Cardiac Point-of-Care Ultrasound: State of the Art in Medical School Education

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The development of small, user friendly, handheld ultrasound devices has stimulated the growth of cardiac point-of-care ultrasound (POCUS) for the purpose of rapid, bedside cardiac assessment. Medical schools have begun integrating cardiac POCUS into their curricula. In this review the authors summarize the variable approaches taken by several medical training programs with respect to duration of POCUS training, prerequisite knowledge, and methods of delivering these skills (including e-learning, hands-on training, and simulation). The authors also address issues related to the need for competency evaluation and the limitations of the technology itself. The studies reviewed suggest that undergraduate education is a viable point at which to introduce basic POCUS concepts. (J Am Soc Echocardiogr 2018;■:■-■.)

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Cardiac point-of-care ultrasound for the purpose of rapid, bedside cardiac assessment has changed practice. A cardiac ultrasound study performed at the point of care in this manner is distinct from transthoracic echocardiography (TTE), which is a formal diagnostic test with a particular billing code, a standardized protocol, an advanced analytic component, and archiving and documentation requirements defined by rigorous accreditation standards for acquisition and reporting (Table 1).[3] Although cardiac POCUS does not yet have such a body of literature and quality programming underpinning its performance, it may complement TTE in an integrative manner not only by accelerating the identification of disease but also by enhancing the physical examination and as a teaching tool for understanding cardiac anatomy and physiology.

The utility of cardiac ultrasound as a teaching tool is of particular interest to medical school educators. Many medical schools have begun to incorporate novel teaching protocols that include cardiac ultrasound in their curricula. The American Society of Echocardiography (ASE) also defined its position by stating that POCUS may be viably integrated into medical school curricula and may be used by noncardiologists and nonsonographers.[4] However, at this time, there is no standardized curriculum or universal testing benchmark for cardiac ultrasound at this level. Although the ASE is currently in the midst of developing such a recommended curriculum, the intent of this review is to summarize published reports to date of medical schools reporting their experiences in teaching cardiac POCUS. The intent is not to develop a training guideline but to summarize the literature that would underpin such a future effort.

For the purposes of this review, POCUS refers to the cardiac setting. Other terms used in the literature referring to cardiac POCUS include *focused cardiac ultrasound* and handheld cardiac ultrasound (HHU). We do not use the terms *mini-echocardiography* nor *pocket echocardiography*, in order to distinguish POCUS from limited standard TTE, which is a test that can be converted to a full protocol during the course of the study by a trained operator as dictated by the lesion encountered (Table 1). Formal standard TTE has a body of literature associated with appropriateness, quality control, accreditation, archiving, and certification that is beyond the scope of this review.

WHAT DO WE TEACH? CURRENT GOALS OF CARDIAC POCUS MEDICAL SCHOOL EDUCATION

The ASE and the European Association of Echocardiography both assert that POCUS should not be considered as a substitution for either the clinical examination or standard echocardiography.[2,5] Rather, such scans should be demonstrated to provide diagnostic value when used as adjuncts to a clinical examination.[6-9] Because fundamental clinical examination skills have been shown to develop during medical school, POCUS training during this time may therefore have the most significant impact.

An overview of the current literature demonstrates significant variability in the design of the curricula used by medical schools, ranging from no teaching to highly extensive teaching in all years and all blocks of education. When used by most medical schools, the overall goals of teaching POCUS appear to be summarized as follows: (1) introduction of the concept of ultrasound relatively early in medical education, including demonstration of common imaging views, correlation with anatomy, and physical examination skills; (2) development of scanning

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Abbreviations

ASE = American Society of Echocardiography

HHU = Handheld cardiac ultrasound

OSAUS = Objective Structured Assessment of Ultrasound Skills

POCUS = Point-of-care ultrasound

TTE = Transthoracic echocardiography

techniques to a basic level of competence; and (3) recognition and differentiation between normal anatomy and basic pathology.

With these goals in mind, the majority of studies introducing POCUS education to medical students have stressed curricula intended to educate students in making qualitative diagnoses of specific pathologies (such as the presence or absence of pericardial effusion) and developing scanning technique, as opposed to making quantitative diagnoses of severity.[6-8,10-13] In some studies, image acquisition and scanning technique using handheld devices took precedence over the recognition of specific pathologies. A preliminary curriculum created by Ho *et al.*[13] focused primarily on teaching fundamental POCUS theory and image acquisition and only briefly focused on clinical pathologies and diagnosis. Their curriculum was justified with the notion that diagnosis and interpretation require extensive time and clinical experience to acquire, whereas HHU technique and image acquisition can be learned within a brief training program. Eighty-two percent of the students enrolled in the study were deemed successful in their ability to acquire the correct images, whereas image interpretation was only lackluster. In contrast, some studies implemented educational goals aimed equally at image acquisition and quantitative diagnosis.[14-16]

Beyond the performance of image acquisition, some schools use cardiac POCUS and general ultrasound teaching to facilitate the learning of basic cardiology concepts such as the physical examination in the medical school curriculum. One such application is the use of POCUS to assess right atrial pressure through visualization of the inferior vena cava, analogous to the physical examination technique of jugular veins.[17] Visualization of cardiac valve structure and function may also allow the teaching of auscultation and differentiation of cardiac murmurs and heart sounds.[18]

Summary. Currently, medical schools are using cardiac ultrasound to teach anatomy, physical examination, and basic image acquisition and to introduce recognition of simple disease pathology such as pericardial effusion and valvular regurgitation.

WHEN DO WE START? PREREQUISITE KNOWLEDGE BEFORE POCUS TEACHING

Creating a time frame for introducing POCUS education depends on consideration of prior knowledge. For example, an upper-year student with prior education in cardiology and/or ultrasound imaging would have an advantage over a novice first-year student without

Table 1 Comparison of POCUS and traditional TTE, with a brief overview of technological capabilities and limitations, indications for techniques, and operators

	POCUS	TTE
Operators	Typically • Nonsonographer • Nonradiologist • May be conducted by traditional expert (ePOCUS)	• Level II, level III echocardiographer (physician)[1] • ARDMS (sonographer) • Credentialing laboratory
Indications	Assessment of • Valvular function (gross) • Pericardial effusion/tamponade • LV function/thickness • RV function • IVC • Expert consensus available[2]	• Wide spectrum • See available published guidelines*
Technological capabilities	• Usually portable (<15 lb) • 2D imaging • Color Doppler	• Full-service machine • 2D imaging • Color Doppler • 3D imaging • Strain • Pulsed-wave Doppler • Continuous-wave Doppler • Telemetry signal • Contrast can be applied
Advantages	• Portability • Accessibility • Relatively inexpensive compared to traditional TTE machines • Immediacy of results	• "Gold standard" • High-quality images • Standardized guidelines for examination and reporting • Multiple techniques available (3D, strain, contrast) • Archiving of imaging studies
Limitations	• Lack of formal training benchmarks • Paucity of guidelines • Technological limitations	• Portability • Access • Cost of machines greatly exceeds that of portable units

2D, Two-dimensional; *3D*, three-dimensional; *ARDMS*, American Registry for Diagnostic Medical Sonography; *IVC*, inferior vena cava; *LV*, left ventricular; *RV*, right ventricular.
*A list of published ASE guidelines is available at http://asecho.org/ase-guidelines-by-publication-date/.