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Ultrasonography in Emergency Department; a Diagnostic Tool for Better Examination and Decision-Making

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Abstract

Context: The aim of this study is to evaluate the applications of ultrasonography (US) as a diagnostic tool in emergency settings.

Evidence acquisition: In the present review article, search engines and scientific databases of Google Scholar, Science Direct, PubMed, Medline, Scopus, and Cochrane were searched for the applications of US in emergencies. Finally, related articles which were published between 2000 and 2017, were selected and by reviewing them an attempt was made to evaluate various applications of US for examining and facilitating decision-making in emergency department (ED).

Results: As a diagnostic tool, US can be of diagnostic help in emergency settings for the specialists and the treatment team regarding trauma, measuring intracranial pressure (ICP), hemothorax pneumothorax, abscess and its drainage, deep vein thrombosis (DVT), dyspnea, acute abdomen, appendicitis and biliary problems, renal colic and renal stones, shock, foreign object, bone fracture, peripheral nerve block, establishing central and peripheral venous access, lumbar puncture (LP), and confirmation of nasogastric tube (NGT) and endotracheal tube (ETT) placement.

Conclusion: The results of this review study showed that US can be of help to EMPs as a diagnostic tool in a wide range of diseases and clinical conditions, which in turn can result in a decrease in the time needed for diagnosis and treatment, and therefore improve both the quality and quantity of the service provided in ED.

Key words: Diagnosis; Emergency Treatment; Emergency Service, Hospital; Ultrasonography

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Context

What measures can be taken by an emergency medicine physicians (EMP) using ultrasound (US) in the emergency department (ED)? Can this tool be used for more accurate examination of the patient on the bedside, speeding up diagnostic measures and finally, more proper disposition of the patients in ED?

Evidence acquisition

Ultrasonography (US) is a diagnostic method that has received more attention than before in recent years. This tool uses high-frequency sound waves for evaluating the structure and function of internal organs and tissues. Recent advances in the quality of imaging and increased portability of the devices have facilitated the use of US in difficult situations and have therefore introduced as a great, readily available and inexpensive screening and diagnostic method for various patients (1). For this reason, in the past decade use of US has significantly increased among EMP and the topic of "point of care ultrasound" has received much attention (2, 3).

Using ultrasonography, EMP have been able to improve the speed and accuracy of diagnosis and consequently, treatment of diseases (4-6). Researchers believe that with proper training, EMP are able to perform ultrasonography with a reliable accuracy, which will therefore have a significant effect on the quality of their diagnostic and therapeutic measures (1, 7).

In the present review article, search engines and scientific databases of Google Scholar, Science Direct, PubMed, Medline, Scopus, and Cochrane were searched for the applications of US in emergencies. Finally, related articles which were published between 2000 and 2017, were selected and by reviewing them an attempt was made to evaluate various applications of US for examining and facilitating decision-making in ED.

Results

The findings were categorized in 3 parts including critical care, medicine and surgery, and procedures. Thereafter, in each part, subheadings were defined.

Critical care

- **Shock state**

Using the protocols of abdominal and cardiac evaluation with sonography in shock (ACES) and rapid ultrasound in shock (RUSH) for rapid diagnosis and treatment of critically ill and in shock patients by EMP has received attention from many researchers (8). ACES protocol with 6 views of cardiac, inferior vena cava, abdominal artery right and left flanks and pelvic view can provide the specialists with a relatively complete evaluation and RUSH protocol with its 3-step algorithm can provide the specialists with a rapid assessment in emergency settings to evaluate the probable differential diagnoses for the patients in shock (9-18).

In critical clinical situations, these protocols can evaluate important differential diagnoses such as hypotension with undetermined cause, sepsis, cardiac arrest and other cases in the shortest time and with the most accuracy and therefore, significantly increase the probability of diagnosis, treatment, and successful resuscitation (19-23). For quantify intravascular volume status, carotid artery corrected flow time (FTc) has recently been introduced, but the researches in this era is still on (24-27).

- **Multiple trauma**

Performing ultrasonography in trauma patients [Focused Assessment with Sonography in Trauma (FAST)] is one of the most common applications of US in ED (28). When there is an acute hemorrhage it has the ability to flow and is seen without an echo (black). However, when the hemorrhage is sub-acute and blood has clots it is hypoechoic (gray) (29). Various studies have shown that FAST has a high sensitivity in diagnosis of diseases in ED (from 73% to 99%) (30). In addition, a meta-analysis performed on 62 studies and 18000 patients showed that FAST can have a sensitivity of 78.9% and specificity of 99.2%, which indicates the high diagnostic value of this tool in trauma patients (31).

- **Cardiac tamponade**

Injuries to large thoracic vessels and cardiac tamponade are among the most important reasons for death before reaching the hospital in patients with blunt or penetrating trauma to the thoracic area (32). Rapid diagnosis of tamponade in a few seconds can significantly increase the chance of survival for the patient (32-35). A study by Mandavia et al showed that US can diagnose pericardial effusion with 97.5% accuracy (36); meanwhile, it was claimed that computed tomography (CT) scan and magnetic resonance imaging (MRI) have a lower value compared to US and performing them is not necessary most of the time (37).

- **Intracranial pressure assessment**

Increase in intracranial pressure (ICP) is a relatively common and dangerous phenomenon in brain injuries and its severity and duration have a significant correlation with patients' mortality (38, 39). A study by Chesnut et al showed that there is no significant difference between invasive methods and non-invasive imaging regarding ICP measurement (40). Since invasive methods of measuring ICP can bring about side effects such as infection or bleeding, using US as a non-invasive method in measurement of ICP in emergency situations can be very helpful (41-43). Studies have shown that ultrasonography can be used as a rapid, inexpensive, and reliable method for measuring ICP in emergency settings as a replacement for the common invasive measurement methods (44).

Medicine and surgery

- **Musculoskeletal injuries**

Using US for detecting fractures in ED has many advantages, among which not needing to move the patient out of the ED and not having ionizing radiations can be pointed out (45-47). Studies have shown that US can detect fractures with 93% sensitivity and 83% specificity for long bones in adults, 98% sensitivity and 69% specificity for various types of fracture in children and 95% sensitivity and 96% specificity for clavicle fractures in children. The study by Griffith et al showed that regarding detection of fractures, ultrasonography can detect more fractures (10 times) and in more patients (6 times) in comparison with radiography, which is higher than similar studies in this regard (48-52). This diagnostic superiority is especially proposed regarding rib fractures, and metastases, nose fractures, sternal fractures, metatarsal bone stress fracture, clavicle and lower arm fracture in newborns and children, calcaneus fracture, and pelvic fracture. Meanwhile, various evaluations have shown that chest radiography can detect rib fractures in only 12% of the cases (53, 54). The numerous benefits of US in detection of chest diseases have resulted in its use as a proper diagnostic method in patients with unexplainable chest pain and without a history of trauma, patients who cough and clinical cases with suspected

fracture despite their chest radiography results being normal (55).
Low frequency US has also been used for diagnosis of shoulder dislocation and required assessment after reduction in the ED. In comparison to radiography, US had a sensitivity of 100.0%, specificity of 80.0% in diagnosis of shoulder dislocation; as well, the specificity of US in diagnosis of proper reduction of the joint, was estimated to be 98.7% (56).
US was also used regarding diagnosis of tendon ruptures following penetrating extremity trauma and the overall sensitivity and specificity were reported as 94.4% and 100% respectively. Therefore, US is now being considered as one of useful modalities in this area (57).

- **Eye trauma**

Retinal detachment (RD) is an eye emergency, which needs rapid intervention for preventing irreversible blindness (58, 59). Definitive diagnosis must be done by an ophthalmologist, but since most patients visit the ED first, using a method for a reliable primary diagnosis by EMP is of great importance (60). Despite the high value of fundoscopy in these patients, due to the problems of using it, especially in patients with cataract or bleeding in the eyeball, its use in ED has not been recommended (60). Using ultrasonography for diagnosis of RD has started from 1970 and its clinical value in diagnosis of eye pathologies, especially RD, has been confirmed little by little (61, 62).
Studies have shown that using Emergency Department Ocular Ultrasound (EOUS) has a similar sensitivity and specificity to ultrasonography performed by ophthalmologists in diagnosis of RD and based on the studies only 19% false positive results have been reported (63).
Dislocation of eye lens can happen following blunt trauma or in an idiopathic manner in patients. These patients usually present to ED with reduced eyesight (64). Studies have shown that US can detect dislocation and subluxation of the eye lens easily and in the shortest time possible (64, 65).
Blunt trauma of the eye can also lead to scleral rupture of the eye, the diagnosis of which is a clinical challenge in clinical emergencies and US can help the physicians to diagnose it in the shortest time possible (65). However, in eye traumas it should be noted that in case of suspicion to eye globe rupture, using US is contraindicated. Applying more pressure does not lead to improvement of the image and theoretically it leads to worsening of the eye injury (66).

- **Foreign body**

Numerous evaluations have shown that US can be a reliable tool for diagnosing foreign bodies in soft tissue (67, 68). Radiography can only detect radiopaque foreign objects such as sand, glass, metal, with 98% sensitivity, but does not have the ability to detect radiolucent foreign objects like wood, plastic, or cactus spine. Meanwhile, based on existing studies, 36% of foreign bodies are wood; this might be the reason that based on the studies 38% soft tissue foreign bodies are not detected in initial examinations (48). Sensitivity of US for detection of foreign bodies is 40% for sand, 45% for metal, 50% for glass and wood, 30% for cactus spine and 40% for plastic. Its overall, sensitivity, specificity, false negative and false positive for detection of foreign bodies are 43%, 70%, 50% and 30%, respectively. False negative and false positive for detection of foreign objects with radiography are 50% and 1.6%, respectively (69). In comparison with radiography, US can detect most of the foreign objects with accuracy and is therefore considered a proper approach for detecting as well as removing foreign bodies in ED.

- **Abdominal Aortic Aneurysm**

The importance and place of US in diagnosis of abdominal aortic aneurysm (AAA) was determined in 1992-1993 and with the initiation of screening using US for early detection of this disease (70). Many of the patients who visit ED are unaware of their abdominal aortic aneurysm; and since most of these patients are affected with cardiovascular risk factors, therefore, not diagnosing it in a timely manner is a common medical problem (71, 72). Evaluations have shown that combination of clinical examination and US can have a high clinical value in timely detection of AAA (70, 72). Meanwhile, CT scan and angiography have a much less important diagnostic place due to their long duration of performance, high cost, and complications (72).

- **Aortic Dissection**

Aortic dissection is a life threatening disease (73). Clinical diagnosis of aortic dissection is a medical challenge; because the symptoms of patients can vary based on the affected organ and therefore, the true prevalence of this disease in not known (73). Not diagnosing this disease in a timely manner can be associated with a mortality rate more than 1% in each hour during the first 24 hours and 80% after 2 weeks (74). Aortography, as a diagnostic method for aortic dissection, has 88% sensitivity, 94% specificity, 96% positive predictive value, and 84% negative predictive value. However, this method cannot differentiate many of the pathologies of aorta and is also an expensive, time-consuming method associated with a high rate of side effects compared to other imaging methods (73). Studies have shown that US in combination with various performance techniques can have 97-99% sensitivity and 99-100% specificity in diagnosis of this disease (73, 75).

- **Deep vein thrombosis**

Annually, 20 million new cases of deep vein thrombosis (DVT) occur in the United States (76). Sensitivity and specificity and positive and negative predictive values of US in detection of DVT in symptomatic patients and patients after undergoing surgery is higher than 92%. In addition, US with 86% specificity and 96% sensitivity can help EMP detect DVT following ankle fracture (77). Different studies have shown that US can be used as a non-invasive method for early detection of DVT in ED. These studies have expressed 93% sensitivity and 99% specificity for US in comparison with venography (78). In addition, among other points indicating the superiority of US to other methods in detection of DVT are its high accuracy, low cost, portability of the device and not having ionizing radiations (79, 80).

- **Pulmonary system**

Shortness of breath is a common complaint among patients visiting ED and differentiating its cardiac and non-cardiac causes is among the common clinical problems (81, 82). Various studies have shown that US can diagnose the causes of shortness of breath with 93.6% sensitivity, 84% specificity, 87.9% positive predictive value and 91.3% negative predictive value. Actually, using ultrasonography of lung and pleural cavity for patients with shortness of breath in ED by can be efficient for accurate and timely diagnosis of cardiac or non-cardiac causes of shortness of breath and diagnosing alveolar-interstitial syndrome and also be used for diagnosis of respiratory failure and monitoring response to treatment (81, 83).

In a survey that US was compared with chest x-ray for diagnosing patients with acute shortness of breath indicated more than 95% conformity in most pulmonary diseases, especially lung edema; in addition, there was no significant statistical difference between ultrasonography and radiography regarding lung disorders such as free pleural effusion, lobulated pleural effusion, pneumothorax and lung consolidations. Other studies also showed similar findings (84, 85).

- **Abdomen**

Acute abdomen is one of the common complaints by patients presenting to ED and the differential diagnoses of this pain include a wide range of clinical problems from self-limited diseases to those with high morbidity (86). Various studies have shown that US can aid in detection of acute appendicitis with 75-90% sensitivity, 86-100% specificity, 87-96% accuracy, 91-94% positive predictive value and 89-97% negative predictive value (87-91). Considering the difficulty of differentiating appendicitis with many gynecologic disorders, US must be routinely performed for all the young women presenting to ED with right lower quadrant (RLQ) pain. In addition, due to the lack of ionizing radiations in ultrasonography, it is the method of choice in pregnant women and children (86, 92).

The study by Allemaann et al. in University of Zurich showed that using ultrasonography in acute abdominal pain can increase the probability of correct diagnosis from 70% to 83%. Additionally, the diagnostic accuracy for acute appendicitis and biliary tract diseases changed from 92% to 98% and from 93% to 99%, respectively, which can increase the speed and quality of diagnosis and treatment, and decrease the duration of hospitalization (86).

- **Renal stone and colic**

The numerous problems of various methods of imaging in detection of urinary tract stones such as the side effects of the contrast agent and long duration in intravenous urography, low diagnostic sensitivity in plain radiography and the high dose of ionizing radiation and high cost in CT scan have been assessed in various studies.

In a study by Patlas et al. diagnostic sensitivity of ultrasonography was reported to be relatively equal to CT scan, 93% vs. 91%. In another study, the sensitivity of US regarding renal colic was 95% and its specificity was 67%. These variables have been reported as 81% and 100%, respectively, in hydronephrotic kidneys (9, 10, 93, 94).

In fact, considering the many advantages of US in detection of kidney stones in ED, it has been suggested to use CT scan only in cases that ultrasonography is not available or there is suspicion regarding the diagnosis (10).

- **Soft tissue**

Infection of soft tissue can commonly cause cellulite or abscess (95). Differentiation of cellulite with abscess for selecting the proper treatment is a routine challenge in ED (96). Various studies have shown that US can be a valuable tool in diagnosis of abscess and differentiating the two mentioned diseases (97, 98).

Ultrasonography not only can differentiate them, but can also determine normal structures of the tissue as well as cellulite and abscess changes (98-101). In addition, after timely and correct diagnosis of abscess using US, drainage can be attempted (102).

Procedures

- **Peripheral nerve block**

Using US compared to peripheral nerve stimulation for blocking neural branches can significantly increase the success rate, shorten the duration of procedure, accelerate the onset of the block and elongate the duration of block (103). Additionally, based on existing studies, other variables such as the required dose of anesthetic agent, pain at the time of performing block, the number of needles required, percentage of success in the first attempt and patient satisfaction in performing nerve block are also in favor of US (104-109). In addition, using US can increase the accuracy and quality of performing brachial neural network block (110). Similar results were obtained by Casati et al. for femoral nerve block; the result of this study showed that US not only leads to increase in the speed and quality of performing nerve block, but can also decrease the volume of anesthetic agent required for block by 42% (111). Other studies confirm more than 95% success for blocking ilioinguinal and iliohypogastric nerves (112).

- **Peripheral vein access**

Establishing peripheral venous access is one of the very important and usual initial measures taken in ED. Using US for placing a peripheral vein route in difficult cases has been considered in the past two decades and different studies have reported its success rate between 94% and 97% (113-115). In addition to the high success rate, less time is required compared to other methods and less complications are among the other benefits of using US for placing peripheral vein catheter by EMP, which are important especially in critically ill patients, children, obese patients, and those with venous pathologies and chronic diseases (116-120).

- **Central vein access**

Placing central vein access: each year about 200000 operations of central vein access placement are performed in the United States (121). In various studies success rate, problems, number of attempts, and the time required for placement of central vein access via internal jugular vein using anatomic indices have been evaluated in detail (122-124). Based on these studies in only 57.3% of the patients, central vein access could be placed in first attempt and reaching a success rate over 99.3% required repeated attempts, which results in complications such as carotid perforation, hematoma, hemothorax, horner syndrome, and dysphagia. However, in the study by Denys et al. on 1230 patients using US no important complications, including pneumothorax, were seen (125). In another study, carried out on critically ill patients, a significant superiority was reported for using US compared to other common methods (125). A meta-analysis on 208 studies, aiming to compare the placement of central vein access using US with other methods, revealed a decrease in complications when placing vein access via internal jugular vein (RR=22; CI=95% 0.10 to 0.45) or subclavian vein ((RR=0.11; CI=95% 0.02 to 0.56), drop in the number of attempts needed for placement (RR=0.60; CI=95% 0.45 to 0.79), decrease in the time needed, and increase in the probability of success after failure of placement using other methods (126).

- **Lumbar puncture**

Lumbar puncture (LP) under US guide was described in 1971 for the first time and can be used for patients in whom using the landmarks method can be difficult (for example patients who are obese, are affected with scoliosis or those who cannot make a kyphotic spinal curve for performing this process) (127). Different studies have shown the high value of US in LP performance, especially in children (128). The study by Nomoura et al. indicated the significant superiority of LP placement using ultrasonography compared to other methods and this superiority was higher in patients with BMI>30 and those who did not have proper landmarks (129).

- **Nasogastric tube placement**

Traditional methods used for confirming nasogastric tube (NGT) placement such as kidney, ureter, and bladder (KUB) x-ray with contrast, pH test of stomach secretions and etc. are time consuming and do not always have 100% sensitivity or specificity (130). Auscultation with stethoscope is not reliable, especially in crowded places like ED, and pulmonary sounds might be mistaken for NG sounds (131). Evaluations have shown that US can be used for stomach lumen imaging as a rapid and non-invasive method without exposing the patient to radiation. Using US for confirming the placement of gastrostomy tube (G-tube) is still a relatively new concept but recent studies support its high sensitivity and accuracy (130).

- **Endotracheal place assessment**

Various tools and methods exist for confirming the proper placement of endotracheal tube (ETT), the most common and available of which is pulmonary auscultation (131). Studies have shown that pulmonary auscultation is an unreliable method for assessing the placement of ETT (132). In addition, using capnography also lacks sufficient accuracy in determining the placement of ETT in situations such as cardio-pulmonary arrest and long duration of ventilation with mask and bag (133). Despite some recommendation against, meanwhile, based on numerous studies and considering the ability of US to differentiate anatomic structures, such as pleura, lungs, and esophagus, and directly monitor pulmonary movements during ventilation, by using US the placement of ETT can be assessed with a high sensitivity (134-138).

Discussion

Considering the large amount of available evidence regarding various application of US in ED, it is logical to use the tool more extensively. When it comes to trauma, detecting intra-abdominal free fluid and tamponade are among the uses of US in critical situations. On the other hand, it is useful for diagnosis of musculoskeletal injuries including bone fractures, joint dislocation, and tendon ruptures. Apparently, US is also applicable for foreign body detection and helpful regarding its removal. Differentiation of abscess and cellulitis was another challenging task in ED that can be easily resolved using US. Assessing the proper placement of ETT, NGT, or as a guide for better LP performance or inserting central and peripheral vein access or peripheral nerve block are among other uses of US. In dealing with vascular disorders, benefit of its usage for diagnosis of DVT and AAA is undeniable.

The easy and complication-free application of US devices has provided most of the physicians and even other treatment team members with the opportunity to use them. Changes in the devices' structure and facilitation of their use in recent years have resulted in proposition of more applications for US and their consideration and assessment by researchers. It might be safe to say that ultrasonography has transformed into a tool for performing more accurate clinical examinations.

Conclusions

The results of this review study showed that ultrasonography can be of help to EMPs as a diagnostic tool in a wide range of diseases and clinical conditions, which in turn can result in a decrease of the time needed for diagnosis, management, and disposition, and therefore improve both the quality and quantity of the service provided in ED.

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Authors' contribution

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Conflict of interest

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