Abstract

Introduction

Point-of-care (POC) ultrasonography is rapidly expanding within clinical practice. POC ultrasonography is per definition a bedside examination performed and interpreted by the treating physician. The development witnessed, in part, reflects equipment of increased quality, mobility and availability—the latter as a result of reduced costs. POC ultrasonography appears to be a safe and valuable tool, supporting the physician in patient management. It holds obvious advantages in being an easily repeatable and real-time examination that supplies images, which correlate directly to the patient’s symptoms or the clinically suspected diagnosis. In terms of airway, breathing, circulation (ABC-) ultrasonography, it covers cardiac, pulmonary, abdominal and vascular ultrasound. The aim of this critical review was to discuss POC ultrasonography.

Conclusion

The diffusion of POC ultrasonography will continue into the acute care specialities, such as emergency medicine, intensive care and anaesthesiology (both used peri-operatively) and in the pre-hospital setting. The use of focused echocardiography by non-cardiologists has recently been endorsed by the American Society of Echocardiography.

Major reasons for the diffusion of ultrasonography into other specialities are advances in technology and a considerable reduction in costs of ultrasonographic equipment. Over the last decade, portability has increased with the introduction of cart-based compact models and even handheld devices. Enhanced image quality has given rise to several different POC ultrasonography protocols.

As a real-time examination limited in time consumption and easily repeatable, POC ultrasonography holds obvious advantages. It assists the clinician in screening, diagnosing and decision-making, and is hence, developing into an important tool in supporting the clinical examination and conventional monitoring, of which the latter has shown low sensitivity regardless of the setting.

Indiscriminate use of POC ultrasonography among inexperienced users can lead to false positive results, further unnecessary testing and increased expenses. Even worse, false negative results can lead to inadequate examination. Thus, the need to ensure competency among users by training and quality assurance is evident. The increased and to sustain the quality of this user-dependent technology by education and accreditation, preferably involving hands-on practical training, is a major challenge.

This critical review primarily focuses on cardiac POC ultrasonography. Pulmonary and abdominal applications and vascular access are also briefly addressed.

Discussion

In this critical review, the authors have referenced some of their own studies. These referenced studies have been conducted in accordance with the Declaration of Helsinki (1964) and the protocols of these studies have been approved by the relevant ethics committees associated to the institution in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in the studies.

Airway, breathing and circulation ultrasonography

The integration of POC ultrasonography into the systematic airway, breathing and circulation (ABC) assessment of critically ill patients, has given rise to several different POC ultrasonography protocols. Advantages of this integration seem numerous; when performed by the treating physician, ultrasonography may aid in the identification of life-threatening conditions and enables the physician to immediately intervene with emergency treatment. Information is acquired in real-time, supplying the physician with dynamic images that can be correlated directly with the patient’s symptoms or clinically suspected diagnosis. In light of the time-critical nature of pathologies faced in acute care, the limited time consumption of POC ultrasonography is very...
Critical review

important. It is easily repeated if the patient’s status alters, and may serve as a monitoring tool alongside intervention/treatment. If necessary, it may also aid in the referral, to the correct speciality, for a more comprehensive diagnostic ultrasonographic examination. Furthermore, ultrasonography is safe. It is non-invasive and does not expose the patient to ionising radiation, in contrast to other imaging techniques, such as X-rays and computed tomography.

The advantages of the ultrasonography-assisted examination can be illustrated, when thinking of the multiple differential diagnoses that are plausible in the frequent case of a patient presenting with dyspnoea, low saturation and haemodynamic instability. However, ultrasonography is highly user-dependent, and therefore the use of POC ultrasonography demands both that the treating physician is sufficiently skilled and aware of personal limitations.

Point-of-care cardiac ultrasound

Different standardised focused POC cardiac ultrasonography protocols have been developed, which are exemplified by the focus assessed transthoracic echocardiography (FATE) protocol, focused echocardiography entry level (FEEL), bedside-limited echocardiography by the emergency physician (BLEEP), haemodynamic echocardiography assessment in real time (HEART) and Rapid Ultrasound in SHock (RUSH). In general, they share common goals as follows: to assess systolic function (contractility), diastolic function (compliance and relaxation), cardiac morphology (chamber dimensions, ventricular wall-thickness) and the presence of obvious pathology. Pre-defined clinical questions are examined and bimodal (‘yes/no’), as well as qualitative/semi-quantitative answers are sought. As with other acute care-related POC ultrasonography, these focused examinations are not meant as a substitute for the comprehensive echocardiographic examination performed by the cardiologist; it merely serves as a supplement to the clinical evaluation as illustrated in Figure 1.

The left ventricular contractility is most commonly evaluated by eyeballing, as most alternative quantitative measurements are complex, time-consuming, exhibit considerable variation and hold multiple pitfalls. Ultrasonographic estimation of preload is based on either relatively simple volumetric principles or more advanced Doppler-based methods. Afterload assessment, according to Laplace’s law regarding wall tension, requires information on chamber dimension and myocardial thickness, together with cavity pressure. To evaluate diastolic function of the left ventricle, advanced Doppler methods exist, but these are recommended only with higher levels of echocardiographic skills. However, the presence of left ventricle hypertrophy, with normal systolic function and lack of other pathologies, indicate possible diastolic dysfunction, especially in combination with a dilated left atrium.

The FATE protocol was developed in the 1990’s. It consists of four scanning positions (Figure 2). The objectives of this protocol in particular are as follows: exclude cardiac pathology; assess wall thickness, chamber dimensions and bilateral ventricular function; visualise pleura on both sides and finally, associate the information gathered to the clinical context of the patient.

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Position 1: Sub-costal four-chamber view: The patient is placed in the supine position. If possible, prolonged inspiration often improves image. The transducer is placed below the right costal curvature and close to the midline. The orientation marker should be pointing towards the patient’s left side, and the probe should be rotated approximately 20° counter clockwise to the skin. The ultrasound beam should be directed towards the heart or approximately towards the left shoulder. From this view, it is possible to roughly assess dimensions of the different chambers, as well as the contractility of the left ventricle. In particular, pericardial fluid can be visualised as a black, hypoechoic area around the heart (Figure 3).

Position 2: Four-chamber apical view: This can often be visualised with the patient placed in the supine position. If possible, placing the patient on the left side generally improves imaging. The transducer is placed at the apex of the heart (ictus cordis). The orientation marker should point towards the patient’s left side and the ultrasound beam directed towards the right shoulder. From this view, the size of the different chambers can be measured and systolic function can be assessed semi-quantitatively and categorised as normal, or mildly, moderately or severely impaired.

Position 3: Parasternal long-axis (PLAX) and short-axis (PSAX) views: This can often be visualised with the patient in the supine position. If possible, prolonged expiration and placing the patient on the left side generally improves images. The transducer should be placed immediately to the left of the sternum, at a line from ictus cordis to the medial part of the right clavicle. With the orientation marker directed towards the patient’s right shoulder, the long-axis view appears and with a 90° rotation clockwise and the orientation marker directed towards the left shoulder, the short axis appears. The PLAX projection allows for measurements of the left ventricle systolic dimension, ejection fraction and hypertrophy, i.e., septal- and posterior-myocardial wall thickness. In case of myocardial ischemia and regional myocardial dyskinesia, the PSAX view makes it possible, roughly to differentiate which individual coronary artery is affected. Furthermore, in the PSAX view, signs of pulmonary embolism can be evident as an apparent D-configuration of the left ventricle due to the septal impression caused by elevated right ventricular pressure.

Position 4: Pleural view – bilaterally: The patient is placed in the supine position with the thorax slightly elevated. The transducer is placed on the lateral, posterior thoracic wall, approximately parallel to the posterior axillary line, at the level of the diaphragm. The diaphragm will appear as a curved hyperechoic line, above the liver or spleen. This view can reveal pleural effusion or haemothorax, which will appear hypoechoic (pay attention to gravitational effects, i.e., fluid shifting with patient position).

Clinical implication
Haji et al. have recently reviewed the impact and accuracy of transthoracic echocardiography (TTE) performed by non-cardiologists4. Their review concluded that TTE, when performed by intensivists, caused a change in management (e.g., initiation or alteration of inotropic or vasoactive agents and fluid therapy) in 16%–51% of intensive care unit (ICU) patient cases. When performed on intubated patients, they found only 2.0%–4.5% failure in obtaining interpretable images. Regarding physicians in the emergency department (ED), Haji et al. highlighted a randomised trial by Jones et al.14.
which demonstrated that the probability of detecting the correct diagnosis of non-traumatic hypotension increases from 50%–80%, with early TTE, performed by ED-physicians. Furthermore, Haji et al. presented four studies regarding POC TTE performed by anaesthetists in the peri-operative settings of non-cardiac surgery. Here, change in management (e.g., changes in anaesthetic technique, cancellation of surgery or referral to comprehensive pre-operative echo) ranged from 43%–82% of patient cases. The accuracy of non-cardiologist-performed TTE is high, with regard to assessment of left ventricular function and the presence of pericardial effusion in critical-care patients, when compared to expert cardiologists. Some studies report a diagnostic agreement up to 96%.

POC-cardiac ultrasound has also been evaluated during life support and peri-resuscitation. In a prospective trial, Breitkreutz et al. found that the use of TTE led to a change in therapy in 89% of patients undergoing cardiopulmonary resuscitation. The use of POC is recommended in the European Resuscitation Council’s guidelines.

Jensen et al. examined the feasibility of the FATE protocol in intensive care and found that new information was added in 37.3% cases, decision-making was aided in 24.5% of cases and supportive clinical information was provided in 35.6% of cases. The study included 227 examinations and 97% of the images were of sufficient quality.

The FATE protocol has been successfully performed using a pocket system in comparison to a high-end cart-based system. When performed in semi-recumbent position, pocket devices showed image quality interchangeable with larger systems. Using FATE protocol, Frederiksen et al. reported improved technical skill among novice examiners, with limited educational intervention of 10 supervised examinations.

Although the use seems feasible, little has been published concerning POC-cardiac ultrasonography, with patient-centred outcomes. A recent published study by Canty et al., addressed the impact of pre-operative focused TTE by anaesthetists, on mortality of hip fracture surgical patients. The authors concluded that the intervention was associated with lower mortality. The routine use of POC-cardiac echocardiography in selected patients undergoing surgery could be a focus for future research. Other focus areas for future research could be cardiac arrest, shock and dyspnoea.

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Point-of-care fast examination

In trauma setting, the focused assessment with sonography for trauma (FAST) POC protocol is used for detection of free intraperitoneal or pericardial fluid. Visualised as hypoechoic black areas, pericardial fluid is diagnosed in the sub-costal view, while free intraperitoneal fluid can be detected around the liver and spleen or in the pelvic area above and around the bladder. The protocol consists of four pre-defined scanning positions: the subcostal cardiac view, the right upper abdominal quadrant, the left upper abdominal quadrant and the longitudinal/transverse bladder view. Time consumption is extremely limited, and in respect to clinically significant intra-abdominal injury in trauma, specificity above 94% and sensitivity above 70% have been reported. The FAST examination is usually performed with cart-based ultrasound systems, but studies with handheld devices have also been published. The European guidelines on education, documentation and maintenance of competence exists and implementation of these have been shown to impact clinicians’ decision-making.

Point-of-care lung ultrasonography

POC-lung ultrasonography targets both pleural and lung tissue pathologies. It holds the potential to diagnose pleural fluid (haemothorax and pleural effusion) and pneumothorax, interstitial syndrome (e.g., pulmonary oedema, lung contusion, pneumonia and adult respiratory distress syndrome) and alveolar consolidation; and can be used to verify correct placement of endotracheal tube. Pleural fluid can be visualised above the diaphragm as a black hypoechoic area. When diagnosing pneumothorax and interstitial syndrome, lung ultrasonography relies on the presence or absence of certain artefacts (e.g., a-lines, b-lines, lung sliding, lung pulse and lung point). It is beyond the scope of this critical review to give a detailed description of all of these artefacts. With regards to pneumothorax; ‘lung-sliding’ is an artefact arising from the close associations and movements of the visceral and parietal pleura during respiration. The absence of lung sliding makes a pneumothorax plausible, and the presence of a ‘lung point’, which appears where the two pleural leaflets intermittently get into contact, is a highly specific sign of pneumothorax. To visualise very subtle movements, motion (M)-mode is usable. Because air collects at the highest point, in 98% of all patients placed supine, the separation of pleura will be found anteriorly on thorax, and examination should begin here. When assessing patients with trauma, ultrasonography has been shown more than twice as sensitive as conventional supine chest X-ray scan in detecting occult pneumothorax, with similarly high specificity (>98%).

Ultrasound-guided vascular access

Ultrasonography can successfully be used as guidance for vascular access, i.e., central- and peripheral-venous catheters and arterial cannulation. Two main approaches are described; the in-plane technique, where the needle travels within the ultrasonographic images and are visualised in its full length, and contra, the out-of-plane technique, where the needle-tip travels in and out of the ultrasonographic images, as the transducer and needle alternately are advanced. The latter is also referred to as the dynamic needle tip positioning (DNTP). Web-based teaching and short-time practical tutorials of ultrasonography-guided vascular access (UGVA) have proven efficient. Recommendations, based on expert consensus, to assist physicians and guide future clinical research have recently been published.

Education

The rapidly increasing availability of POC ultrasonography within clinical practice and the highly user-dependent nature of the technology urge large-scale systematic education. Though educational requirement is present within most specialties, uniquely positioned in dealing with primary ABC patient-assessments and in being specialist in multi-organ pathophysiology, it seems highly relevant that acute care physicians (within emergency medicine, anaesthesiology and intensive care), achieve ultrasonographic skills. Furthermore, the development calls for education of medical students. Several medical faculties have already endorsed ABC ultrasonography. The University of South Carolina, School of Medicine is an example of such an integrated-ultrasound curriculum, across all four years of medical school course.

Recently, the European Society of Intensive Care Medicine (ESICM), in collaboration with 11 critical care societies, published an international expert statement on training standards for critical-care ultrasonography. The panel agreed that general critical-care ultrasonography (covering abdominal, lung, pleural and vascular ultrasound) and ‘basic’ critical-care echocardiography should be mandatory in the curriculum of ICU physicians. POC-cardiac ultrasonography training programmes aimed at non-cardiologists, have been developed in several countries (i.e., Basic FATE Denmark, fast assessment diagnostic echocardiography (FADE) Portugal), following recommendations from several different international ultrasound societies and groups, amongst those the World Interactive Network Focused on Critical care Ultrasound (WINFOCUS). The WINFOCUS group especially points out that a combination of supervised practical training and interactive online learning will facilitate learning at basic level.

Conclusion

The interest in POC ultrasound is rapidly increasing, as is the expansion of equipment. The diffusion of POC ultrasonography will continue...
into the acute care specialties, such as emergency medicine, anaesthesiology and intensive care. With appropriate training as well as quality and competence assurance, optimal use of this technology could lead to a reduction in medical errors, accurate diagnosis, optimal treatment, accurate referral and better overall results. Future research should focus on patient outcome in relation to implementation.

Conflict of interests
Erik Sloth has given lectures for GE of BK-medical and in return received a minor fee.

Abbreviations list
ABC, airway, breathing and circulation; ED, emergency department; FAST, focused assessment with sonography for trauma; FATE, focus assessed transthoracic echocardiography; ICU, intensive care unit; PLAX, parasternal long-axis; POC, point-of-care; PSAX, parasternal short-axis; TTE, transthoracic echocardiography; WINFOCUS, World Interactive Network Focused on Critical care Ultrasound

References