"Introducing Ultrasound as standard tool for Emergency Medical Service in Disaster Management". A literature review of ultrasound utilisation in emergency cases.

Abstract

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Emergency Medical Service (EMS) is considered an essential item and unseparated to the Disaster Management. EMS healthcare providers have to perform rapid and accurate diagnosis on the field, as well as the first-aid treatment. In some major disaster, triage and Life-support become more challenging due to shortage of diagnostic tools and difficulties in performing advanced life support with limited resources. Ultrasound is a well-known diagnostic tool which mostly utilised for elective medical imaging. Nowadays, there are increased number of research in ultrasound and how it can be effective not only as an 'elective medical tool' but also in emergency setting. This article discusses the studies developed for the ultrasound in emergency setting, both as diagnostic tool and tool for imaging-guided procedures. We will discuss the ultrasound utilisation in early diagnosis of major trauma, ultrasound-guided procedures, and how to assess the effectiveness of the initial therapy in this article. As the conclusion, we found that ultrasound is an important EMS tool needed in every major disaster. For that reason, we suggest equipping every physician who involved in Disaster EMS with ability to operate the emergency ultrasound.

Keywords: Ultrasound (US), Emergency Medical Service (EMS), Major Disaster, diagnostic, imaging-guided procedure

Introduction

Emergency medicine is an integral part of disaster management and response. Disaster management and preparedness are not merely to prevent or minimising the casualties through early detection and warning of any possible disaster that may happen in the future (1,2). Some of the disaster, either natural or human-made, can be possibly predicted long before it appears. However, missed or unpredicted disasters still possible to happen and cause catastrophy with big number of collateral casualties. These situations are where emergency medicine play its role. Good preparation of Emergency Medical Services (EMS) have an important role in reducing the number of morbidity and mortality during management of disaster (2). Therefore, equipping EMS personnel for the next level of skills and knowledge considered essential, particularly for those who are performing EMS in an isolated location of a disaster.

Ultrasound (US) was introduced in medicine by an Austrian doctor, Karl Theodore Dussik in 1942 when performing brain investigation through utilisation of ultrasonic waves (3). However, the utilisation of US as a diagnostic tool was first time performed by George Ludwig in 1949 to detect gallstones. US became well-known imaging tool in medicine when Ian Donald published a 2D ultrasound machine called "Diasonograph" in 1958 (4). Since then, researches and investigations were carried out to find further potential of US in medical settings (3,4).

The application of US in Emergency Medicine is not a new issue in medicine. It developed in 1980s primarily to diagnose emergency problems which silently occurred, particularly in abdomen (5). US current extended utilisation is not only as diagnostic tool but also as an integrated part of therapeutic procedures and monitoring. The main factor of discoveries in extended utilisation of US probably because it promises future dual-functioning tool with low cost, energy, space, and relatively cheap and easy training for the procedures (6).

Application of US in emergency setting is extensive since it can be applied to almost all field of medicine. Emergency application of US is most common in diagnosing most of life-threatening trauma, as well as US-guided procedures (5). The application of US in emergency setting is extensive. For that reason, this article only discuss the utilisation of US in diagnosing some of emergency cases which most possibly appear in disaster setting.

Application of Ultrasound in Thoracic Emergency

Pneumothorax

Standard chest examination is adequate to detect the massive to tension pneumothorax. Inspection of chest movement and any visible organ deviation, shift of air vibration on palpation, hyperresonance during percussion, and losses of lung sound during auscultation (7). However, in mild pneumothorax diagnosis through physical exam can be difficult; sometimes even without any complaint (8,9). Pneumothorax with significant findings or missed during physical exam can be discovered by using imaging tools (5,8,10).

Ultrasound in chest imaging is an act of imagination through analysis of visual echogenic artefacts. The image recognition of chest ultrasound is basically the interaction between sound wave with air and fluid. As presented in Figure 1, there are three main indicators with one additional indicator to diagnose pneumothorax using ultrasound (11). Lung sliding (Figure 2A) is a dynamic slippery movement of visceral pleura against parietal pleura, which will appear as 'sea-shore' in M-Mode (12). If the lung sliding does not appear (Figure 2B), the next step is to analyse 'comet tail artefacts' which known also as 'B-lines' (Figure 2C). It appears as the sound waves pass through some fluids, and so becomes the sign of an interstitial syndrome (11). Even though the pneumothorax progressives, the lung activity still can be detected if the probe moves closer to axillary line. This small movement of lung activity called as ‘lung point’ (Figure 2D) (13). If the lung point does not appear, the last step is checking the lung pulse (Figure 2E). It is the sign of totally no lung activity, and the M-Mode will appear as if the lung has synchronised movement with the heart beating. Lung pulse is the sign that the patient suffers complete atelectasis and not pneumothorax (14).

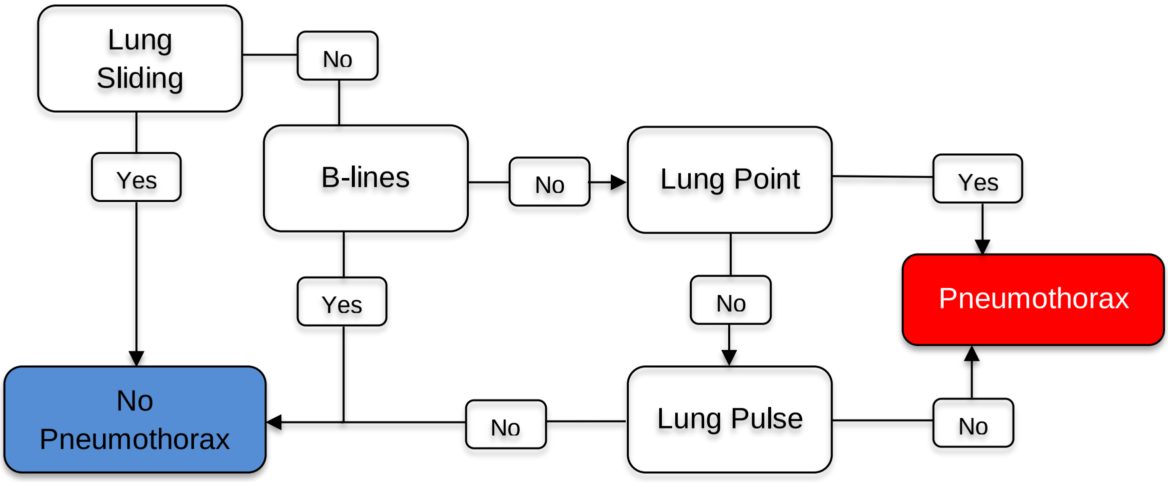
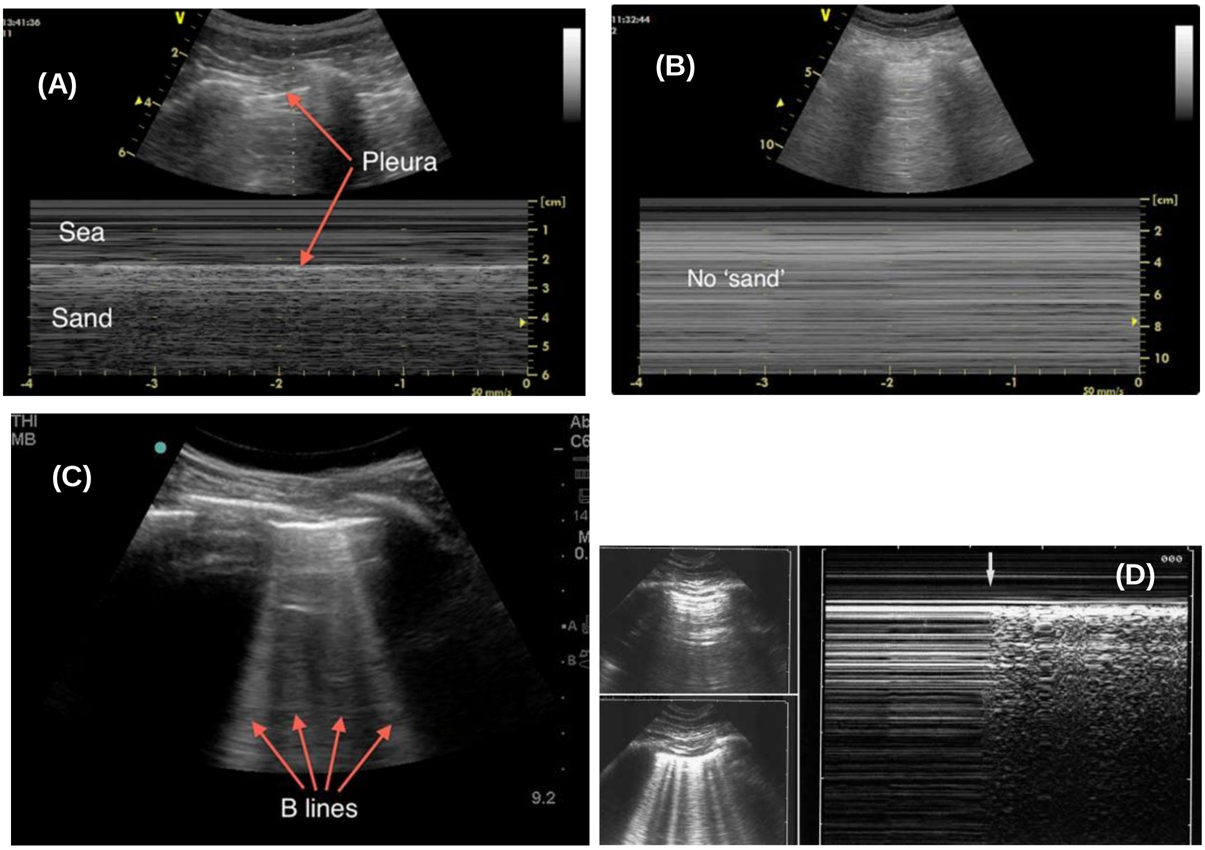


Figure 1. Flow chart of diagnosing Pneumothorax using ultrasound (Adapted from Miller (11))



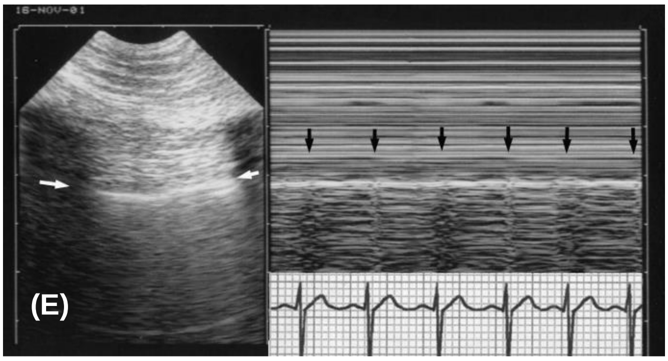


Figure 2. The ultrasound appearance of (A). Lung sliding and 'seashore/sand' sign (11); (B) Absence of lung sliding (11); (C) B-lines (11); (D) Lung Point (13); (E) Lung Pulse (14)

<u>Pleural Fluid</u>

Most common pleural fluid found in disaster area is blood as the output of chest trauma. Ordinary chest examination can determine the diagnosis of pleural fluid, including massive intrathoracic bleeding (15). Even though, sometimes imaging needs to perform to clarify the findings of the physical examination.

The sensitivity and specificity of ultrasound to detect pleural fluid is close to its golden standard. Another benefit of using ultrasound in diagnosing pleural fluid is because it can help to distinguish between transudates and exudates. The primary principle of detecting the pleural fluid is similar in another part of the body by detecting the "anechoic" image just above the diaphragm (Figure 3) (5,11).

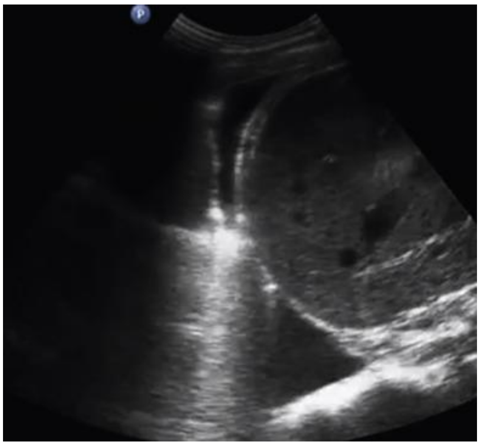


Figure 3. Ultrasound Imaging of Pleural Fluid (5).

US-Guided Thoracostomy

Though thoracostomy can be performed without guidance of imaging tools, the application of ultrasound can reduce the side effects of the procedure. Complications that caused by technical reasons can be tube malposition, reexpansion pulmonary oedema, nerve injuries, cardiac and vascular injuries, oesophageal injuries, residual/postextubation pneumothorax, fistulae, herniation through the thoracostomy site, chylothorax, and possible cardiac dysrhythmia. These complications primarily caused by technical issue such as inadequate training and experiences (16).

The critical aspect of chest tube insertion is knowledge of anatomical part of chest cavity and position of intra-thoracic organs, in order to prevent undesired injuries due to the inaccurate procedures (17). As shown in Figure 4, after identifying the location to make the initial incision (commonly on fourth or fifth intercostal space), ultrasound can help to predict how deep the tube will be inserted (18).

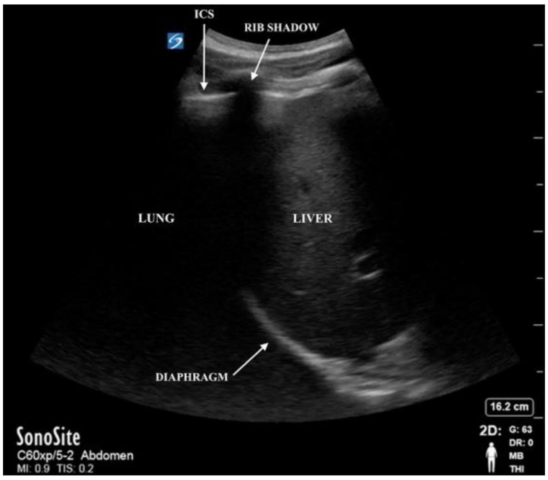


Figure 4. Application of ultrasound in discovering the landmark of chest tube insertion (18)

Pericardial Fluids and Pericardial Drainage

Cardiac tamponade was discovered and explained by Claude Beck in 1935. He described the cardiac tamponade as clinical findings of jugular venous distention, muffled heart sound, and hypotension, also known as Beck-triad symptoms of cardiac tamponade. The on-going process of pericardial effusion to become tamponade mostly asymptomatic and become symptomatic once the fluid disrupts the heart beating activity (19). The utilisation of ultrasound in heart cases, commonly known as echocardiography, firstly applied to reveal the presence of pericardial effusion. The idea is simple: discover the inter-spatial echoes between visceral and parietal layer. The pericardial effusion happened if there is echo-free space which separates visceral with parietal layer to create space. If the fluid enough to press heart wall, the heart muscle can be seen as if it externally blocked, mainly seen in diastolic period (20).

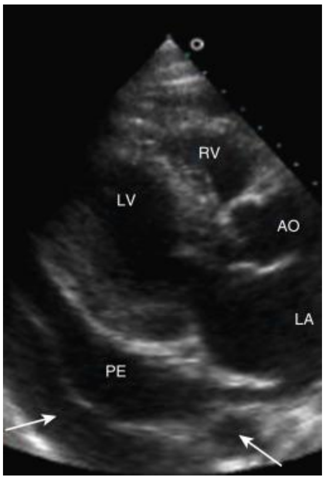


Figure 5. Echocardiography of Pleural Effusion (PE) (20). LV=Left Ventricle; RV = Right Ventricle; AO = Aorta; LA=Left Atrium

Blind method of pericardial drainage is a dangerous procedure, even if performed by trained medical personnel. “Blind” method means pericardiocentesis performed only depend on anatomical landmark with “sense” that the needle is in the right position, without guidance of any imaging tool (21). Ultrasound helps to guide the needle tip directly to the fluid site by visualising the needle and tissue around the needle (22).

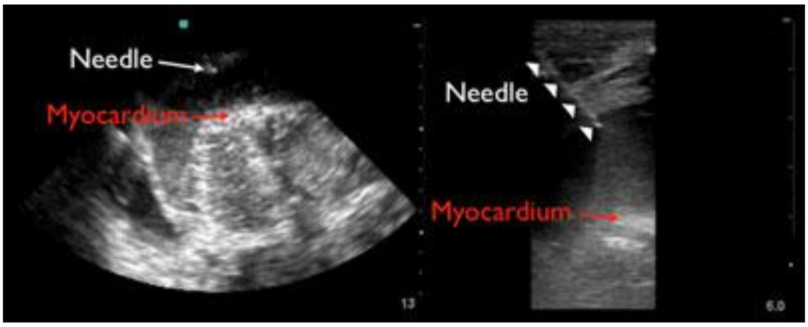


Figure 6. Application of ultrasound in Pericardiocentesis (22).

Application of Ultrasound in Abdominal Emergency

<u>Abdominal Bleeding</u>

Solid abdominal organs have rich in vascularisation so it will be easy to get bleed, giving visualisation of intra-abdominal free fluid. Most cases of abdominal injuries, particularly blunt trauma, are hard to assess through physical exams resulted in progressive occult bleeding which will be detected once the patients are starting to enter shock condition (23,24).

Ultrasound is already well-known imaging modality to assess abdominal organs. The utilisation of ultrasound in trauma currently performed bedside to assess the patients who are hemodynamically unstable with suspected intra-abdominal organ injury. The procedure commonly called “Focused-Abdominal Sonography for Trauma” (FAST) (24).

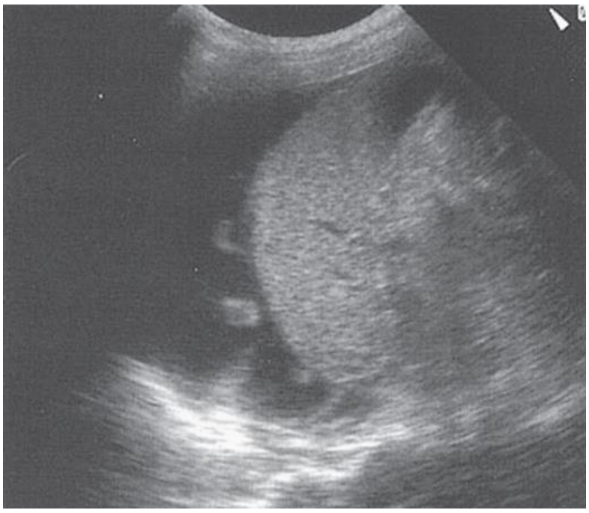


Figure 7. Ultrasound imaging of abdominal bleeding around spleen (24).

Other Application of Ultrasound in Emergency Setting

US-Guided Airway Procedures

Ultrasound can help the procedures of two emergency airway management: endotracheal tube (ETT) insertion and tracheostomy (5,25). The main problem of ETT insertion is how to make sure that the tube has passed the pharynx and not the oesophagus. In some cases and patients, the epiglottis cannot be visible to the operator (26). Ultrasound utilisation can help to guide the insertion of ETT and so can help to reduce the time for insertion. Thomas et al. (2017) performed intubation to 100 patients guided by ultrasound and found 95% successfully inserted to trachea. From the 5% failure, 2% of them caused by operator mistakenly fail to distinguish trachea from oesophagus. Primary objectives of ultrasound application in ETT insertion are to identify trachea from oesophagus (since only two lumens will be visible; Figure 8), and confirming that the tube inserted precisely in the right place (27).

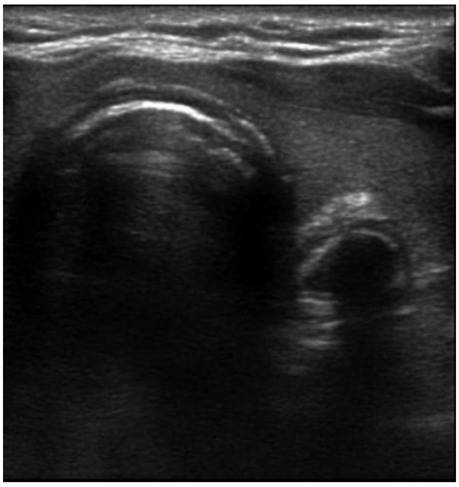


Figure 8. Ultrasound imaging of trachea and Oesophagus also called as ‘double track’ sign (27).

Since the invention of new less invasive adjunctive intubation techniques, Cricothyrotomy (or also called Cricothyroidotomy) no more become a popular procedure (25,28). The primary indication to perform cricothyrotomy, therefore, are other less invasive airway procedures unable to treat impending or ongoing hypoxia. However, there no specific indication of when this surgical procedure should be performed, mostly through case-by-case analysis (28). Application of ultrasound in cricothyrotomy is determining the cricothyroid membrane for the initial incision. The solid-fluid-air (air-tissue) interaction of sound wave will reveal the tracheal components. Two images can become landmarks for cricothyroid membrane: ‘thyroid cartilage–Airline–Cricoid cartilage– Airline (TACA)’ through transverse technique and ‘string of pearls’ through longitudinal technique (Figure 9) (29).

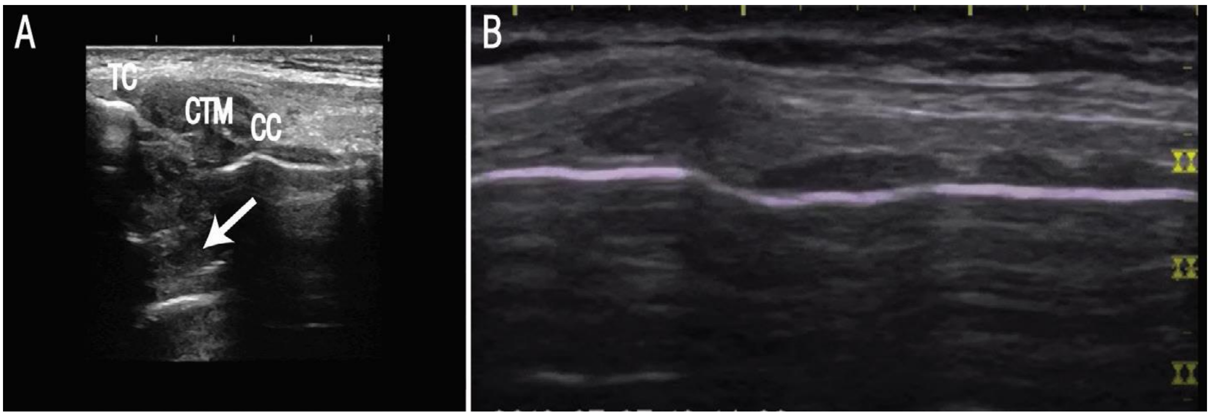


Figure 9. Ultrasound image with longitudinal technique shows (A) a 56-year-old male with distortion cricothyroid membrane and mass (arrow); and image of normal airway (25).

US-Guided Intravenous Access

Vascular access more accurately achieved through visualisation of needle tip and vascular lumen. The practice of US-guided intravenous access consists of two major steps: determine the location of vascular lumen and then guide the needle to that lumen. Guiding the needle into vascular lumen can be performed using two approaches: out-of-plane and in-plane. In out-of-plane approach, the needle inserted in the middle of US prone to visualise the vascular lumen.

On the other hand, in the in-plane approach, the needle inserted under the prone in the same direction with the US prone to visualise longer vascular lumen (Figure 10). The in-plane approach is the most common method used in performing US-guided intravenous access. However, the choice of technique depends on which one the operators more comfort to adopt (5).

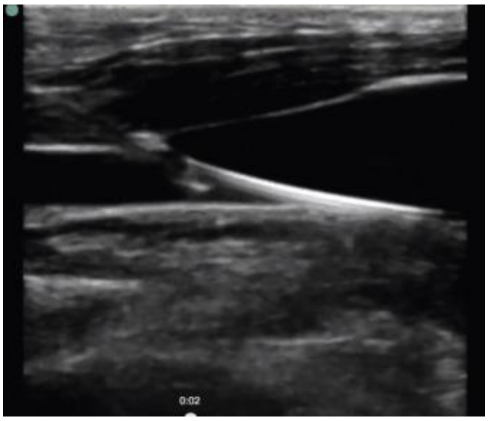


Figure 10. Ultrasound imaging of intravenous access of internal jugular vein (5)

US-Guided Assessment of Fluid Therapy

There are two approaches of ultrasound utilisation to monitor the fluid therapy: assessing the heart ventricles and assessing the inferior vena cava (IVC) (30). The IVC role in haemodynamic monitor basically because of its anatomical location correlate with the functions of the right heart, and it is physiological high collapsible. IVC reflects the volume status better than other parameters because its diameter does not change when the body's compensatory vasoconstrictor arise as the response of loss of body fluid. Meta-analysis study supported measurement of IVC diameter can be used to monitor fluid therapy (31). Though more difficult than assessing IVC, heart activities can also determine the effectiveness of fluid therapy. Some indicators such as Systolic Pressure Variation (SPV), Pulse Pressure Variation (PPV), and Stroke Volume Variation (SVV) can be predictive to fluid responsiveness (32). However, more specialised training needed to monitor fluid therapy through analysing the heart activities. The picture of ultrasound imaging in IVC presented in Figure 11.

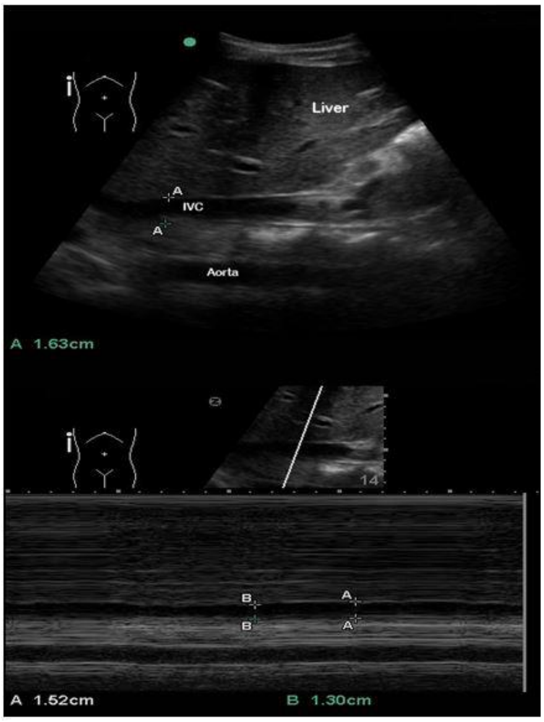


Figure 11. Ultrasound imaging of inferior vena cava (IVC) in B-Mode (top) and M-Mode (bottom) during passive respiration (A) and inspiratory effort (B) (33)

Utilisation of Ultrasound in Disaster Setting

The ultrasound uses in out-of-hospital setting has been applied in many settings. Military has used in combat ground, support hospital, and other tertiary health centres. US also helped in emergency medical service of several disasters such as Haiti earthquake in 2010 and Boston marathon bombing 2013. Ultrasound can be connected through satellite and so allow guidance and interpretation. In remote and isolated area, ultrasound can be very effective to help discover occult internal injuries in order to provide accurate initial medical treatment (5).

Conclusion

These are small number of what ultrasound can do to provide fast diagnosis and helping medical personnel to perform emergency medical procedures. Ultrasound relatively easy to carry and through adequate training, it is a handy tool for the EMS personnel who is performing their duty when disaster happens in a very remote area. As conclusion, we suggest every EMS personnel who works in disaster management to be equipped with skills and tools to perform initial ultrasound imaging and guided medical procedures which most needed in a remote disaster area.

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