Whole-body ultrasound in the intensive care unit: A new role for an aged technique

Andreas Karabinis MD, PhD, Mariantina Fragou MD, Dimitrios Karakitsos MD, PhD*

Intensive Care Unit, General Hospital of Athens, Athens 11527, Greece

Keywords: Critically ill; Lung echo; Echocardiography; Transcranial doppler; Ultrasound guided techniques

Abstract Management of critically ill patients requires rapid and safe diagnostic techniques. Ultrasonography has become an indispensable tool that supplements physical examination in the intensive care unit. It enables early recognition of neurological emergencies, assists the diagnosis of abdominal and lung pathologies, and provides real-time information on the cardiac performance of critically ill patients. Furthermore, it detects possible infectious sites and renders therapeutic invasive procedures more convenient and less complicated. Whole-body ultrasound in the hands of adequately trained intensivists has the ability to reinvigorate the physical examination, without subjecting the patient to excessive irradiation and the risks of transport.

© 2009 Elsevier Inc. All rights reserved.

1. Introduction

As the field of critical care medicine has grown, so has the need for rapid and accurate diagnosis of the pathologies observed in critically ill patients. Eventually, this has led intensivists to seek other tools, besides their stethoscope, to cope with the difficulties of routine practice. Although ultrasound was first introduced in the 1950s, its numerous applications in the intensive care unit (ICU) became evident recently. The main reason for its growing popularity is that ultrasound represents a safe and easily accessible by-the-bed examination. In this review, we try to outline the philosophy of whole-body ultrasound adapted to the intensive care setting. This visual approach is characterized by the utilization of simple imaging techniques that enable the rapid optimization of management of critically ill patients.

1.1. Head ultrasound applications

Starting with the head level, transcranial Doppler (TCD) sonography is a technique that measures cerebral blood flow within the intracranial and the extracranial arteries. Transcranial Doppler may be used for the detection of vasospasm in patients with subarachnoid hemorrhage [1], a condition often responsible for the delayed ischemic neurological defects observed in these cases. The American Academy of Neurology Expert Committee provides type A, class II level of evidence supporting the use of TCD in the identification of vasospasm [2]. Transcranial Doppler may be used for the continuous monitoring of the changing cerebral hemodynamics in brain injury [3]. The development of algorithms that estimate cerebral perfusion pressure and intracranial pressure based upon TCD recordings, along with other critical parameters such as cerebral CO₂ reactivity, may assist in adapting different therapeutic strategies in the individual patient with traumatic brain injury.
injury [4]. The early diagnosis of brain death has gained interest because of the advances in transplantation and the growing demand for organ and tissue procurement. Transcranial Doppler has a high specificity for the diagnosis of cerebral circulatory arrest [5]; hence, it may be used as a confirmatory test of clinically established brain death. At the head level, 2 basic applications are the use of optic nerve sonography and the bedside evaluation of maxillary sinusitis in mechanically ventilated patients. Several reports suggest that measurements of increased maxillary sinusitis could alert clinicians for the presence of increased intracranial pressure in children and adults with brain injury [6,7]. Ultrasound diagnosis of maxillary sinusitis could avoid referral to computed tomography (CT) of a febrile ICU patient and guide transnasal puncture [8,9].

### 1.2. Lung echography

Another vital organ that can be fully assessed by ultrasound is the lung. Using standardized signs and techniques, it is easy to recognize, in most cases, a normal lung pattern that comprises lung sliding and horizontal artifacts called A lines [10]. Virtually all major lung pathologies of critically ill patients can be visualized [11]. A pleural effusion appears as a dependent dark zone free of echo on a longitudinal view; and the lung, as a bright pleural line if it remains aerated [12].

The former may provide a basic static sign (square root) and a dynamic sign (sinusoid sign), which both indicate that the image is located outside the lung. Alveolar consolidation is a fluid lesion that provides a tissue-like image and the absence of the sinusoid sign representing the behavior of a solid lesion. The above lung signs are fundamental in general chest ultrasound and may also aid in the imaging analysis of data provided by transthoracic echocardiography in mechanically ventilated patients such as mobile echocardio-

Ultrasound examination enables safe thoracic drainage and placement of thoracic tubes [14]. In pneumothorax, the normal lung pattern (lung sliding and/or the presence of vertical B lines) is replaced by the pneumothorax pattern (absent lung sliding and horizontal A lines). This so-called lung point is a specific sign, and it is easily detected in time motion mode [15,16]. Furthermore, multiple B lines 7 mm apart are caused by thickened interlobular septa and represent interstitial edema, whereas B lines 3 mm or less apart are caused by ground-glass areas and characterize alveolar edema [17]. The above signs are useful in the differential diagnosis of pulmonary edema from an exacerbation of chronic obstructive pulmonary disease [17].

Massive loss of lung aeration seen in lobar bronchopneumonia, massive lung edema, pulmonary contusion, and lobar atelectasis is visualized in ultrasound as a hypoechoic tissue structure, wedge shaped and poorly defined [18]. Sometimes, hyperechoic punctiform images can be seen too, corresponding to air bronchograms [19]. Hence, the clinician is provided with real-time imaging information to evaluate a pleural effusion, rule out or in pneumothorax, and identify cardiogenic pulmonary edema. This may decrease the irradiation of CT and avoid transport of a patient with acute respiratory distress syndrome.

### 1.3. Echocardiography

Successful management of critically ill patients requires optimization of their cardiac performance and intravascular volume [20]. Transthoracic echocardiography may provide invaluable information for cardiac structure and function. Due to the fact that several factors may hinder the quality of transthoracic echocardiography in mechanically ventilated patients, the application of transesophageal echocardiography (TEE) is rather popular in the ICU [21,22]. Echocardiographic and ultrasound studies may assist to identify the cause of hemodynamic instability and, hence, to adapt therapy such as fluid administration and inotropic or vasoconstrictor agent infusion [23,24]. Echocardiogra-

Echocardiography and ultrasound studies may assist to identify the cause of hemodynamic instability and, hence, to adapt therapy such as fluid administration and inotropic or vasoconstrictor agent infusion [23,24]. Echocardiography provides information regarding left ventricular systolic and diastolic function, global ejection fraction and ventricular filling pressures, the causes of acute right ventricular overload under mechanical ventilation, and data concerning the general volume status [25-30]. The latter could be combined with ultrasound studies of the variation of the diameter of the inferior vena cava with respiration and thus aid in determining the preload [31]. Unusual conditions such as dynamic LV obstruction, an entity causing paradoxic worsening of hypotension after intra-

ventricular volume loading [32], represent only examples of the diagnostic capabilities of echocardiography in experienced hands. However, let us underline that there are no gold standards to evaluate the intravascular volume and, hence, to achieve optimization of fluid therapy by means of echocardiography.

Despite the limitations of echocardiography, its role in emergency settings is invaluable. Echocardiographic diagnosis of cardiac tamponade revealing pericardial effusion and diastolic collapse of the right atrium [33] or the right ventricle [34] approaches 100% sensitivity, and pericardio-

centesis can be performed safely under ultrasound guidance [35]. In particular, TEE is useful for evaluation of suspected aortic dissection [36,37], prosthetic heart valves (especially in the mitral position), source of cardiac emboli, valvular vegetations in infective endocarditis [38], and possible intracardiac shunts, using contrast studies. Finally, TEE-guided cardioversion of patients with atrial fibrillation, especially in postoperative cardiac surgical patients, has a proven efficacy [39]. The application of echocardiography requires adequate training and a great amount of experience especially when performed by noncardiologists.
1.4. Abdominal ultrasound

Immediately after trauma, ultrasound may assist the clinician with a focused goal-directed examination that could confirm life-threatening diagnosis, such as hemoperitoneum. The Focused Assessment With Sonography for Trauma protocol has become routine in the management of blunt abdominal trauma [40,41]. Four torso regions, pericardial, perisplenic, perihepatic (Morison pouch), and pelvic (pouch of Douglas), are examined, and pericardial, intra-abdominal fluid, or organ damage may be identified. Let us underline that the above protocol may be difficult to apply in all cases and especially in obese patients. Furthermore, a number of different intra-abdominal pathologies, either primary or secondary, such as cirrhosis, fatty liver disease, abscesses, ruptured tumors, infected cysts, and lacerations, can be detected by ultrasound [42]. Acute cholecystitis may be depicted by characteristic ultrasound images, whereas acalculous cholecystitis is oftentimes a challenging diagnosis in the ICU [43]. Although CT is considered the imaging modality of choice for abdominal pathologies, ultrasound represents a fine alternative [43]. The list of abdominal ultrasound applications is vast, including diagnosis of pneumoperitoneum [44], aortic aneurysms, and mesenteric infarctions. Finally, ultrasound has a role in the diagnostic workup of acute renal failure and of thromboembolic disease [45,46]. Apart from the Focused Assessment With Sonography for Trauma protocol, a more detailed ultrasound approach of intra-abdominal pathologies requires a considerable amount of expertise, and hence, formal training is necessary.

1.5. Ultrasound-guided interventions

Sepsis is a major clinical concern in critical care patients. Ultrasound detection of sources of infection could enable better management and prognosis [47]. Using a whole-body ultrasound approach, we could visualize and perform guided interventions on infectious sites [47]. Also, ultrasonography has proven to be helpful in many techniques traditionally performed blindly by physicians. The fact that ultrasound-guided central venous cannulation is advantageous as performed blindly by physicians. The fact that ultrasound has proven to be helpful in many techniques traditionally complications, is well documented [48-50]. Internal jugular vein catheterization has been studied extensively [51], but the subclavian and femoral vein sites, as well as the radial artery, are also accessible by ultrasound guidance [52-54]. Recently, in anesthesia, regional blocks for pain therapy and sympathetic blockade are performed with ultrasound techniques, improving the outcome of patients [55,56]. Percutaneous drainage of fluid collections becomes more convenient and less complicated under ultrasound guidance [57,58]. Other studies describe promising applications, including ultrasound verification of feeding tubes [59], endotracheal tube placement [60], and guided percutaneous tracheostomy [61].

1.6. Concluding remarks

Ultrasoundography is a powerful tool in the hands of the modern intensivist [2,6,13,17,18,21,23,27,30,47,51,56]. However, formal training is clearly required before the intensivist is able to use ultrasonography in a reliable fashion. Is there a time to discuss the necessity of including standard teaching of basic ultrasound techniques in the ICU training program? This is a serious educational issue that should be discussed by expert academic authorities. The above initiative could lead to a consensus about the training time and the teaching modalities required of such a program for the individual intensivist. Whole-body ultrasound can supplement physical examination and assist a diagnosis rapidly, with minimal cost and without the need for radiation or patient transport. Hence, the ultrasound beam may serve as the intensivist’s “third eye.” It is wise to remember that ultrasound is surely not the “Cyclops’ sole eye.”

References


