Ultrasound and Other Innovations for Fluid Management in the ICU

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KEYWORDS

• Image based resuscitation • Ultrasound • Echocardiogram

KEY POINTS

- Ultrasound is a user-dependent tool that can help guide therapy.
- The use of ultrasound to guide central line placement decreases complication rates.
- Cardiac ultrasound can help with the diagnosis of cases of hypotension.
- Lung ultrasound and pleura ultrasound are useful adjuncts for diagnosis causes of desaturation.
- Abdominal ultrasound can help in rapid visitation of fluid and intra-abdominal structures.

INTRODUCTION

Guiding therapy for a rapidly deteriorating patient continues to be an issue of interest in critical care. Having a tool that can aid in the decision making to treat shock expeditiously can be lifesaving in some instances. Please see Bracken A. Armstrong and colleagues' article, "Sepsis and Septic Shock Strategies," in this issue, for a discussion on the uses of ultrasound to rapidly diagnose causes of deterioration and guide therapy.

ULTRASOUND TO GUIDE THERAPY IN THE ICU

Ultrasound has been introduced in the past couple decades as a tool to guide therapy for critically ill patients.[1] The advantages of this technique are that it offers imaging immediately, it is portable, and it does not carry ionizing energy; therefore, the consequences of repeating the test are minimal.[2] It is, however, operator dependent. Because it is a diagnostic modality that depends on the transition of sound waves into the tissues, anything that interferes with the sound waves can result in poor

The authors have nothing to disclose.
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Surg Clin N Am 97 (2017) 1323–1337
http://dx.doi.org/10.1016/j.suc.2017.07.009 surgical.theclinics.com
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visualization. Air is not a good conductor of sound; large individuals can be more difficult to image as well as patients with subcutaneous edema and emphysema.[3]

The use of this tools extends from guiding procedures to volume status assessment. This article describes the basics of and technique for performing the test on each organ system.

FUNDAMENTALS

Ultrasound is a mechanical wave that requires a medium to travel. In the case of diagnostic ultrasound, these waves travel through human tissue.[2,4,5] Fluid is a good conductor of ultrasound and can provide a good interface to visualize organs around what otherwise is not visible. An example of this is visualizing the lung in the presence of a pleural effusion.

Ultrasound machines consist of electric pulse generators, transducers, systems for processing received echoes, and image display screens. The key elements of transducers (probes) are piezoelectric crystals, matching layers, backing material, cases, and electrical cables.

There are several transducer types. This article discusses phased array, linear array, and curved array.

The cardiac probe or phased array transducer has a low-frequency capacity and more penetration to tissues (2–4 MHz on average). It also has small footprints that produce images of sector format through small acoustic windows (eg, cardiac and cranial applications). Because these probes have more crystals than a curvilinear probe, the image is crisper. If an operator does not have a curvilinear probe, the phased array transducer can be used to obtain abdominal images as well.

Linear array transducers are traditionally used to visualize superficial structures because of their higher frequency and lower penetration (7–15 MHz in average). These probes are also useful to evaluate muscle and the pleura (**Fig. 1**).

Curvilinear transducers are optimal for abdominal imaging. They have lower frequencies and higher penetration (2–6 MHz). It is hard to place these probes in the thoracic cavity since their shape against the ribs. If an operator does not have a cardiac probe, however, these can also be used for cardiac visualization.

B mode refers to brightness. It uses the amplitude of the reflected ultrasound signals, which is converted into a gray-scale image. M mode measures the movement of structures along a single line (axis of the ultrasound beam). It is useful in evaluating heart wall or valve motion (echocardiography), hemodynamic status (inferior vena cava [IVC] diameter and motion), and lung sliding or movement of the diaphragm.

Doppler mode measures changes in frequency caused by sound reflections off a moving target (Doppler effect), usually blood, in common bedside practice. There are different versions of Doppler mode, including Doppler duplex, continuous-wave Doppler, and pulsed-wave Doppler[6–11] (**Fig. 2**).

VASCULAR ULTRASOUND

Ultrasound is used in many settings in critical care medicine in evaluating, diagnosing, and treating vascular disease. Ultrasound is essential in the ICU for procedures done with its guidance for safer and more efficient patient care.

Arterial

Aorta

Although CT scan is currently the confirmatory study to evaluate for aortic pathology, ultrasound can be used to visualize many different aortic disease processes and often is a useful adjunct in its work-up.

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