasive imaging at the patient's bedside without ionizing radiation. These characteristics make POCUS particularly valuable in time-critical clinical settings.

In trauma care, rapid and accurate assessment is crucial for identifying life-threatening conditions and guiding timely intervention. Early recognition of thoracic and intra-abdominal pathology is particularly important for reducing morbidity and mortality. To facilitate this rapid evaluation, several POCUS protocols have been developed. Among these, the Extended Focused Assessment with Sonography in Trauma (eFAST) is one of the most widely used bedside protocols. Its primary purpose is to rapidly detect major traumatic pathologies such as hemoperitoneum, hemothorax, pericardial effusion, and pneumothorax.[1-8]

The role of POCUS extends well beyond the hospital environment. In prehospital emergency medical services (EMS), ultrasound has the potential to provide valuable diagnostic information that may improve early triage, support appropriate hospital selection, and optimize trauma system efficiency. This capability is particularly relevant in rural regions, disaster zones, mass-casualty incidents, and other resource-limited settings where access to advanced diagnostic support may be delayed.

Despite these advantages, the implementation of prehospital ultrasound remains limited. One of the main barriers is the operator-dependent nature of ultrasonography. The diagnostic performance of POCUS is highly dependent on the skill and experience of the person acquiring and interpreting the images. This limitation is especially important in prehospital settings, where paramedics and other frontline providers may have limited formal training in ultrasonography.

Recent advances in telecommunication technology have introduced tele-ultrasound as a potential strategy for addressing this barrier. Tele-ultrasound enables local operators to acquire images while receiving real-time guidance and interpretive support from a remotely located expert. Historically, tele-ultrasound was explored in extreme and remote environments, including space missions, and has subsequently been applied in rural medicine, maritime and aviation settings, and disaster response.[9] More recent studies have demonstrated its feasibility in emergency and prehospital care, suggesting that remote experts can assist non-expert operators in obtaining diagnostically useful images.[10-15]

However, important gaps remain in the literature. Much of the existing evidence has been derived from simulation-based studies, healthy volunteers, or operators with at least partial prior ultrasound training. Data on tele-guided eFAST performed by completely inexperienced paramedics in real trauma patients remain limited. This distinction is clinically important, as real trauma patients present practical challenges such as pain, agitation, limited positioning, and time pressure, all of which may affect image acquisition and interpretation.

Therefore, the aim of this study was to evaluate the diagnostic performance and technical feasibility of tele-guided eFAST acquired by paramedics without previous ultrasound experience and interpreted by a remote emergency physician, using expert-performed eFAST as the study reference examination in real trauma patients.

MATERIAL AND METHOD

Study Design and Ethical Considerations

This prospective paired diagnostic comparison study was conducted in the Emergency Department of Balıkesir University Faculty of Medicine. The study protocol was approved by the Balıkesir University Clinical Research Ethics Committee on 19 April 2023 (Decision No. 2023/45). Patient recruitment was conducted between 1 June 2023 and 1 March 2025 and commenced only after ethics committee approval had been obtained. The study was supported by the Balıkesir University Scientific Research Projects Unit (Project No. 2022/004). All study procedures were performed in accordance with the ethical standards of the institutional research committee and the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Sample Size Estimation

Sample size estimation for this diagnostic comparison study was performed using the method described by Buderer, which incorporates the expected sensitivity, specificity, and disease prevalence. Assuming an expected sensitivity of 90% and specificity of 75% for tele-guided eFAST examinations, with an estimated prevalence of eFAST positivity of 42%, a 95% confidence level, and an acceptable absolute precision of ±10%, the minimum required sample size was calculated as 80 patients for sensitivity-based estimation and 128 patients for specificity-based estimation. Therefore, a minimum of 128 patients was considered necessary to adequately evaluate the diagnostic performance of the index test. The final study population consisted of 147 patients, which was considered sufficient for the planned analyses. The sample size calculation was designed to estimate agreement-related diagnostic performance against expert-performed eFAST and not against definitive clinical, radiological, or operative diagnoses.

Study Population, Operators, and Training

Patients presenting to the emergency department after trauma were assessed for eligibility. Patients were included when an eFAST examination was clinically indicated by the attending emergency physician and when both the expert-performed and tele-guided examinations could be performed according to the study protocol.

Exclusion criteria were hemodynamic instability, defined as a systolic blood pressure below 90 mmHg; penetrating injury; failure to establish or maintain the tele-ultrasound connection; and inability to complete the tele-guided eFAST examination according to the study protocol. Connection-related failure categories are reported in the Results section and in **Figure 1**. Specific reasons for the six examinations that could not be completed were not separately recorded in the study dataset.

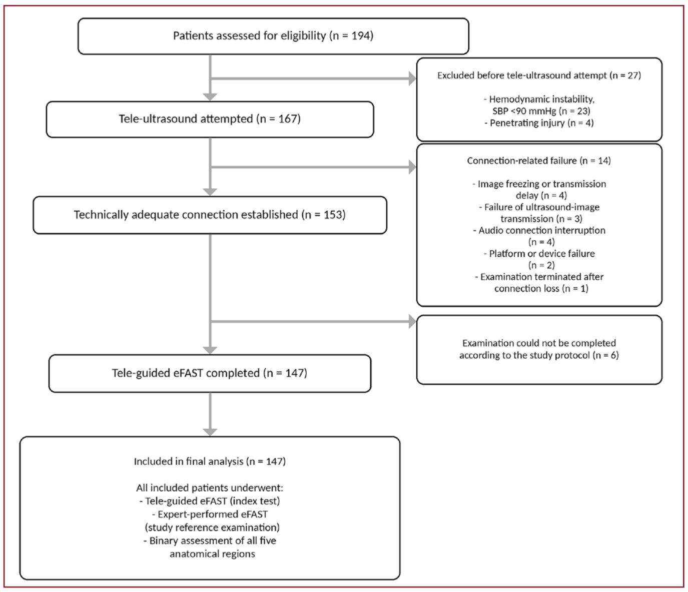

Figure 1. STARD flow diagram showing patient eligibility, technical connection success, examination completion, and inclusion in the final analysis.

Three paramedics were selected as the local ultrasound operators before the commencement of patient recruitment. None had previous formal ultrasound training or clinical ultrasound experience.

Before patient enrolment, the paramedics completed a standardized eight-hour basic ultrasound training programme consisting of four hours of theoretical instruction and four hours of practical training. The programme focused on the eFAST protocol, use of the handheld ultrasound device, probe manipulation, and acquisition of the standard eFAST views.

The number of supervised practice examinations completed by each paramedic during training was not formally recorded. No formal competency examination or predefined minimum number of successful supervised examinations was required before patient enrolment.

Equipment and Telecommunication Infrastructure

Ultrasound examinations were performed using a handheld, portable ultrasound device (Philips Lumify, Philips Healthcare) equipped with a phased-array probe (S4-1 transducer). Real-time image transmission and remote audiovisual communication were facilitated using a Samsung Tab-7 tablet computer running the Reacts (Remote Education, Augmented Communication, Training, and Supervision) collaborative platform. This setup allowed for live streaming of the ultrasound images and simultaneous voice communication between the paramedic and the remote guide.

Technical connection success was defined as the establishment and maintenance of audiovisual communication and real-time ultrasound-image transmission sufficient to conduct the tele-guided examination.

Connection-related failure was defined as a technical problem that prevented the establishment or continuation of adequate audiovisual communication or ultrasound-image transmission. Observed failures included image freezing or transmission delay, failure of ultrasound-image transmission, interruption of the audio connection, platform or device failure, and termination of the examination because of connection interruption.

Study Protocol

The study used a paired examination design. Each participant underwent two consecutive eFAST examinations.

Expert-performed eFAST: The first examination was performed by an experienced emergency medicine specialist as part of the patient's clinical evaluation. This examination was used as the study reference examination. It was not considered a definitive diagnostic standard equivalent to computed tomography, operative findings, or clinical follow-up.

Tele-guided eFAST: Immediately after the expert-performed examination, one of the three trained paramedics performed a second eFAST examination on the same patient. The examination was conducted in the same emergency department environment.

During the tele-guided examination, the paramedic was responsible for probe manipulation and image acquisition. A second experienced emergency physician, located remotely, provided real-time verbal guidance and interpreted the transmitted ultrasound images. The final positive or negative classification for each anatomical region and the overall eFAST result was made exclusively by the remote emergency physician.

The remote emergency physician was blinded to the findings of the expert-performed eFAST examination and to detailed clinical information. The paramedic had access to the general clinical context but did not have access to the result of the first examination.

A maximum duration of five minutes was predefined for the tele-guided examination. The interval between the expert-performed and tele-guided examinations was also limited to a maximum of five minutes.

Data Collection and Interpretation

Both examinations assessed the following anatomical regions in the same sequence:

1. Right Upper Quadrant (RUQ)/Morison's Pouch
2. Left Upper Quadrant (LUQ)/Splenorenal Recess
3. Pelvic View (Suprapubic)
4. Cardiac View (Subxiphoid or Parasternal)
5. Lung Views (bilateral)

The expert-performed and tele-guided examinations were recorded as binary positive or negative findings for each anatomical region. A patient was classified as eFAST positive when at least one anatomical region was classified as positive.

For the 147 completed examinations included in the final analysis, a positive or negative result was available for each of the five anatomical regions. Examinations that could not be completed according to the study protocol were excluded before the final analysis. A separate indeterminate category and a standardized image-quality grading scale were not used in the final study dataset.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were summarized as mean±standard deviation or median with interquartile range, as appropriate. Categorical variables were presented as frequencies and percentages.

The diagnostic performance of tele-guided eFAST was evaluated against expert-performed eFAST, which served as the study reference examination. True-positive, false-positive, true-negative, and false-negative results were calculated for each anatomical region and for overall patient-level eFAST positivity.

Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were reported with 95% confidence intervals calculated using the Clopper-Pearson exact binomial method. Positive and negative likelihood ratios were reported with 95% confidence intervals calculated using the logarithmic method. When a zero cell prevented log-based confidence interval estimation, the corresponding likelihood-ratio confidence interval was reported as not estimable.

Overall eFAST positivity was defined as the presence of at least one positive finding in any anatomical region. All reported diagnostic performance measures therefore represent comparison with expert-performed eFAST and not with definitive clinical, radiological, or operative diagnoses.

RESULTS

Study Population Characteristics

A total of 194 patients were assessed for eligibility. Twenty-three patients were excluded because of hemodynamic instability, defined as a systolic blood pressure below 90 mmHg, and four were excluded because of penetrating injury. Tele-ultrasound was attempted in the remaining 167 patients.

A technically adequate tele-ultrasound connection was established in 153 of 167 attempted cases, corresponding to a technical connection success rate of 91.6%. Fourteen patients experienced connection-related failure. Six additional tele-guided examinations could not be completed according to the study protocol; the individual reasons for non-completion were not separately recorded. Consequently, 147 patients completed both expert-performed and tele-guided eFAST examinations and were included in the final analysis. The overall completed examination rate among patients in whom tele-ultrasound was attempted was 88.0% (147/167). Among patients in whom an adequate connection was established, the examination completion rate was 96.1% (147/153).

Of the 147 included patients, 64 (43.5%) were female. The mean age was 49.5 years, with an age range of 18–81 years. Detailed information on trauma mechanism, body mass index, injury severity score, complete admission vital signs, and final clinical or radiological diagnoses was not prospectively recorded in the study dataset.

The 14 connection-related failures consisted of image freezing or transmission delay in four cases, failure of ultrasound-image transmission in three cases, interruption of the audio connection in four cases, platform or device failure in two cases, and inability to complete the examination because of connection interruption in one case.

Diagnostic Performance

The diagnostic performance of tele-guided eFAST was evaluated against expert-performed eFAST, which served as the study reference examination. These results represent comparison between the two eFAST examinations rather than diagnostic accuracy against computed tomography, operative findings, or clinical follow-up.

Region-specific sensitivity ranged from 75.0% to 100.0%, whereas specificity ranged from 93.1% to 98.6%. At the patient level, 62 of 147 patients were classified as eFAST positive by the expert-performed examination. Tele-guided eFAST correctly classified 56 of these patients as positive and produced six false-negative results. Of the 85 patients classified as eFAST negative by expert-performed eFAST, 63 were correctly classified as negative and 22 were classified as false positive by tele-guided eFAST. Overall patient-level sensitivity was 90.3%, specificity was 74.1%, positive predictive value was 71.8%, negative predictive value was 91.3%, and accuracy was 81.0%.

The lower specificity observed for overall eFAST positivity, compared with the high specificity of the individual anatomical regions, is explained by the patient-level classification rule used in this study. Because a patient was considered eFAST positive if any single anatomical region was interpreted as positive, even one false-positive regional finding resulted in an overall false-positive classification.

Table 1. Diagnostic performance of tele-guided eFAST compared with expert-performed eFAST.

Anatomical View	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV % (95% CI)	NPV % (95% CI)	LR (+) (95% CI)	LR (–) (95% CI)	Accuracy % (95% CI)
RUQ	95.7 (85.5–99.5)	94.0 (87.4–97.8)	88.2 (76.1–95.6)	97.9 (92.7–99.7)	15.96 (7.33–34.75)	0.05 (0.01–0.18)	94.6 (89.6–97.6)
LUQ	90.3 (74.2–98.0)	93.1 (86.9–97.0)	77.8 (60.8–89.9)	97.3 (92.3–99.4)	13.10 (6.65–25.81)	0.10 (0.04–0.31)	92.5 (87.0–96.2)
Pelvic	85.7 (57.2–98.2)	97.0 (92.5–99.2)	75.0 (47.6–92.7)	98.5 (94.6–99.8)	28.50 (10.61–76.59)	0.15 (0.04–0.53)	95.9 (91.3–98.5)
Cardiac	100.0 (47.8–100.0)	96.5 (92.0–98.8)	50.0 (18.7–81.3)	100.0 (97.3–100.0)	28.40 (12.01–67.18)	0.00 (NE)	96.6 (92.2–98.9)
Lung	75.0 (19.4–99.4)	98.6 (95.0–99.8)	60.0 (14.7–94.7)	99.3 (96.1–100.0)	53.63 (12.11–237.46)	0.25 (0.05–1.38)	98.0 (94.2–99.6)
Total eFAST (+)	90.3 (80.1–96.4)	74.1 (63.5–83.0)	71.8 (60.5–81.4)	91.3 (82.0–96.7)	3.49 (2.41–5.05)	0.13 (0.06–0.28)	81.0 (73.7–87.0)

* PPV, positive predictive value; NPV, negative predictive value; LR (+), positive likelihood ratio; LR (–), negative likelihood ratio; CI, confidence interval; NE, not estimable; RUQ, right upper quadrant; LUQ, left upper quadrant. Exact Clopper-Pearson confidence intervals are reported for proportions. The underlying true-positive, false-negative, false-positive, and true-negative counts are presented in **Table 3.**

The contingency table underlying the overall patient-level diagnostic performance measures is presented in **Table 2.**

Table 2. Patient-level 2×2 contingency table for tele-guided eFAST compared with expert-performed eFAST.

	Expert-performed eFAST positive	Expert-performed eFAST negative
Tele-guided eFAST positive	56	22
Tele-guided eFAST negative	6	63

* Overall eFAST positivity was defined as the presence of at least one positive finding in any examined anatomical region. The tele-guided result represents the final interpretation made by the remote emergency physician.

Region-Specific Paired Results

Region-specific paired results are presented in **Table 3**. The highest number of true-positive findings was observed in the right upper quadrant, with 45 concordant positive examinations. False-positive findings occurred most frequently in the left upper quadrant (n=8), followed by the right upper quadrant (n=6) and cardiac view (n=5). False-negative findings were uncommon and ranged from zero in the cardiac view to three in the left upper quadrant.

Table 3. Region-specific paired results of tele-guided eFAST compared with expert-performed eFAST.

Anatomical Region	Expert+/ Tele+(TP)	Expert+/ Tele–(FN)	Expert–/ Tele+(FP)	Expert–/ Tele–(TN)
RUQ	45	2	6	94
LUQ	28	3	8	108
Pelvic	12	2	4	129
Cardiac	5	0	5	137
Lung	3	1	2	141

*TP, true positive; FN, false negative; FP, false positive; TN, true negative; RUQ, right upper quadrant; LUQ, left upper quadrant. Tele-guided eFAST results represent the final interpretations made by the remotely located emergency physician.

DISCUSSION

The rapid identification of life-threatening thoracic and intra-abdominal injuries remains a central component of trauma care. eFAST provides a rapid, repeatable, and non-invasive bedside assessment, but its performance is highly dependent on image acquisition and interpretation skills.[3,16-19] In this prospective study, we evaluated a synchronous tele-ultrasound model in which paramedics without previous ultrasound experience acquired eFAST images under real-time guidance, while the final interpretation was made by a remotely located emergency physician. The principal findings were high region-specific diagnostic performance compared with expert-performed eFAST, lower specificity when results were aggregated at the patient level, and clinically relevant technical connection failures despite examinations being conducted in a fixed emergency department environment.

An important feature of the present study is the separation of local image acquisition from remote interpretation. The paramedics were responsible for probe manipulation and obtaining the required views, whereas the remote emergency physician made the final positive or negative decision for each anatomical region and for the overall examination. Therefore, the reported results reflect the performance of the complete tele-guided system rather than the independent diagnostic performance of the paramedics. This distinction is important when considering implementation, training requirements, and the transferability of the findings to other tele-ultrasound models.

When the five anatomical regions were evaluated separately, sensitivity ranged from 75.0% to 100.0% and specificity ranged from 93.1% to 98.6%. At the patient level, tele-guided eFAST correctly identified 56 of the 62 patients classified as positive by expert-performed eFAST, resulting in a sensitivity of 90.3%. However, 22 of 85 expert-negative patients were classified as positive by tele-guided eFAST, resulting in a specificity of 74.1%. These performance estimates represent comparison with expert-performed eFAST, which served as the study reference examination. They should not be interpreted as diagnostic accuracy against computed tomography, operative findings, or subsequent clinical follow-up.

The difference between the high region-specific specificity and the lower patient-level specificity is partly explained by the classification rule used in this study. A patient was considered eFAST positive when at least one of the five anatomical regions was interpreted as positive. Consequently, a single false-positive regional finding resulted in a false-positive patient-level classification. Region-specific paired results showed that false-positive findings occurred most frequently in the left upper quadrant, right upper quadrant, and cardiac views. The greater number of positive findings reported during tele-guided examinations compared with expert-performed eFAST may indicate a tendency to overinterpret subtle or equivocal findings during remote guidance.

The 22 false-positive patient-level results have potential clinical implications. In practice, a false-positive tele-guided eFAST result could contribute to unnecessary advanced imaging, trauma-team activation, interfacility transfer, resource utilization, or inappropriate escalation of care. Although trauma evaluation often prioritizes the avoidance of missed life-threatening pathology, the consequences of reduced specificity should not be underestimated. Tele-guided eFAST findings should therefore be interpreted together with the overall clinical assessment and should not serve as the sole basis for invasive intervention or definitive disposition decisions.

Previous studies have demonstrated that real-time tele-ultrasound can support image acquisition by non-expert operators in emergency, prehospital, remote, and transport settings.[4,10-15] The present study adds to this literature by evaluating a paired examination protocol in actual trauma patients rather than exclusively in simulation models or healthy volunteers. Real trauma patients may present challenges such as pain, limited cooperation, restricted positioning, and time-sensitive clinical priorities. Conducting the study in this population therefore improves its clinical relevance, although the controlled emergency department setting differs substantially from an ambulance or field environment.

The paramedics completed an eight-hour training programme consisting of four hours of theoretical instruction and four hours of practical training. The findings suggest that a structured introductory programme combined with real-time expert guidance may permit inexperienced operators to acquire diagnostically useful views. However, no formal competency examination was performed before patient enrolment, and the number of supervised practice examinations completed during training was not recorded. In addition, individual operator identifiers and the number of examinations performed by each paramedic were not available in the final analytical dataset. Operator-specific differences and a possible learning effect from repeated exposure to remote guidance could therefore not be evaluated. These factors should be considered when designing standardized training and quality-assurance pathways for future tele-ultrasound programmes.

Technical connectivity was a major determinant of feasibility. Following the exclusion of patients with hemodynamic instability or penetrating trauma, tele-ultrasound was attempted in 167 patients. A technically adequate connection was established in 153 cases, corresponding to a connection success rate of 91.6%, while 14 cases experienced connection-related failure. These failures included image freezing or delay, inability to transmit the ultrasound image, interruption of audio communication, platform or device failure, and termination of an examination following connection loss. The occurrence of an 8.4% connection-failure rate in a fixed hospital environment raises concern that technical limitations may be more pronounced in moving ambulances, rural areas, disaster zones, or locations with unstable mobile network coverage. Previous work involving image transmission from moving ambulances also emphasizes the importance of network reliability and system robustness.[14]

The protocol imposed a maximum duration of five minutes for tele-guided eFAST to minimize disruption of routine trauma care. However, individual examination durations were not prospectively recorded. The five-minute period should therefore be interpreted as a predefined protocol limit rather than a measured examination-time outcome, and the present study cannot determine the mean, median, or variability of examination duration. Future studies should prospectively record acquisition time, interruption time, and total remote-consultation time to more completely evaluate workflow feasibility.

Beyond diagnostic support, synchronous tele-ultrasound may have educational value because the local operator receives immediate feedback during image acquisition.[12] Nevertheless, educational benefit and improvement over time were not formal outcomes of this study. Future investigations should incorporate standardized competency assessments, predefined minimum training volumes, operator-level analyses, and prospective learning-curve evaluation.

Limitations

Several limitations should be considered when interpreting the findings. First, this was a single-center study performed in a controlled emergency department environment. The results may not be generalizable to moving ambulances, disaster settings, rural locations, or other prehospital environments in which vibration, noise, limited space, lighting conditions, patient access, and network instability may affect image acquisition and communication.

Second, expert-performed eFAST was used as the study reference examination. Computed tomography, operative findings, and clinical follow-up were not used as definitive diagnostic reference standards. Accordingly, the reported sensitivity, specificity, predictive values, and accuracy represent comparison with expert-performed eFAST rather than diagnostic accuracy against definitive traumatic diagnoses. The expert performing the study reference examination was also not blinded to the clinical presentation because the examination was conducted as part of routine care.

Third, the number of positive cardiac and lung findings was small, resulting in wide confidence intervals and limited precision for these anatomical regions. Fourth, detailed baseline variables, including trauma mechanism, body mass index, injury severity score, complete admission vital signs, and final clinical or radiological diagnoses, were not prospectively collected in the study dataset. This limited detailed characterization of the study population and prevented clinically relevant subgroup analyses.

Fifth, the number of examinations performed by each paramedic was not available, preventing operator-specific performance analysis and formal evaluation of a learning effect. The number of supervised practical examinations completed during the training programme was also not recorded, and no formal competency assessment was performed before patient enrolment. Sixth, individual examination durations were not recorded; therefore, the distribution and variability of examination times could not be assessed.

Seventh, a separate indeterminate category and a standardized image-quality grading scale were not used in the final dataset. A binary positive or negative result was available for all five anatomical regions in the 147 completed examinations, whereas examinations that could not be completed according to the study protocol were excluded before analysis. The specific reasons for non-completion in six cases were not separately recorded. Finally, connection-related failures occurred in 14 of 167 attempted cases. The exclusion of these technically unsuccessful or incomplete cases from the diagnostic performance analysis may result in performance estimates that apply primarily to examinations in which adequate connectivity and examination completion were achieved.

CONCLUSION

In a controlled emergency department environment, paramedics without previous ultrasound experience were able to acquire eFAST images under real-time remote guidance, with final interpretation provided by an experienced remote emergency physician. Tele-guided eFAST demonstrated high region-specific diagnostic performance when compared with expert-performed eFAST. However, patient-level specificity was lower, and 22 false-positive results were observed, emphasizing that tele-guided eFAST should be integrated with clinical assessment rather than used as an isolated basis for definitive management decisions.

The findings represent comparison with expert-performed eFAST and not diagnostic validation against computed tomography, operative findings, or clinical follow-up. In addition, connection-related failures occurred despite the controlled hospital setting. Reliable connectivity, standardized training and competency assessment, prospective image-quality evaluation, and clear communication protocols are therefore essential for future implementation. Studies conducted in moving ambulances and actual prehospital environments, together with external validation in different EMS systems, are required before routine prehospital use can be recommended.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was approved by the Balikesir University Clinical Research Ethics Committee on 19 April 2023 (Approval No. 2023/45). Patient recruitment commenced on 1 June 2023, after ethics committee approval had been obtained.

Informed Consent: Informed consent was obtained from all the subjects involved in the study.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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