Military Use of Point of Care Ultrasound (POCUS)

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Disclosures: The views expressed are solely those of the authors and do not reflect the official policy or position of the US Army, US Navy, US Air Force, the Department of Defense, or the US Government. The authors have no financial relationship relevant to this article to disclose.

Funding: Defense Health Agency J9

This research was supported in part by an appointment to the Postgraduate Research Participation Program at the U.S. Army Institute of Surgical Research administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and USAISR.

Abstract

Background

POCUS offers multiple capabilities in a relatively small, lightweight device to military clinicians of all types, and levels in multiple environments. Its application in diagnostics, procedural guidance, and patient monitoring has not been fully explored by the MHS. The purpose of this narrative review of literature was to examine the overall use of POCUS in military settings, as well as the level of ultrasound training provided.

Methods

Studies related to use of POCUS by military clinicians, with reported sensitivity/specificity, accuracy of exam, and/or clinical decision impact met inclusion criteria. After initial topical review, and removal of duplicates, two authors selected 16 papers for inclusion consideration. Four of the authors reviewed the 16 papers and determined the final inclusion of 13 studies.

Results

We identified six prospective studies, of which two used randomization of subjects to groups. Five reports described use of POCUS in patients; two used healthy volunteers; two were in simulation training environments; three used animal models to simulate specific conditions; and one used a cadaver model. Clinician subjects ranged from one to 34. Conventional medics were subjects in five studies and four studies included special operations medics. One study included non-medical food service inspectors. The use of ultrasound in theater by deployed consultant radiologists is described in three reports.

Conclusion

The body of evidence related to the use of POCUS by military clinicians is limited, but does provide proof of concept. More research with larger sample sizes and evaluation of patient outcomes is needed

Introduction

Ultrasound has long been used for trauma assessment in the initial evaluation of patients with suspected blunt trauma. The focused assessment of sonography for trauma (FAST) assesses for intra-abdominal, intra-thoracic, and pericardial injury. Recently the Extended FAST (EFAST) added the lungs to the exam. The FAST/EFAST have become standard of care in trauma resuscitation and have been associated with decreased time to intervention, length of stay, cost, and complications.[1,2] The utility of the EFAST exam in the prehospital setting is described as, facilitating early diagnosis and interventions such as needle decompression for pneumothorax, as well as informing evacuation priority.[2,3,] There are many other uses for POCUS, including musculoskeletal to evaluate for the presence of fracture, or foreign bodies; to increase accuracy in vascular access, and airway procedures; [4] as well as focused cardiac ultrasound (FoCUS)[5] for decision making in cardiac arrest. Emergency ultrasound cannot replace a thorough history and exam, but may quickly answer specific questions and support decision-making. [2,3]

Ultrasound technology has the potential to improve diagnostic accuracy and enhance patient care in emergency medicine, and the prehospital austere setting.[2,3,7,8] Diagnostic capabilities in the combat setting may be limited, without X-ray or computed tomography (CT). Portable ultrasound can be used from point of injury forward to provide support for clinical decision making by military clinicians. The Defense Advanced Research Project Administration (DARPA) awarded a grant for the development of a portable ultrasound for battlefield use in 1996. SonoSite (formally SonoSight) collaborated with the University of Washington to develop one of the first handheld ultrasound devices. In addition, several other companies began making portable ultrasound devices for civilian use.[9]

Rozanski et al.[10] describe the early use of the SonoSite 180 Plus by the US Army's 21st Combat Support Hospital (CSH) North facility in northern Iraq over a 6 month period. Multiple physician specialties performed 401 exams effectively and efficiently. The most common exam types were renal (n=174), FAST (n=69), nontrauma abdominal (n=44), and obstetric (n=40). They found the device to be versatile and reliable with clear and interpretable imaging. The use of portable ultrasound increased local diagnostic capabilities, decreased unnecessary evacuation and was considered greatly beneficial to the far forward-deployed CSH.[10]

Military emergency medicine residency programs have incorporated extensive ultrasound training into the curriculum, and in 2009 a one-year emergency ultrasound fellowship was established and is now available at three military locations.[11] In 2011, the Joint Special Operations Medical Training Center (JSOMTC) began to incorporate a 24-hour ultrasound curriculum [Special Operators Clinical Level Ultrasound (SOLCUS) training] with didactic and hands-on training for special operations medics.[12] The Special Operations Medical Community values ultrasound as a diagnostic tool, and emphasizes the potential role of POCUS in prolonged field care.[13] The SOLCUS education project was begun to provide open-access online resources to accompany hands-on training (https://sofsono.org/).[13] The curriculum is based on the American College of Emergency Physicians (ACEP) recommendations for training of emergency physicians on emergency ultrasound. The SOLCUS program focuses on the EFAST exam and includes, ocular, musculoskeletal, and soft tissue scans, as well as assessment for thrombosis.[12,13] Soon after the implementation of the SOLCUS training, the 1st Battalion, 3rd Special Forces Group (Airborne) SFG(A) deployed to Afghanistan, with nine portable ultrasound machines. Morgan et al. provide an anecdotal report of the experiences of 29 18Ds who evaluated 109 patients using POCUS. The most common exams were for musculoskeletal issues (n=39), and FAST for abdominal trauma (n=34).[12]

POCUS offers multiple capabilities in a relatively small, lightweight device to military clinicians of all types, and levels in multiple environments. Its application in diagnostics, procedural guidance, and patient monitoring has not been fully explored by the MHS. The purpose of this narrative review of literature was to examine the overall use of POCUS in military settings, as well as the level of ultrasound training provided.

Methods

We searched PubMed, Cochrane, Scopus, Web of Science, and the Defense Technical Information Center databases using the key terms military and ultrasound. Studies related to use of POCUS by military clinicians, with reported sensitivity/specificity, accuracy of exam, and/or clinical decision impact met inclusion criteria. After initial topical review, and removal of duplicates, two authors reviewed 40 full-text publications and selected 16 papers for inclusion consideration. Four of the authors reviewed the 16 papers and determined the final inclusion of 13 studies. Authors excluded reports that did not report sensitivity/specificity, accuracy of exam, and/or clinical decision impact, as well as literature reviews. We rated the studies using the Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence.[14]

Results

Thirteen studies (See Table 1) met the inclusion criteria, however due to variance among study types, reported results, and levels of evidence; a meta-analysis was not attempted. We identified six prospective studies,[15-17,23-25] of which two[15,17] used randomization of subjects to groups. Five reports[22,23,25-27] described use of POCUS in patients; two[18,20] used healthy volunteers; two[15,24] were in simulation training environments; three[16,19,21] used animal models to simulate specific conditions; and one[17] used a cadaver model. Numbers of clinician subjects ranged from one to 34. Conventional medics were subjects in five studies[15-19] and four studies[19-22] included special operations medics. One study included non-medical food service inspectors.[19] The use of ultrasound in theater by deployed consultant radiologists is described in three reports.[25-27] The levels of evidence ranged from two to four, from a prospective randomized trials[15,17] to a case study with four patients.[22]

Training

Training for five[17-20,27] of the included studies ranged from three to 25 minutes and included a brief lecture, or slide show, followed by hands-on practice. Five studies[15,16,19,23,24] reported training ranging from 90 minutes to four hours that also included didactic instruction followed by hands-on practice. One study reported results after completion of the SOLCUS course by special operations medics. Participants attended various components (8 to 52 hours, mean of 16.7 hours) of the SOLCUS training, prior to deployment.[22] With the exception of the three reports[25-27] on radiologists, all participants had no to little prior ultrasound experience. These studies demonstrate the ability of ultrasound naïve clinicians to successfully perform specific ultrasound exams with minimal training and practice.

Utilization by Military Medics and Other Non-physicians

Conventional Army Medics were the subjects of three prospective studies[15-17] The medics in these studies had no prior experience or training with ultrasound. After completion of a 4-hour EFAST training, when compared to emergency medicine residents, medics took longer to complete the EFAST exam (532 vs. 227 seconds); but had similar diagnostic accuracy when comparing sensitivity (Medics 88-95%, Residents 92-95%).[15] Twenty-eight medics completed a 2-hour training, and identified foreign bodies in a soft tissue model with sensitivities of 73% and 78% (size dependent), and specificity of 78%.[16] A cadaver model was used to evaluate the ability of medics to detect endotracheal tube placement, after a 15-minute lecture and hands-on practice. Cadavers were randomly assigned to esophageal or tracheal tube placement for 32 participants. In an average time of 47.3 seconds, medics correctly identified tracheal placement at a rate of 72% and esophageal placement at 71%.[17] Backlund et al.[18] conducted a pilot study to assess the ability of 12 Army National Guard medics to determine cardiac activity in healthy volunteers, after a 5-minute lecture and brief hands-on training. In this pilot study, 92% of the exams accurately documented the presence of cardiac activity with a mean time to completion of 5.5 seconds.[18]

Two early publications report the ability of **special operations medics** to detect fracture in a simulated model,[21] and in four human cases.[22] Twenty Army SOF medics with minimal to no previous US experience completed a 3-minute training, and correctly identified presence or absence of long bone fracture in a simulated model (Sensitivity 100%, Specificity 90%).[21] US Army Special Forces medics deployed to Afghanistan evaluated 109 patients using POCUS, after completion of an average of 16.7 hours training in the SOLCUS curriculum. Medics applied their SOLCUS training in four cases, and in all cases correctly diagnosed fractures (femur, distal fibular, phalanx, tibial) which were later confirmed by X-ray.[22] In a prospective study,[20] 23 special operations medic trainees underwent training to measure the optic nerve sheath diameter (ONSD) in healthy volunteers and compared their measurements to those of emergency medicine physicians. After undergoing a 5-minute lecture and demonstration, medic trainees reported similar measurements in comparison to emergency medicine physicians (mean physician = 0.465mm vs. mean trainees = 0.459 mm, $p = 0.76$).[23] Twenty-two physician assistants, special operations and conventional medics, veterinary technicians, and food service inspectors (numbers of each group not specified) were able to accurately detect pneumothorax in a porcine model, after a 10-minute slide show and brief orientation to ultrasound equipment. These ultrasound naïve participants correctly identified 21 of 22 pneumothoraces achieving a sensitivity of 95.5% and a specificity of 100%.[19]

Utilization by Military Physicians

Five studies[23-27] reported physician use of POCUS, one simulation study,[24] one in-garrison,[23] and three reports[25-27] of the use of ultrasound in the combat setting. Fifteen trainee physicians completed a 2-hour ultrasound course and were provided US devices to use at will, in a simulated combat setting. The participants performed EFAST/POCUS on 44 of 168 (26%) simulated patients and in 51% of US cases there was a significant impact on therapeutic and evacuation priorities. Therapeutic decisions changed in 67% of cases and evacuation priorities in 72% of cases.[24] Two military medicine residents performed POCUS on 48 patients in a French Army teaching hospital. POCUS improved diagnostic accuracy in 73% of cases.[23] Two studies reported the use of POCUS by radiologists, for 585 exams at a Role 3 MTF in Afghanistan. The reported FAST sensitivity was 56 and 75%; however, specificity reached 98 and 99%, with overall accuracy of 89 and 94.4%.[26,27] A prospective six-month survey of a consultant radiologist in a Role 2 MTF, where CT capability was not available, found POCUS increased diagnostic confidence in 68% of cases and led to change in patient management in 29% of cases.[25]

Discussion

The evidence related to the use of POCUS by military clinicians is limited. This literature review included 13 published studies with mostly moderate levels of evidence. The sample sizes were small and there was not enough duplication of findings for specific exams. However, the findings consistently demonstrate the ability of military clinicians from conventional medics to physicians to perform focused exams with moderate to high success. With minimal training, conventional medics can achieve acceptable sensitivity and specificity in FAST exams, and fracture detection. However, we found no published reports related to retention of knowledge and ability.

Conventional medics demonstrated less accuracy in the detection of foreign bodies, and confirmation of airway placement. Army Special Forces medics receive extensive training in POCUS, however only one study reported sensitivity (100%) and specificity (90%) in a simulated fracture model. Only two of five studies with physician subjects reported specificity and sensitivity. Military physicians report increased accuracy, and confidence in diagnoses, as well as impact on patient management. In-theater radiologists demonstrated an overall accuracy in FAST exams of 89 to 99% (specificity 98 to 99%); however, sensitivity was only 56 to 75%.[25,26]

The findings of our review specific to military clinicians are similar to previous literature reviews. Overall higher specificity verses sensitivity add support to the finding that POCUS has more utility in ruling in specific conditions than ruling out a condition. A systematic review of point-of-care ultrasound (POCUS) use in prehospital critical care included 27 studies and concluded POCUS is feasible and changes patient management in trauma, breathing difficulties and cardiac arrest, but it is unknown if this improves patient outcomes.[3] A Cochrane review specific to use of POCUS in diagnosing thoracoabdominal injuries in patients with blunt trauma included 34 studies with 8,635 participants. The report concluded that in suspected blunt thoracoabdominal trauma, positive ultrasound findings could help guide treatment decisions.[4] Netherton et al.[28] reviewed 75 studies on the diagnostic accuracy of the EFAST in the trauma patient, published between 1989 and 2017. The systematic review and meta-analysis suggested that EFAST was useful in ruling in pneumothorax, pericardial effusion, and intra-abdominal free fluid in trauma patients; however, the ability to “rule out” was not supported. Similar findings were reported in a review of six papers on military use of the FAST exam.[29]

More extensive reviews of POCUS in civilian settings provide additional evidence of the potential POCUS has to offer in military health care. The use of POCUS in the deployed setting has not been fully explored; however, the growing evidence in support of its utility warrants ongoing study. Research needs to address which applications have the most potential to improve outcomes in combat casualty care. Training guidelines and standards should be established to determine optimal course content, length, delivery method, and the minimum number of scans for each type to achieve competence. Evidence supports image acquisition and interpretation can be taught to medical novices; however, clinical background is important for appropriate patient management.[2] Future research should consider strategies to prevent skill decay and promote knowledge retention. Research to consider the role telemedicine can play to support prehospital POCUS, the logistics of image transmission and communication with higher-level providers is warranted. More research to determine sensitivity and specificity of various POCUS applications in the hands of military clinicians will inform best practices related POCUS.

Further investigation into which ultrasound machine is best suited for the combat environment is required. Portable ultrasound is lightweight, easy to carry, and has minimal power requirements when compared to portable x-ray, therefore increasing its utility in austere environments.[21] However, it is important to plan for anticipated conditions in the austere and resource constrained combat theater. Considerations for device selection include; performance at high altitudes, function in extreme temperatures, protection from moisture; ultrasound gel supply, storage, and response to extreme temperatures; battery life, condition, and supply; and overall ruggedness, and ability to withstand extreme conditions. SonoSite developed the first handheld device used by the military and the SonoSite M-Turbo was the most common device reported in the studies we reviewed. There are other devices (See Table 2) with potential utility in combat care. The end-users should be consulted to determine desired device characteristics. Research comparing available technology needs to be conducted.

Conclusion

The body of evidence related to the use of POCUS by military clinicians is limited, but does provide proof of concept. More research with larger sample sizes and evaluation of patient outcomes is needed.

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Table 1: Reports of Military Use of Ultrasound

Reference	Study Type & Aim	Subjects	Device	Training/ Intervention	Results	Conclusions	LOE
Monti et al.[15] 2020	Prospective, randomized, cohort study in the Medical Simulation Training Center at Joint Base Lewis McChord. The primary objective was to assess the impact of a 4-hour introductory training intervention on ultrasound-naïve military medic participants' knowledge/performance of the eFAST application.	34 Army medics naïve to US	Fukuda Denshi USA device with phased array (2-5 MHz) & linear array (5-12 MHz) transducer	Participants were randomized to receive either conventional, expert-led classroom didactic training or didactic training via an online, asynchronously available platform. Medic Cohorts: 1) 90 minute classroom didactic & 150 minutes hands-on scanning instruction (n=19) 2) 90 minute video from SonoSim & 150 minutes hands-on scanning instruction (n=15)	50 question knowledge assessment pre/post Medic overall knowledge increased from 27 to 83%. EM residents score 92%. There was no statically significant difference between knowledge, technical performance, or diagnostic accuracy between medic groups. The medics took more than double the time to complete the exams compared to EM residents (532 vs. 227 seconds). Hemoperitoneum Present Sensitivity: Medics 95%; EM residents 93%. Hemoperitoneum Absent specificity: Medics 90%; EM resident 95%. Hemopericardium Present Sensitivity: Medics 88%; EM Residents 92%. Hemopericardium Absent Specificity: Medics 60%; EM residents 100%.	A 4-hour introductory eFAST training intervention can effectively train conventional military medics to perform the eFAST exam. Combat medics (MOS 68 W) with no previous US training compared to EM physician residents (n= 20) with at least month-long emergency US rotation & performed minimum of 20 eFAST exams.	2
Driskell et al. [16] 2018	Prospective, single blinded, observational simulation to determine army medics' accuracy performing bedside US to detect radiolucent foreign bodies (FBs) in a soft-tissue hand model.	28 Army medics naïve to US	SonoSite M-Turbo with 13-6 MHz linear transducer	1 hour didactic & 1 hour hands-on training, used chicken model (chicken thigh in surgical glove), each medic was presented with	< 2 mm FB: Sensitivity 73%, Specificity 78% ≥ 2 mm FB: Sensitivity 78%, Specificity 78%	Army medics can detect FBs in tissue models with similar sensitivities and specificities as radiologists and emergency medicine physicians in similar studies.	2

				20 randomized models.			
Hanlin et al. [17] 2018	Prospective randomized trial to determine ability to detect endotracheal tube placement in a fresh human cadaver model.	32 Army Medics, recently completed EMT- B certification, enrolled in flight paramedic training	SonoSite M-Turbo with a 10-5 linear transducer	15-minute lecture on transtracheal US techniques, followed by hands-on practice	Sensitivity 66.7%, Specificity 76.4% Average time 47.3 seconds Correctly identified 13/18 tracheal placements & 10/14 esophageal placements	Trainees were moderately accurate when using transtracheal US to identify ETT placement after a short educational session.	2
Backlund et al. [18] 2010	Pilot study to assess ability of combat medics to perform a limited bedside echocardiography (BE) to determine cardiac activity in healthy volunteers.	12 Army National Guard combat medics trained to level of EMT-B	Not specified	Received 5 - min. lecture and brief hands-on training.	44 of 48 (92%) exams accurately documented presence of cardiac activity. Median time to completion – 5.5 seconds	With minimal training, the majority of the medics were able to rapidly perform a focused BE on live models that was adequate to assess for the presence of cardiac activity.	3
Monti et al. [19] 2009	Descriptive study to examine the potential for non-physician providers to determine the absence or presence of a pneumothorax in a porcine model, with the use of a portable ultrasound machine, after receiving minimal training.	22 participants (PAs, SOF & conventional force medics, veterinary technicians & food service inspectors) with no prior ultrasound training	SonoSite Vet (SonoSite 180 equivalent) with 10-5MHz linear transducer	Received 10 minute slide show training & orientation to ultrasound machine.	Sensitivity was 95.4% Specificity was 100% 21 of 22 pneumothoraces were correctly identified.	Non-physician healthcare providers can accurately detect a pneumothorax with portable ultrasound after receiving minimal focused training.	3
Betcher et al.[20] 2018	Proof of concept descriptive study to evaluate military trainees' ability to measure the optic nerve sheath diameter (ONSD) in healthy volunteers.	23 SOCM trainees during emergency medicine rotation with minimal prior training in US.	Mindray® M7	5 minute lecture, followed by demonstration & 20-minute practice	Compared trainee measurements to those of EM physicians: $M_{physician}$ = 0.465mm vs. $M_{trainees}$ = 0.459 mm, P =0.76.	This study demonstrates that optic nerve sheath diameter measurement can be accurately performed by novice ultrasonographers after a brief training session. If validated, point-of-care optic nerve sheath diameter measurement could	3

						impact the triage of injured patients in remote areas.	
Heiner et al. [21] 2010	Descriptive study - simulation to evaluate the ability of 18Ds to detect the presence of long bone fracture.	20 Army Special Forces (18Ds), had no or minimal prior use of ultrasound	SonoSite M-Turbo with 10-5 MHz transducer head	Received 3-min. orientation and training.	Sensitivity 100% Specificity 90% 5 fracture models (turkey legs) - 1 no fracture, 4 different fracture types	Using a portable ultrasound device, 18Ds were able to correctly detect the presence or absence of a simulated long bone fracture with a high degree of sensitivity and specificity.	3
Vasios et al. [22] 2010	Case Study to describe the use of portable US by 18Ds for fracture detection.	29 US Army Special Forces (18Ds) – 1st Battalion, 3rd Special Forces Group (Airborne) SFG(A) deployed to Afghanistan. 109 pts evaluated with ultrasound, 39 were musculoskeletal	Not specified	Received an average of 16.7 hours training using SOLCUS outline. Included FAST exam, pneumothorax detection & musculoskeletal exam.	4 cases presented – in all cases the medic correctly diagnosed fractures with ultrasound that were later confirmed by x-ray.	Hi-lights the potential role of the SOLCUS and the use of US by Special Operations Medics.	4
Perrier et al. [23] 2019	Prospective study to evaluate the usefulness of point-of-care ultrasound (POCUS) performed by young military medicine residents after short practical training in the diagnosis of medical emergencies.	2 military medicine residents in a French Army teaching hospital March 2015 – March 2016.	SonoSite M-Turbo	Received a 90 minute theoretical and practical (10 US in healthy students, 50 US in patients with symptoms, observed by trainer) US training focused on the gall bladder, kidney & upper urinary tract & the deep venous network of the lower extremities.	Did not report sensitivity & specificity. 48 patients had ultrasounds, 18 gall-bladder, 16 renal, 14 lower extremity. POCUS improved diagnostic accuracy in 73% of cases, was misleading in 2% and did not contribute to 25%.	POCUS performed after clinical examination increases the diagnostic accuracy of young military medicine residents.	4

Renard et al.[24] 2019	Prospective observational pilot study to evaluate whether the implementation of E-FAST was possible in conditions close to combat and if it changed the therapeutic and evacuation strategies.	15 trainee doctors during French pre-deployment simulation training	Vscan (GE)	MEDICHOS (medical courses in hostile environments) internship November 2017, March and June 2018; 2 hour training on the use of the Vscan & US devices were provided, trainees to use their discretion.	eFAST or POCUS exams performed on 44 of 168 (26%) simulated patients. 51% of US cases had a significant impact of therapeutic and evacuation priorities, it changed therapeutic decisions in 67% of time and evacuation priorities in 72% of time	US on the simulated battlefield was possible and useful. To confirm these results, ultrasound needs to be democratized and assessed in a real operational environment.	4
Sellon et al.[25] 2019	Prospective questionnaire-based (6 month) study aimed to assess the usefulness of departmental diagnostic US in the remotely deployed role 2 hospital setting.	Consultant radiologist at a Role 2 MTF - Op TRENTON 3	SonoSite M-Turbo with a 2.5 MHz convex probe and 10 MHz linear probe	41 departmental scans 28 July – 28 December 2017 by radiologist	In 28 of 41 (68%) cases US increased diagnostic confidence & 29% (12/41) led to a change in patient management. 1 (3%) had no clinical impact. Musculoskeletal exams had the greatest impact.	This study highlights the utility of this capability at role 2 , CT scan is not available.	4
Carter et al.[26] 2018	Retrospective record review to determine accuracy of FAST in the deployed environment.	3 consultant radiologists, deployed to the Role 3 MTF, Camp Bastion Jan. - May 2014.	SonoSite 4-6 MHz with curvilinear probe	Radiologists were embedded in the trauma bay.	187 FAST exams performed. 169 of 187 had subsequent laparotomy or CT full body trauma scan and were included in analysis. Sensitivity 75%, Specificity 99.3% Overall accuracy 94.7% ID of intraperitoneal free fluid - PPV 96.2% & NPV 94.4%	FAST provided by the integrated radiologist as part of damage control radiology, gives the team leader rapid diagnostic information to improve decision-making & ultimately patient outcomes in the combat MTF.	3
Smith et al.[27] 2015	Retrospective review of registry data to determine use and accuracy of FAST and CT	Attending radiologist at Role 3 MTF, Camp Bastion July – Nov 2012	Not specified	Attending radiologists	468 casualties, 85% underwent FAST & 86.1% had CT, 34% had abdominal injury Detection of intra-abdominal injury; FAST: sensitivity 56%, specificity 98%, PPV 87%, NPV 90%, accuracy 89%	FAST & CT were useful in resuscitation care at Role 3, to enhance diagnostic sensitivity and specificity in battlefield injuries. FAST should be available in the	

					CT: sensitivity 99%, specificity 99%, PPV 96%, NPV 100%, accuracy 99%	absence of CT capability. The use of radiologists for FAST can free emergency MD to focus on other aspects of care.	

Table 2: Portable Hand-Held Devices

Model	Features	Size	Weight	Transducers
GE Healthcare Vscan Extend	Handheld device with dual-headed probe, store images through Wi-Fi or USB, 60-minute continuous scanning on full charge, online apps available to augment studies, educational videos available, requires gel https://www.gehealthcare.com/products/ultrasound/vscan-family	Device: 170 · 78 · 21 mm (6.6 · 3.0 · 0.8 in); Dual Probe: 12.9 · 3.9 · 2.8 cm (5.1 · 1.5 · 1.1 in)	Device: 365g (0.7 lbs); Dual probe: 120 g (0.3 lbs) Sector probe 85g Main unit with Dual probe 400g	Two transducers in one probe: linear and sector
SonoSite iViz	Durable aluminum tablet with multiple transducers, cloud storage, and 64 GB flash drive, three swappable batteries each with 1 hour continuous scan time, embedded educational tools, requires gel **Uses aircraft aluminum, can be dropped up to 3 feet** **IPX-7 rated – fully submergible in water** https://www.sonosite.com/	Tablet: 18.3 · 11.7 · 2.7 cm (7.2 · 4.6 · 1.1 in)	Tablet: 570 g (1.1 lbs)	Curved C60v, Linear L25v, Linear L38v, Phased P21v
Philips Lumify	Transducers attach to android devices, app-based, uses tablet as a power source, no long-term commitment, battery life depends on attached device, requires gel App based, transducers plug into devices, how-to videos Lumify System Bundle includes device https://www.usa.philips.com/healthcare/sites/lumify	Curved transducer: 4.5 · 11.4 cm (1.8 · 4.5 in)	Curved transducer: 136 g (0.3 lbs)	Linear L12–4, Curved C5–2, Phased S4–1
Butterfly iQ	Transducer attaches to Apple mobile devices, built-in battery, wireless charging, unlimited cloud storage, uses silicon chip, does not use Piezo crystal technology, 2 hours of continuous scanning on full charge, **no gel required** **Anodized aluminum body, thermally efficient,** educational videos available https://www.butterflynetwork.com/	Transducer: 185 – 56 – 35 mm (7.2 · 2.2 · 1.4 in)	Transducer:313g (0.7 lbs)	Single transducer emulates any kind of transducer
Clarius C3 Convex	App based, wireless, does not require internet access to operate Handheld device with 3 probes in 1, works on iOS and android. educational videos available **Has magnesium shell, waterproof & withstands drops up to 1 meter**, 60 min battery power, 3 swappable batteries 2 – 6 MHz, max depth 32cm https://clarius.com/	Device: 167 – 99 - 42 mm (6.6 – 3.9 – 1.6 in)	Device: 540g (1.2 lbs)	Three clip-on tips to scan entire body

Adapted from Canepa and Harris (2019).[2]