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Evidence and Practicality of Real-Time Ultrasound-Guided Procedures in the Intensive Care Unit: A New Skill Set for the Intensivist

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Introduction

Over the past few decades, ultrasonography has become an increasingly popular method of imaging in various clinical settings, from rapid assessment of patients who are critically ill to real-time visualization of invasive procedures. This increasing utility of ultrasonography can be largely contributed to its ability to visualize blood vessels and organs with little to no risk for the patient, which reduces the need to rely on subjective experiences with procedures. For example, compared with central venous cannulation through anatomical landmark palpation, ultrasound-guided cannulation is associated with a significantly lower rate of overall and first-attempt failures in adults as well as significantly fewer complications and less time to venous access.[1] Ultrasound guidance, however, is not without limitations, as it has variable utility based on the operator's proficiency.

Current Limitations

Despite the numerous advantages of ultrasound-guided procedures, some current limitations can impact their effectiveness. The major limitations are related to training and operator error and variability. Other limitations include, but are not limited to, poor acoustic window or anatomy for ultrasound, ultrasound accessibility, and limitations in spatial resolution.[2] With more widespread use of ultrasound and point-of-care ultrasound, discussions around establishing standard education, a definition of competency, and quality assurance programs also apply to ultrasound-guided procedures.[3] Various institutions provide training and certification, including the National Board of Echocardiography's Critical Care Echocardiography certification. However, standardized training and evaluation of actual performance of the ultrasound are still lacking. Therefore, standardized training methods and evidence-based assessments of competency, such as the Interventional Ultrasound Skills Evaluation,[4] are crucial in reducing inconsistent utility across operators.

Recent Developments

Although ultrasonography has been mostly used for vascular access, paracentesis, pericardiocentesis, and thoracentesis, it has also increasingly been used on other organs and their related procedures (Table I). For example, ultrasound-guided procedures involving the airways; the ears, nose, and throat; the musculoskeletal system; and neuraxial and peripheral nerves have been evolving and more widely used across multiple specialties. The noninvasive, relatively safe, and more portable nature of ultrasound has technology led to its adaptation in these various procedures.[5] Furthermore, the use of biplane mode and the ability to evaluate multiple axes make ultrasonography

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advantageous for these procedures. The use of biplane mode has been shown to have a greater overall success rate even among novice practitioners,[6] and its impact on safety and efficiency is continuously being investigated.[7]

Bedside ultrasound guidance is also being increasingly used in mechanical circulatory device placement and management. Transthoracic subcostal and parasternal views can assist in extracorporeal membrane oxygenation (ECMO) cannulation, positioning, and management. Parasternal views can assist in Impella (Abiomed) device positioning and management[8] (Fig. 1). Although challenging, the intra-aortic balloon pump can also be visualized and positioned using suprasternal notch view. Transesophageal echocardiography is easier for visualizing the mechanical support devices, but because of its invasiveness and the need for sedation, it is not as widely adapted for use in the intensive care unit as is transthoracic echocardiography. Transhepatic views, which are obtained from the right lateral side of the patient,[9] can be used in ECMO cannulation and positioning and left ventricular assistance device visualization (Fig. 2).

Future Directions

The safety and benefits of ultrasound-guided procedures have been well documented over the years. Ultrasound technology has improved, and the mobility of the devices allows more physicians to use and perform ultrasound-guided procedures. Several applications are currently being studied or developed, including robotics, automation, artificial intelligence, and augmented reality. Recently, the use of augmented reality–assisted ultrasonography, compared with standard ultrasonography, has been associated with favorable learning curves for image-guided biopsies among novice operators, with no significant difference in time to puncture.[10] Such technological advancements are not foreign to nonmedical fields and are already widely used in some medical fields. Real-time 3-dimensional imaging can increase the precision and accuracy of procedures, decrease complications and margin of error, and provide remote assistance, ultimately increasing access to these procedures.[11,12] Ultrasound-guided procedures will continue to play a significant role in medicine, and the technology will continue to evolve and improve in the coming years.

TABLE I. Ultrasonography-Guided Critical Care Procedures

Procedures
Central venous access
Peripheral intravenous access
Arterial catheter placement
Pericardiocentesis
Paracentesis
Endotracheal intubation
Chest tube placement
Lumbar puncture
Tracheostomy
Cricothyrotomy
Peripheral nerve blocks
Joint injections

Abbreviations and Acronyms

ECMO extracorporeal membrane oxygenation

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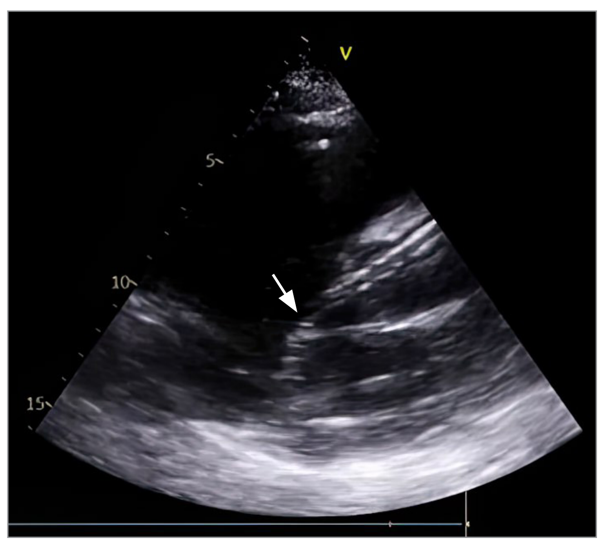

Fig. 1 Ultrasound image with a parasternal long-axis view shows an improperly positioned Impella (arrow), which is causing suctioning of the anterior mitral valve leaflet.

Supplemental motion image is available for Figure 1.

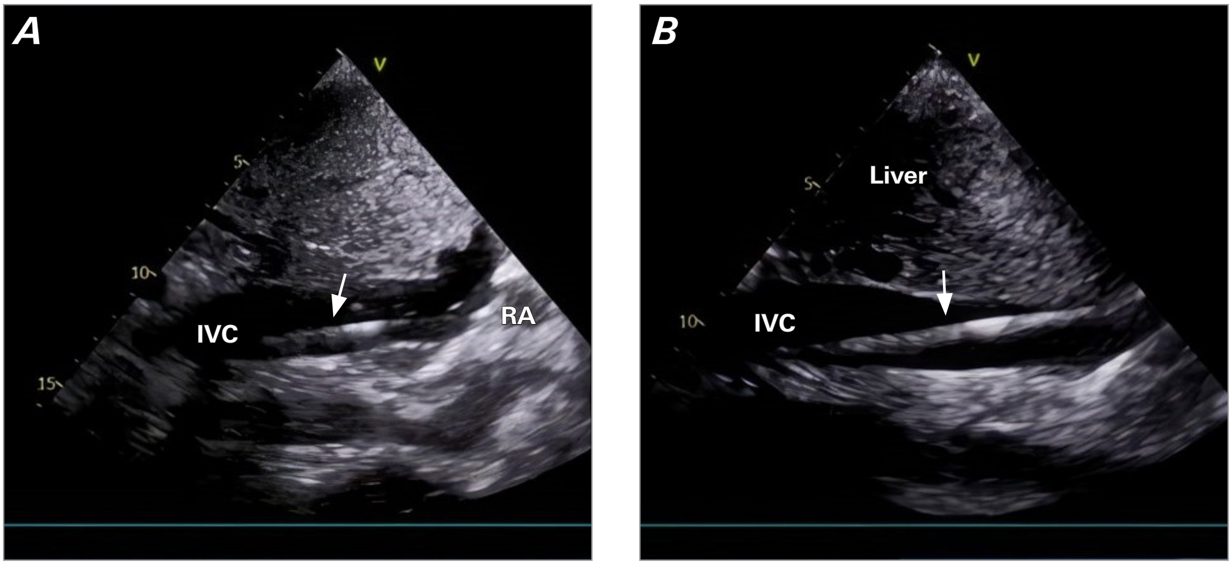

Fig. 2 Transhepatic view during venous cannula extracorporeal membrane oxygenation cannulation. The IVC is visualized in transhepatic view. The ultrasonographic image shows **A**) wire (arrow) placement in the IVC toward the right atrium, not the hepatic vein (asterisk) and **B**) the venous cannula (arrow) positioned correctly in the IVC.

IVC, inferior vena cava; RA, right atrium.

Supplemental motion image is available for Figure 2B.

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