Point-of-Care Ultrasound in the Intensive Care Unit

Steven J. Campbell, MD[a], Rabih Bechara, MD[b], Shaheen Islam, MD[a,*]

KEYWORDS

• Ultrasound • Critical care • Point-of-care • Thoracic ultrasound • Cardiac ultrasound

KEY POINTS

- Point-of-care ultrasound has vast potential and is generally underused in the critical care setting.
- The rapid and portable nature of ultrasound makes it an ideal tool to help guide decision making in time-sensitive scenarios.
- As professional societies continue to formulate and adapt training protocols or standards in ultrasound, it is rapidly becoming an indispensable tool for the intensivist.

Video content accompanies this article at http://www.chestmed.theclinics.com/.

INTRODUCTION

Point-of-care (POC) ultrasound in medical intensive care units (ICUs) is increasingly used, to the extent that many intensivists now consider it the modern form of the stethoscope.[1] Further enhancing this claim is the increased portability of ultrasound because several current models are marketed as handheld units (**Fig. 1**). Although ultrasound has been recognized as an invaluable bedside tool for several decades, its rapid ascent arguably started within the emergency medicine community around 2008, when it was recognized as a fundamental component of resident training and education.[2] Not far behind came the critical care community with similar endorsements by several professional societies around the world.[3] In 2009, the American College of Chest Physicians (ACCP) endorsed competency in critical care ultrasound as an important component to the intensivist's skillset.[4] An expert panel through consensus opinion delineated 4 domains of a bedside critical care ultrasound examination, including cardiac, thoracic, pleural, and vascular. In 2015, the Society of Critical Care Medicine (SCCM) put forth a comprehensive set of guidelines for use of ultrasound in the ICU.[5] The SCCM guidelines cover a wide range of applications, spanning each of the 4 domains previously outlined by the ACCP. As a further example of the push toward moving ultrasound into the forefront of the ICU, the National Board of Echocardiography now offers a national-level certification in advanced critical care echocardiography that was previously only available to fellowship-trained cardiologists.[6] The impact of POC ultrasound on clinical diagnosis and decision-making, especially in regard to cardiac function and fluid status, is substantial. One report showed that up to 25% of cases had the initial diagnosis altered based on ultrasound findings.[7]

A basic understanding of the underlying physical principles of ultrasound is important to help

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[a] Section of Interventional Pulmonology, Division of Pulmonary, Critical Care and Sleep Medicine, Ohio State University Wexner Medical Center, 201 DHLRI, 473 West 12th Avenue, Columbus, OH 43210, USA; [b] Cancer Treatment Centers of America, Southeastern Regional Medical Center, 600 Celebrate Life Parkway, Newnan, GA 30265, USA
* Corresponding author.
E-mail address: shaheen.islam@osumc.edu

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Fig. 1. Portable ultrasound unit (iViz, Fujifilm SonoSite Inc, Bothell, Washington, USA) featuring a 7-inch touchscreen, interchangeable probes, and weighing only 1.1 lb.

interpret the image output. Ultrasound machines use piezoelectric crystals to generate sound waves that are emitted from a transducer. The ultrasound waves are above the human threshold of hearing at 20 kHz, whereas most medical ultrasound emits waves at 2 to 15 MHz. As the ultrasound waves pass through various structures, they are reflected back to the transducer, which is able to convert mechanical vibrations to an electrical signal and vice versa.[8] Another important concept is that as sound travels through a medium it will become attenuated or weakened. Tissue density also affects attenuation, with different types of tissues classified according to their attenuation coefficient. For example, water has a very low attenuation coefficient, thus making it an excellent acoustic window. Higher frequency sound waves will attenuate faster, whereas lower frequency sound waves can penetrate deeper before the image quality will suffer. These concepts formulate the basis of different probe options available for the user, primarily including the linear array, curvilinear array, and phased array (Fig. 2). The linear probe has a linear sequence of piezoelectric crystals emitting a higher frequency of 7.5 to 10 MHz, thus allowing higher resolution for superficial applications such as vascular access. The curved array, also referred to as the abdominal probe, emits lower frequency sound waves of 2 to 5 MHz through linear arrays shaped into convex curves that grant a larger field of view. This allows visualization of deeper structures, which is useful in examining large pleural effusions or ascitic fluid collections. Finally, phased array transducers, or sector probes, also emit soundwaves at 2 to 5 MHz and provide a good view of deeper structures similar to the curvilinear probe. The phased array is smaller, thus in certain instances may be favored; for example, visualizing pleural effusions through tight rib interspaces in smaller patients. Additionally, for cardiac ultrasound, the phased array is the probe of choice. A more in-depth discussion of ultrasound physics is beyond the scope of this article but can be found elsewhere.[9]

As with other technical skills, there is a learning curve with bedside ultrasound before the operator can safely make diagnostic and therapeutic decisions based on the acquired images. Manipulation of the transducer to obtain ideal images is often the rate-limiting step for novices because small adjustments can alter the picture dramatically. The fundamental transducer movements have been codified into 6 elements: slide, rock, sweep, fan, compression, and rotation (Fig. 3).[10] Experienced operators have the vocabulary with which to communicate to the novice user how to improve their image quality. Furthermore, operators should also be comfortable with the appropriate use of the gain and depth knob adjustments. The Accreditation Council for Graduate Medical Education (ACGME) mandates the incorporation of ultrasound into critical care fellowship training.[11] The ACGME explicitly mentions trainees' competence in ultrasound use for line placement and thoracentesis. A recent survey of academic centers found that there is a paucity of formal ultrasound

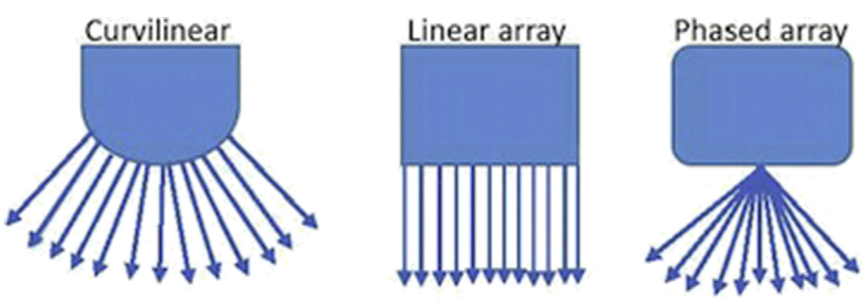

Fig. 2. Different types of ultrasound probes. Note that all sound waves are traveling in different directions on a paper-thin plane to create a 2-dimensional image of structures on that plane.