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Ultrasonography Use in Emergency Health Services

Acil Sağlık Hizmetlerinde Ultrason Kullanımı

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Abstract

Ultrasonography (US) technology, which is currently used to facilitate the diagnosis and treatment of myriad conditions, was introduced into the field of medicine in 1940s. US has been increasingly spreading to nearly all branches of medicine in proportion to the developments in US technology. Therefore, pre-hospital emergency healthcare providers routinely use small size portable devices, even in ambulances, during the transfer of patients from the field to the hospital, which reduces the diagnosis and triage time of the patients and increases the survival rates relatively. However, due to the lack of necessary training activities, proper use of US devices constitutes a professional challenge for pre-hospital emergency healthcare providers. Although there are some in-service training programs targeting the use of US, a more functional and ideal approach should be to integrate both the theoretical and practical knowledge pertaining to US into the educational curricula of the related departments in the universities. A possible program should be mainly pragmatic by focusing on the life-threatening conditions in the pre-hospital area.

Key Words: Emergency Health Care, Pre-hospital, Ultrasonography

Öz

Halen sayısız durumun teşhis ve tedavisini kolaylaştırmak için kullanılan ultrasonografi (US) teknolojisi, 1940'larda tıp alanına girmiştir. US teknolojisindeki gelişmelerle orantılı olarak tıbbın neredeyse tüm branşlarında giderek yaygınlaşmaktadır. Bu nedenle, hastane öncesi acil sağlık hizmeti sağlayıcıları, hastaların alandan hastaneye nakledilmesi sırasında ambulanslarda bile çoğunlukla küçük boyutlu taşınabilir cihazları rutin olarak kullanmakta, bu da hastaların teşhis ve triyaj süresini azaltıp, hayatta kalma oranlarını nispeten artırmaktadır. Bununla birlikte, gerekli eğitim faaliyetlerinin eksikliğinden dolayı, US cihazlarının uygun şekilde kullanılması, hastane öncesi acil sağlık hizmeti sağlayıcıları için profesyonel bir zorluk teşkil etmektedir. US kullanımını hedefleyen bazı hizmet içi eğitim programları olmasına rağmen, daha işlevsel ve ideal bir yaklaşım, US alanında hem teorik hem de pratik bilgilerin üniversitelerdeki ilgili bölümlerin eğitim müfredatlarına entegre edilmesi olmalıdır. Hastane öncesi alandaki yaşamı tehdit eden koşullara odaklanması beklenen bu türde hazırlanacak olası bir program esas olarak pragmatik olmalıdır.

Anahtar Kelimeler: Acil Sağlık Bakımı, Hastane Öncesi, Ultrasonografi

Introduction

Ultrasound technology is one of the most important reflections of engineering science in the medical field and was initially used for a device developed to detect submarines. It was Pierre Curie in 1880, who first demonstrated the use of sound reverberation (1). Then, the data obtained by the propagation, refraction, reflection, and absorption of sound in an environment were used in Sound Navigation and Ranging (SONAR) devices. SONARs are devices used to locate other marine vehicles and creatures underwater.

Ultrasonography in Medicine

Since the 1940s, ultrasonography (US) has been used in medicine. The medical US device used for diagnosis and treatment uses US waves that are beyond the sensitivity of the human ear. In 1942, Austrian Karl Theodore Dussik first used a medical US device for displaying brain ventricles and

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brain tumors for diagnostic purposes (2). In 1948, the first US congress (Congress of Ultrasound in Medicine) was held in Germany (3,4). Douglas Howry developed a new technique and found Brightness-Mod (B-Mod) imaging. The first studies on the heart were carried out in 1953 by Wolf Dieter Keidel. In 1960 and 1970, great advances were made in the field of US and the Doppler imaging mode, aimed at sensing the blood flow of the heart at a different depth, was developed by Don Baker, Dennis Watkins and John Reid. The World Federation for Ultrasound in Medicine and Biology was established in 1967 (2).

US in Emergency Medicine

The US device, which entered in the medical field during 1940s, began to be used in emergency in the 1980s, when emergency medicine (EM) was not yet defined as a separate branch of medicine in Turkey (2). First of all, EM specialization training was defined in the United States of America (USA) as an independent one from other branches in 1960 (5). In 1961, the first emergency medical specialist was trained. In 1979, EM Specialization was accepted as a separate branch specialty by the American Specialization Board (5). Emergency Medical Specialties was added to the Regulation of Specialties in Medicine in Turkey for the first time with the title of "First and Emergency Aid" in 1993. The first Department of EM in Turkey was established in 1993 at İzmir Dokuz Eylül University (6).

In 1970, Goldberg et al. (7) revealed that intraperitoneal fluid can be recognized by US device in their study after giving fluid into the peritoneum on the cadaver. In 1980s, the use of US in trauma patients in Germany began to replace Deep Peritoneal Lavage and gained widespread popularity (8). In the early 1990s, the use of US became more widespread among trauma surgeons in the USA, and US training to evaluate trauma patients accelerated.

The first review on the principles of US use in EM was published by Dave Plummer in 1989 (9). In the same year, Jehle et al. (10) published their positive experiences in their own emergency room (ER) related to bedside US (cardiac, biliary, vascular, and gynecological). James Mateer is the father of bedside US training for EM professionals in America (11). Publications about the use of US in blunt trauma patients began to emerge in some other countries including Turkey in the 1990s (12). In 1990, American College of Emergency Physicians (ACEP), published a statement supporting the use of US by trained emergency physicians (EP) and started a 2-day bedside US course for a total of 16 hours (13). In 1994, the first Emergency Ultrasound Education Curriculum was published (14). In 1995, Focused Abdominal Sonography in Trauma (FAST) protocol was included into the algorithm of evaluation of the patient with abdominal trauma by the American College of Surgeons (11). After a short time, extended FAST (e-FAST) was formed with the addition of lungs to the FAST administration protocol (15). The book "Ultrasound in EM" for EM was first published in 1995 by Michael Heller and Dietrich Jehle. In 2002, the more comprehensive "Emergency Ultrasound" book, also defining Point of Care US (POCUS) was published by O. John Ma and James Mateer (11). In 1992, French intensive care specialist Daniel Lichtenstein published his book "L'echographie generalle en reanimation" about the use of US in critical patient care (11). The second edition of the book was translated into English and published in 2004 under the name "General US in the Critically ill" (11). Lichtenstein became one of the organizers of the "the First World Congress on Ultrasound in Emergency and Intensive Care", hosted in Italy in 2005 by World Interactive Network Focused on Critical Ultrasound (WINFOCUS) (11).

The first bedside US course in Turkey (15 hours, 2 days) was held in İzmir in 2003 (11). After this date, POCUS courses were started to be given to intensive care, and a large number of physicians in dealing other branches by Turkey EM Association (EMAT) and EP Association of Turkey (EPAT), and these courses are still given. In light of the developments, practical use of bedside US of EM specialists in the emergency departments (EDs) in Turkey has started and spread over time. Today, interest in this issue is increasing and the use of US continues to become widespread in EDs. In 2016, a website was established by EMAT, where US training and case videos, guides and articles about the use of US in EM were published, and training courses were announced (16). Also, in 2016, a website containing online US courses was established by EPAT (17).

In this way, US, whose importance and use continue to increase rapidly, has started to be used in emergency health services, hospital emergency services, and even in the pre-hospital area, in an ambulance, and its use in these areas is gaining speed (18).

There is a close relationship between the prevalence of the use of the US device in patient imaging in EM and the features of the device. US is a safe and fast imaging technique. With the development of technology day by day, the production of cheaper, smaller, more portable devices has increased the use of these devices for bedside imaging in emergency services. While the patients were directed to the radiology units where the US device was previously used for US imaging, with the advancement of the technology, the US device can now be brought to the patient and bedside imaging can be performed without patients having to leave the emergency critical care room. Especially in critical patients, the use of US is of great importance in reaching the correct diagnosis and providing effective treatment in a short time. In addition, as not containing ionizing radiation and only using sound waves, it does not require contrast agent for imaging and is reproducible; US device, which has become an indispensable tool for most ED in the differential diagnosis of

both traumatic and hypotensive, unstable patients, provides early diagnosis and early treatment. Since the 1980s, EPs have been performing bedside US and increasing their experience and knowledge in this field (2).

US in Pre-hospital Area

US devices have been used in the evaluation of critical patients in the pre-hospital area as they have become portable even fit in a pocket and connectable to mobile phones. These technological developments have enabled the use of them for pre-hospital cases such as disasters and multiple injuries. Physicians, military and emergency medical staff use the US to diagnose pathologies such as pleural, peritoneal and pericardial effusion and deep vein thrombosis in patients on the field (18,19). In 1998, French intensive care specialists first reported that portable US units can be installed in helicopters for patient examination (20). In 2000, the interaction of US within air electronic equipment was examined, and the investigation in usability of it in helicopters revealed no technical obstacle (21). Physicians, flight nurses and US technicians were able to perform FAST in the helicopter. Thus, FAST application was the first usage in the pre-hospital emergency health services (pre-hos EHS), as in the EDs. The US was first used in ambulances in pre-hos EHS in Odessa, Texas, in 2000. Later, pre-hos EHS in Keller (Texas), Littleton (Colorado), Temple Terrace (Florida), San Antonio (Texas), San Antonio Airlife (Texas), Starflite Austin (Texas), Lifelink III (Minnesota) and many more centers used US. In Germany, the German Air Rescue Organization (Deutsche Rettungsflugwacht) and many land-based ambulance services (Darmstadt and Frankfurt/Main) have included US in patient management algorithms in the field since 2002-2003. In these centers, teams consist of EPs and paramedics. In Italy, it has been comprised in pre-hos EHS since 2005 (22).

In America (Portland, Ohio and Minnesota), the use of US has been recognized and applied in many helicopter emergency health services. In the USA, Germany, France, Italy and some other countries, it has been accepted in ambulance services. In the USA, pre-hos EHS are frequently provided with non-physician teams and the patient is targeted to transfer from the field (on-scene) to the ER as soon as possible. However, in some other countries (Germany, France, Italy), more time is spent in the field by pre-hos EHS, as patient management initiates and continues on-scene, and physicians are mostly part of the team. Therefore, the widespread use of US in a country is closely related to the pre-hospital organization model (scoop and run-cap take/stay and play-stay) that the country chooses. In Germany, in the field US has focused on FAST administration and cardiac US imaging, even in patients without trauma. There are portable US devices in both helicopter ambulances and land ambulances in Milan to evaluate three serious clinical conditions: cardiac arrest, torso (bodily) trauma and acute dyspnea. Pre-hospital US (PHUS) is decisive in the diagnosis of reversible causes of pulseless electrical activity (PEA), in the evaluation of the presence of intraperitoneal, pericardial and pleural fluid in trauma and in the differential diagnosis of pulmonary edema and emphysema in a patient with respiratory distress (22). When multiple B-lines (≥3) on lung ultrasound are visualized on multiple locations in the anterior and lateral chest, it is diagnostic of the interstitial syndrome (23,24).

Pre-hospital Emergency Services in Turkey

When we review the pre-hos EHS in Turkey, ambulance service commenced in 1986 named as in original "Hızır Acil Servis" (Hızır Emergency Service). The patients were transported by ambulance in İstanbul, Ankara and İzmir. In 1994, "Hızır Emergency Service" gained a new identity and became "112 Acil Yardım ve Kurtarma" (112 Emergency Assistance and Rescue). On November 5, 1995, 112 was accepted as the formal emergency call number for health of Turkey. First Aid and Emergency Health Services Department was established in 1997, and in 2008, it was combined with Department of Health Services for Emergency and Disasters and became Department of Health Services for Emergency and Disasters. With the Legislative Decree issued in 2011, a management plan was created at the level of the General Directorate of Emergency Health Services (6).

Regarding the US in pre-hospital in Turkey, although there are publications researching the achievement of US paramedics in the field in literature, US has not yet started to be used in pre-hos EHS. However, US trainings are sometimes provided for personnel working in pre-hos EHS. A US course for nurses working in the ED was conducted in Ege University in 2018 (16). Moreover, at North Cyprus Emergency Medical Services (EMS) and First Aid Symposium conducted on 28 May 2019, trainers of Emergency Medical Association Ultrasound Working Group (EMATUS) held the first US course for paramedics (16). For the 112 emergency medical personnel working in the Ministry of Health of Turkey, the first formal US training in the pre-hospital US use in the field was organized at Sivas Numune Hospital under the guidance of the Sivas Provincial Health Directorate on December 14-15, 2019 in Sivas by 2 EM specialists who are the members of EMATUS and the authors of the present review, and by a radiologist (8 hours theoretical, 8 hours practical, 2 days) (16,25). In 2020, a US study group was first established by these authors within the Paramedic and Pre-hospital EM Association about the use of US in the pre-hospital field and on January 25-26, 2020, this group conducted its first training in Ankara (26). In addition, in 2019, about a master thesis about pre-hospital US use titled "Measurement of the Skill Level of Paramedics on Evaluation of Inferior Vena Cava by Ultrasound

in Pre-hospital Area and Ambulance" was written by Çatak (6), who is also a paramedic.

Use of US in Pre-hospital Area

There are many clinical applications of mobile US use in the pre-hospital area to reduce mortality and morbidity, and to improve the outcomes of critically ill patients. The number of studies supporting the use of the US in the pre-hospital area and ambulance is increasing day by day. It provides important information in the diagnosis or exclusion of life-threatening reasons, the evaluation of patients with impaired conscious or unconscious, hypotensive shock, and the decision to transfer these patients to the most appropriate hospital, and in the light of this information, it changes the direction of the emergency intervention and increases its effectiveness. Pre-hospital FAST (PFAST) has several advantages, such as shortening the time of operation to the patient, improving patient results and the triage of critical patients to trauma centers, and redirecting stable patients to another center from over-intensive trauma centers. PHUS is used to diagnose patients with trauma and without trauma in pre-hospital care to start treatment, decide the target hospital and determine the first treatment in the hospital (19).

Studies on the use of US devices for non-physician health personnel are common. Many academic studies on the use of PHUS have revealed that after a short training period, ambulance personnel can easily and successfully use this device (27-29). In a study conducted with 50 team leaders at the Siena Ambulance Service in Italy, even a short training of 8 hours of theoretical and practical training has been shown to yield successful results (82%) (30). In the evaluation made after Pre-hospital Assessment with Ultrasound for Emergencies (PAUSE) protocol training (2 hours) used in the United States for 20 paramedic workers working in integrated ED who have not previously received US training, it was seen that they were able to successfully recognize pneumothorax, pericardial effusion, and cardiac arrest. Moreover, it has been noted that the PAUSE protocol can potentially be useful in quickly detecting certain life-threatening pathologies in the pre-hospital area (31).

In a study with 33 paramedics and air nurses providing pre-hospital air ambulance emergency health services in Texas in 2010, participants took part in theoretical lessons about US physics and e-FAST application, practical application on live and inanimate models, US information cards, module courses accompanied by videos via the website, and finally the use of US devices on real patients in level-1 trauma center ED. They were taken on a 6-week training program. After this training program, it was seen that the participants' overall success scores increased from 43% to 78% (32).

In a retrospective study (between January 2009 and March 2014) of patient US records by physician and non-physician assistant healthcare professionals working in helicopter emergency health services in Canada (Canadian Critical Care Helicopter Emergency Medical Service,) it has been demonstrated the improvement in the pre-hospital interventions for patients in both groups (27). In the investigation of the accuracy of pre-hospital focused assessment with sonography for trauma (PFAST) applied by paramedics in patients exposed to trauma and applying to the ED; paramedics working in hospital EDs have been shown to perform FAST with high accuracy (with a sensitivity rate of 84.62% and a specificity rate of 97.37) (28).

In recent years, incorporating bedside US into standard advanced cardiac life support (ACLS) algorithms has been widely recommended (33). EMS providers in Germany and Italy have already started to use this model in the pre-hospital cardiac interpretation as standard protocol (22).

According to the policy statement published by ACEP in 2016, there has been accumulating evidence pertaining to use US in pre-hospital emergency care (30,34). However, there are several challenges impeding the use of pre-hospital US such as significant requirement for training and equipment, and for careful physician monitoring to ensure the quality (29).

In many practice environments mainly in the USA and Germany, clinical US training is often provided to non-physician staff including Advanced Practice Professionals, Nurses, Paramedics, Military Medics and Disaster Response Team members in the faculty curriculum. To better accommodate the trainees to the courses, such training topics as introductory US physics, knobology, and relevant anatomy and pathophysiology are necessary (35).

There are several training tools currently in use; however, the list of most commonly recommended methods are small group Observed Structured Clinical Examinations, real time supervision during clinical emergency US, one-on-one standardized direct observation tools, weakly question answer (QA) teaching sessions and image review, ongoing QA exam feedback, standardized knowledge assessments, simulation assessments and several intense educational tools (36). Benefits of assessment measures include obtaining reliable data about current trainee competency level and future learning needs, as well as identifying possible ways to provide better local emergency US education (36).

Several protocols were developed for pre-hos US. By using these protocols, it has been aimed to reach the target diagnosis. While performing a clinical US examination, the criteria in Table 1 should be interpreted, and so the possible responses to these questions should be elaborated.

P-FAST Exam

The FAST exam, which aims to effectively use the invaluable time needed for operative procedures and also have the potential to reduce cost of treatment, and hospital admission process (19), has constituted to be a well-researched topic of interest in related literature in EM, demonstrating the possibility of death in traumatic patients, non-radiologists can also accurately diagnose hemoperitoneum, hemopericardium, hemothorax and pneumothorax (37).

Chest, Abdomen, Inferior Vena Cava, and Extremities in Acute Triage Protocol

This protocol stands for the current application of US in disaster medicine including a comprehensive sonographic examination to evaluate the chest, abdomen, inferior vena cava, and extremities in acute triage (CAVEAT) (38).

The simple triage and rapid treatment (START) is standard protocol used mass casualty triage system categorizing the patients to ambulatory (green), delayed (yellow), immediate (red), and expectant (black) based on clinical criteria such as vital signs and the Glasgow Coma Scale (38). Integrating US into START protocol might provide better classification of patients for whom START protocol alone indicates false positive or negative. Complementary use of US may alter triage color of a given patient to red, for whom START protocol assigned yellow.

Focused Echocardiographic Evaluation in Life Support Protocol (Cardiac Evaluation and Resuscitation)

The Focused Echocardiographic Evaluation in Life Support Protocol aims to determine the reversible causes of cardiac arrest such as pulmonary embolism, pericardial tamponade, global left ventricular failure, and hypovolemia, all of which might also be evaluated in pre-resuscitation for the critical patients. For circulation assessment, the US use has been examined and incorporated into standard ACLS algorithms (39). EMS providers in Germany and Italy have also used the US in the pre-hospital cardiac evaluations (22).

PEA states might occur with or without cardiac wall motion, constituting a challenge in recognition of subclinical return of spontaneous circulation, which, according to the new evidence, can only be differentiated by means of echocardiography (39,40).

Medical Illness

Despite the fact that among research fields appealing the researcher, the most common studied EMS ultrasound indication falls in the category of traumatic injuries, the effectiveness of the ultrasound in such non-traumatic illness as normal full-terms gestation, and fetal distress, for both of which it is revealed that the ultrasound use enhanced patients management, have also been studied by limited number of research (34).

Conclusion

Numerous clinical applications have become a possibility with the utilization of pre-hospital emergency ultrasound for patients with life-threatening emergency conditions, all of which have the potential not only to decrease morbidity but also improve outcomes of any therapeutic intervention. Though this imagining device, it is highly possible for pre-hospital providers to enhance accuracy of the diagnosis and obtain vital information resulting in much better management and helping providers to classify patients to appropriate destinations in triage. As for the major obstacles of efficiently using pre-hospital ultrasound, such requirements as training and time are the leading ones. For the acquisition and maintenance of efficient skills in ultrasound by non-physician pre-hospital providers, regular formal training schemes are certainly a necessity. Although it is possible to hypostasize that the efficient pre-hospital utilization of US offers great advantages, establishing its clinical implications on

Table 1: Prehospital fields using US as a diagnostic tool

Protocols for pre-hospital emergency US		
Targets	**Clinical US examinations**	**Protocols**
Arrest rhythm	Cardiac motion	2001 UHP - Undifferentiated hypotensive patient US protocol
Myocardial dysfunction or failure	Left ventricle contractility	2005 P-FAST - Pre-hospital FAST
Aorta Dissection, aorta aneurism	Right ventricle size dilated	2007 FEER - Focused Echocardiographic Evaluation in resuscitation
Significant Valve Failure or Stenosis	Pericardial fluid	2008 C.A.U.S.E. - Cardiac arrest ultrasound exam
Pericardial tamponade	Confirmation of endotracheal tube	2009 RUSH - Rapid Ultrasound for shock and Hypotension
Tension pneumothorax	B-lines on lung ultrasound (≥3)	2010 FEEL - Focused echocardiographic Evaluation in Life Support
Pulmonary embolism	Uncompressibility on veins	2010 FOCUS - Focused cardiac ultrasound in emergent setting
Acute Dyspnea (e.g., COPD vs. CHF)	Volume evaluation on vena cava inferior	2010 RUSH - Rapid ultrasound in shock
Identification of shock	Fluid in the pleura and peritoneum	2010 The CAVEAT examination
Hypovolemia		2011 EGLS - Echo-guided life support
		2014 CORE - Concentrated overview of resuscitative efforts

COPD: Chronic obstructive pulmonary disease, CHF: Congestive heart failure, US: Ultrasonography

wellbeing of the patients certainly requires an accumulation of evidence.

In line with the continuing trend towards bedside ultrasound use by the non-radiologist, ultrasound use by non-physicians have also witnessed a dramatic increase. With the progressive development in the ultrasound with regard to cost, size, and practicality, field ultrasound applications may also continue to develop. As for providing additional information aiding the diagnosis, ultrasound may cast significant light on the supervision of the treatment. Not only the training level of the US provider present in the transportation vehicle mainly ambulance or helicopter, but also the transport time will have a vital impact on the utility of this information. In the related literature, the number of studies evaluating the pre-hospital use of ultrasound is limited; as a result, in order to reach a conclusion considering the necessity of widespread deployment of PHUS, further prospective, outcome-based studies should be conducted.

Main points:

- In critical patient care, mainly hypotensive, shock and trauma patients, US has been actively utilized.
- In EDs, apart from radiologists, EP also make use of bedside US.
- In some countries, life-threatening conditions are diagnosed by EP and even paramedics with mobile US in the field, unlike Turkey.
- Pre-hospital use of US decreases both mortality and morbidity.
- Paramedics should be provided with effective ultrasonography courses in the curriculum in order to enable them utilize US in the pre-hospital field in Turkey.

Ethics

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: B.G., E.G., Design: B.G., E.G., Data Collection or Processing: B.G., E.G., Analysis or Interpretation: B.G., E.G., Literature Search: B.G., E.G., Writing: B.G., E.G.

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