Advanced Echocardiography for the Critical Care Physician

Part 1

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This is the first of a two-part series that reviews advanced critical care echocardiography (CCE) techniques designed for critical care physicians. In this section, we review training in basic and advanced CCE. This is followed by a review of Doppler principles, including pulsed wave, continuous wave, and color flow Doppler. Included are Doppler measurement techniques that are useful for assessing the patient with cardiopulmonary failure and the common pitfalls of Doppler. This section ends with a review of the quantitative and semiquantitative measurements of stroke volume, as well as problems with measurement of stroke volume in the ICU and its useful clinical applications. Video-based examples will help demonstrate the techniques that are described in the text.

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Abbreviations: CCE = critical care echocardiography; CFD = color flow Doppler; CWD = continuous wave Doppler; LV = left ventricular; LVOT = left ventricular outflow tract; NBE = National Board of Echocardiography; PWD = pulsed wave Doppler; SV = stroke volume; TTE = transthoracic echocardiography; VTI = velocity time integral

Echocardiography enables the intensivist to assess the patient with hemodynamic failure. The examination allows the clinician to categorize the shock state and to develop an effective management strategy. Early and repeated echocardiography is a valuable tool for the management of shock in the ICU, and the frontline intensivist should consider skill at bedside echocardiography to be a key element of their training.[1]

The American College of Chest Physicians/Société de Reanimation de Langue Française statement of competence in critical care ultrasonography divides critical care echocardiography (CCE) into two parts: basic and advanced.[2] Competence in basic CCE is a mandatory component of skill in general critical care ultrasonography. Depending on their interest and the requirements of their ICU practice, some frontline intensivists will want to develop competence in the field of advanced CCE.

Basic vs Advanced CCE

Performance of the basic examination requires that the clinician have skill in image acquisition, image interpretation, and clinical application of a limited number of echocardiographic views. The examination can be performed in several minutes, is limited in scope, goal directed, and can be repeated as often as the clinical situation warrants. Competence in basic CCE is readily achieved with a short course of training.[3,4]

Similar to basic CCE, advanced CCE requires a high level of skill in all aspects of image acquisition and interpretation. Mastery of advanced CCE means that the intensivist has a skill level that is similar to a cardiology-trained echocardiographer, although with additional skill in image acquisition at the bedside and more knowledge of relevant critical care applications.

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Advanced CCE avoids the time delays and clinical disassociation that are intrinsic to standard echocardiography, as the examination is performed by the intensivist who has full knowledge of the patient's clinical condition. The advanced CCE examination is flexible in scope, becoming as goal directed or comprehensive as the situation demands. It can be performed immediately and repeated as often as required, an approach that contrasts with the traditional practice of performing a comprehensive exam that is often delayed and rarely repeated.

Training in Advanced CCE

Achieving competence in advanced CCE is challenging and time consuming. It should be regarded as an optional part of critical care practice, unlike competence in basic CCE. The intensivist must develop a comprehensive knowledge of cognitive elements of the field that may be found in standard literature.[5,6] In addition, the intensivist must have definitive training in image interpretation. This requires considerable time spent interpreting a large number of full echocardiographic studies under the direct supervision of an expert level reader. Unlike the cardiologist who relies on highly skilled technicians for image acquisition, the intensivist must spend many hours personally performing full echocardiographic studies. High-level skill at image acquisition is a requirement for advanced CCE.

Part of competence in advanced CCE is that the intensivist understands the limitations and unique applications relevant to their skill set. For example, diagnosis of complex congenital heart disease, guidance of intraoperative valve repair, or detailed analysis of artificial valve function requires an echocardiographer with expertise in these areas. However, determination of preload sensitivity by real-time measurement of stroke volume (SV) variation or straight leg raising, identification and treatment of adverse heart-lung interactions related to ventilator settings, or integration of lung ultrasonography into echocardiographic results are areas where intensivists have expertise.

A recent statement described training standards for both basic and advanced CCE.[7] The working group held that advanced CCE required a formal certification process, given its complexity. In the United States, there is no formal method for certification in advanced CCE at the national level. The National Board of Echocardiography (NBE) offers certification in echocardiography only to physicians who have completed cardiology fellowship training. An alternative approach that intensivists may follow is to satisfy the American Heart Association/American College of Cardiology requirements for competence in echocardiography[8] and then to take the NBE Examination of Special Competence in Adult Echocardiography. Many cardiologists choose not to take the NBE echocardiography examination, and prefer to satisfy the American Heart Association/American College of Cardiology requirement for competence in the field (which does not require passing the NBE examination). Although they are optional, we recommend that the interested intensivist takes the echocardiography board examination, as it is a clear demonstration of a comprehensive knowledge base.

This article will review some important aspects of advanced CCE. These include measurement of SV, evaluation of left ventricular (LV) function, identification of segmental wall abnormalities, measurement of left-sided filling pressures, evaluation of right-sided heart function, and identification of preload sensitivity. This article will not review the evaluation of valvular function using advanced CCE techniques, as this requires a separate discussion. The primary focus is on measurements that are made with transthoracic echocardiography (TTE) and will not include a comprehensive discussion of transesophageal echocardiography. Illustrative video clips are found throughout the text and are a key element of the article. The reader is encouraged to be connected to the *CHEST* video supplements and to call up the video images in sequence with the text. This will greatly augment the utility of the article. This article is not a comprehensive review of the subject; the emphasis will be on measurements that have immediate practical application and that can be performed rapidly at the bedside of the critically ill patient.

Principles of Doppler

Advanced CCE requires comprehensive knowledge of Doppler measurements. It is beyond the scope of this article to review in detail the physical principles of Doppler measurements. For this information, the reader is referred to comprehensive discussions that are found in standard texts.[9] Instead, this section will summarize some key concepts and limitations of bedside Doppler measurements.

The Doppler phenomenon occurs when the sound source (the transducer) and the object reflecting the source (blood cells or myocardium) are moving relative to one another as opposed to the case where the transducer and the reflector are both immobile. In the case of moving reflectors, the frequency of the returning sound wave will be different than the transmitted wave. The Doppler equation uses the measured frequency difference between the transmitted and reflected sound waves to derive the velocity of the reflector. In this way, the velocity and direction of blood flow may be measured within the cardiovascular system. The angle of incidence between the direction