Point-of-Care Cardiac Ultrasound: Feasibility of Performance by Noncardiologists

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ABSTRACT

Cardiac ultrasound has been used for decades to assess a wide variety of structural and functional pathology, as well as to monitor response to therapy. It offers the advantages of noninvasive, real-time dynamic functional assessment without the risk of radiation. Cardiologists have traditionally employed this modality and have established robust guidelines on the use of echocardiography. However, other specialties such as emergency medicine and critical care have realized the benefit of cardiac ultrasound and have established specialty guidelines in its use. There is growing evidence for the benefit of cardiac ultrasound at the point of care on hospital wards, clinics, and even pre-hospital environments as well. The pervasive use of focused ultrasound is perhaps most evident in the advent of ultrasound training in undergraduate medical curricula. This paper reviews some of the key literature on the use of focused, point-of-care ultrasound by noncardiologists. Feasibility, clinical utility, and emerging trends are reviewed.

POINT-OF-CARE ULTRASOUND EMERGES

The utility of point-of-care ultrasound by noncardiologists has been recognized within the cardiology community for decades. Although early published concerns described a lack of established guidelines for cardiac ultrasound performance by noncardiologists [1], emergency medicine has since published its second set of guidelines on training, interpretation, and use of ultrasound [2], and guidelines have been published by intensivists as well [3]. Goal-directed training can assist clinicians by quickly answering focused questions at the bedside, and this should facilitate a wider range of clinicians using the technology to improve patient care acutely [4]. A 2011 review paper highlighted the growing use of point-of-care ultrasound by clinicians in over 20 specialties [5]. Increased training by clinicians across many specialties, coupled with technology improvements yielding lower cost and better quality studies, have contributed to this trend. In 2010, a joint consensus statement by the American Society for Echocardiography and the American College of Emergency Physicians described the scope of practice for focused cardiac ultrasound in emergent settings [6]. The document outlines the utility of focused cardiac ultrasound and distinguishes this type of assessment from comprehensive echocardiography. The statement describes the major goals of focused cardiac ultrasound:

1. Assessment for the presence of pericardial effusion;
2. Assessment of global cardiac systolic function;
3. Identification of marked right ventricular and left ventricular enlargement;
4. Intravascular volume assessment;
5. Guidance of pericardiocentesis;
6. Confirmation of transvenous pacing wire placement.

These goals play an important role in the assessment of acutely ill patients with cardiac trauma, cardiac arrest, shock or hypotension, dyspnea, and chest pain.

It is important to note that for many specialties employing point-of-care ultrasound, the heart is just part of a broader, symptom-based evaluation. Many studies have described evaluations of acutely decompensating patients that include, for example, assessments of the heart, inferior vena cava, lungs, abdominal organs, and deep veins in a multisystem assessment [7−15]. Just as the heart is not the only organ assessed with inspection or auscultation, it need not be the only organ assessed with sonography, especially in the setting of acute hemodynamic decompensation.

With this global historical background in mind, it is relevant to examine the key literature that brought about this sea change in the practice of cardiac ultrasound by multiple specialties in the house of medicine.

EMERGENCY MEDICINE

Noncardiologists first demonstrated the benefit of goal-directed cardiac ultrasound at the point of care in the 1980s. This paradigm shift from traditional ultrasound imaging allowed clinicians to address a focused clinical question in real time at the bedside. A 1988 study demonstrated the feasibility of cardiac scans performed by emergency physicians in 156 critically ill patients [16]. Patients with nonperfusing cardiac rhythms, hypotension, and trauma were evaluated. The investigators described cases where reversible causes of arrest were discovered, and pathology such as pericardial effusion in trauma was identified early, facilitating definitive care.

In 1992, Plummer [17] described emergency physician−performed ultrasound in patients with suspected

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penetrating cardiac injury. Forty-nine patients were evaluated. Those evaluated with 2-dimensional echo demonstrated 100% survival compared with 57.1% in cases where ultrasound was not employed in the early evaluation. Another study of hypotensive patients randomized to ultrasound versus no ultrasound found the likelihood of arriving at the correct diagnosis was increased from 50% to 80% with the use of ultrasound [8].

Emergency physicians were able to demonstrate pericardial effusion with a sensitivity of 96% and specificity of 98% in another study of 515 emergency department patients at risk for effusion [18]. A prospective study comparing emergency physician assessment of global left ventricular function in hypotensive patients found an interobserver correlation with cardiologists of r = 0.86; this matched the correlation between 2 cardiologists reviewing the same studies (r = 0.84) [19]. In a study of 115 emergency department patients, emergency physician assessment of left ventricular function demonstrated 86% agreement with cardiologist-performed echocardiograms [20]. Central venous pressure measurements demonstrated 70% agreement.

The prognostic value of emergency physician–performed cardiac ultrasound has been demonstrated in several studies. In a study of 70 cardiac arrest patients (including 36 asystole and 34 pulseless electrical activity), 59 were found to have no evidence of cardiac activity on ultrasound. No patient with sonographic asystole survived the acute resuscitation [21]. A larger study of 169 cardiac arrest patients found, regardless of their electrocardiogram rhythm, none of the 136 patients with cardiac standstill on ultrasound survived [22].

CRITICAL CARE

Intensivists have increased interest in bedside cardiac ultrasound over the last decade, often as part of a multisystem hemodynamic assessment [3,23]. A study by Goodkin et al. [24] compared the utility of hand-carried ultrasound versus standard echocardiography in 80 acutely ill patients in the intensive care unit (ICU), stepdown units, recovery room, and emergency department. All ultrasounds were performed by experienced sonographers and interpreted by echocardiographers. Hand-carried ultrasound correctly answered 86% of clinical questions it was configured to evaluate but missed important findings including left ventricular function, native valve function, left atrial thrombus, and a case of cardiac tamponade. The investigators described the primary shortcomings of the hand-carried device as lack of sensitivity of the Doppler feature and image quality problems. Thus, it was unclear whether training, experience, or equipment played the major role in missed diagnosis.

In contrast, a more recent study evaluating hand-carried ultrasound in the hands of hospitalists determined that assessment of common cardiac abnormalities was "moderate to excellent" [25]. In this study, 314 patients underwent cardiac ultrasound performed by hospitalists and the results were compared with standard echo evaluations. Positive (+) and negative (−) likelihood ratios (LR) for major cardiac abnormalities were +LR: 4 to 100, −LR: 0.2 for left ventricular dysfunction; +LR: 7 to 28, −LR: 0 for severe mitral regurgitation; and +LR: 52, −LR: 0 for pericardial effusion assessments. In this study, 2% to 6% of bedside assessments were indeterminate.

Adequate image acquisition was demonstrated by emergency physicians in all 151 patients enrolled in another study of pocket-sized ultrasound devices in an ICU [26]. The investigators found good correlation with conventional echocardiography in assessment of global left ventricular systolic function (kappa = 0.87), severe right ventricle dilation (kappa = 0.87), inferior vena cava dilation (kappa = 0.90), respiratory variation of inferior vena cava diameter (kappa = 0.84), as well as pericardial effusion (kappa = 0.75) and compressive pericardial effusion (kappa = 1.00).

Another study of clinical utility in the ICU assessed a protocol of focused transthoracic echo; adequate images were obtained in 97% of cases. The ultrasound studies added new information in 37.3% of cases and helped medical decision making in almost one-quarter of patients [27]. Assessment of cardiac contractility, effusion, tamponade, and other pathology mirrors common indications in emergency medicine and other acute care environments.

Vignon et al. [28] studied residents in an ICU environment who underwent a focused training program consisting of a 3-h training course and 5 h of hands-on practice. Hand-held echocardiography was then studied in 61 ICU patients, and the ability of residents to address clinical questions was assessed. Residents' findings were compared with those of experienced intensivists; pathology such as left ventricular systolic dysfunction (kappa = 0.76) and presence of pericardial effusion (kappa = 0.68) were detected in their patients.

HOSPITAL WARDS AND CLINICS

Many studies have addressed the use of point-of-care ultrasound outside of acute care environments. A clinic-based study of first-year medical students instructed in the use of ultrasound demonstrated they were able to detect pathology in 75% of patients with known cardiac disease, where board-certified cardiologists using stethoscopes could detect only 49% [29]. Pocket-sized ultrasound devices were used by general practitioners in Norway to assess left ventricular function in patients with suspected heart failure. Ninety-two patients were assessed by general practitioners as well as cardiologists. General practitioners were able to obtain standard views and measure septal mitral annular excursion in 87% of patients. Measurements made by general practitioners correlated well with those obtained by cardiologists [30].

Internal medicine residents using ultrasound were able to improve their diagnostic assessment of left ventricle function, valve disease, and left ventricle hypertrophy using ultrasound. Their assessments compared favorably to studies performed by level III echocardiographers, with an average sensitivity of 93% and specificity of 99% for major pathology [31]. Pocket-sized hand-held cardiac ultrasound examinations by medical students and junior residents were found to increase diagnostic accuracy for systolic dysfunction when compared with history and physical examination as well [32]. On the inpatient medical service, internal medicine residents were able to detect ejection fractions of <40% with sensitivity of 94% and specificity of 94% [33]. This was after limited training including 20 practice scans prior to the study period.

Left ventricular function and inferior vena cava diameter were assessed in 31 pediatric ICU patients. There was good agreement with pediatric cardiologist assessment of left ventricular function ($r = 0.78$) and IVC volume estimation ($r = 0.8$) [34]. The assessment of left ventricular function and size in a pediatric emergency department setting also demonstrated agreement with cardiologist echocardiography, in 96% of cases [35].

OUT-OF-HOSPITAL ENVIRONMENTS

Physician-performed ultrasound has been studied in the pre-hospital setting as well, in environments where ambulances are staffed by physicians. Breitkreutz et al. [36] assessed patients in cardiac arrest as well as those receiving peri-arrest care. The FEEL (Focused Echocardiography Evaluation in Life Support) study demonstrated that cardiac ultrasound changed management in 89% of the cardiac arrest patients and 66% of periarrest patients. Another observational study of pre-hospital emergency cardiac ultrasound in cardiac arrest sought to determine its prognostic value. Sonographic cardiac activity was associated with survival, and cardiac standstill was associated with positive predictive value of 97.1% for death at the scene [37]. The feasibility of cardiac ultrasound in the field has been studied in physician and nonphysician providers, and a recent pre-hospital care consensus conference determined that the role of pre-hospital ultrasound should be among the top 5 research priorities in this growing field [38].

The feasibility and diagnostic accuracy of cardiac ultrasound performed in austere environments has been demonstrated by several studies. Using a telemedicine model, Huffer et al. [39] performed cardiac ultrasound on patients with known structural cardiac disease as well as on normal control subjects. Images were obtained by sonographers and transmitted via satellite to reviewing cardiologists at hospital-based viewing stations. In another study, over 1,000 cardiac ultrasounds were performed in a single day in a population of patients in a rural environment [40]. The images were uploaded to a web-based viewing system and interpreted by 75 physicians at medical centers.

Tele-ultrasound systems have been described for ambulance use as well. In a program in Taiwan, 3G communications protocol was used to transfer ultrasound data from the ambulance to dispatch and the receiving hospital emergency department [41]. Ultrasound images obtained in the ambulance can therefore be reviewed remotely by clinicians in a variety of locations. An ongoing telemedicine project for the Mount Everest Advanced Base Camp has included a variety of clinical data transfer protocols, including portable ultrasound devices used on-mountain by the medical team with on-demand training in scanning and remote expert guidance of image acquisition [42]. Satellite image transfer allows clinicians to review studies at a Canadian hospital.

A recent study of pocket-sized ultrasound devices used by novices and guided remotely by cardiologists demonstrated image acquisition could be assisted via FaceTime integration with the real-time ultrasound scanning [43]. Cardiologists guided acquisition and interpretation of real-time images of the heart (for left ventricular function), pleura (for comet tail artifacts suggestive of extravascular lung water), and inferior vena cava (for respiratory variation and plethora). Novices were able to obtain adequate images in 90% of cases.

MEDICAL SCHOOL EDUCATION

Increasingly, ultrasound is being incorporated into the curricula of medical schools. In 1996, Hannover Medical School in Germany first described ultrasound as part of their gross anatomy curriculum [44]. Since then, many other institutions have incorporated this concept into their own educational environments [45–47].

In the United States, several medical schools have developed longitudinal curricula in ultrasound. There is variation among the models developed; some begin in the first year and progress throughout the duration of the medical curriculum. Wayne State University School of Medicine began a longitudinal curriculum in 2006 that teaches normal ultrasound anatomy and basic principles of ultrasound acquisition [48]. Practical scanning sessions, didactics, clinical correlates, multimedia computer-based content, and faculty mentoring are all part of the curriculum. Ultrasound was also incorporated into the physical diagnosis curriculum [49]. Image recognition by students improved significantly, and 89% felt that ultrasound was a valuable tool.

The integrated ultrasound curriculum at the University of South Carolina School of Medicine was begun in the same year [50]. The 4-year curriculum begins in the first year with ultrasound laboratory sessions and web-based learning incorporated into the gross anatomy curriculum. Cardiovascular hemodynamics (cardiac and vascular ultrasound including Doppler assessment) is taught as part of the physiology course.

The University of California, Irvine has also incorporated a multimodal ultrasound curriculum starting in the first year of medical school [51]. Skills in ultrasound image acquisition and interpretation are taught using a combination of web-based lectures modules, peer instruction, and standardized formative evaluations.

At the Icahn School of Medicine at Mount Sinai, ultrasound has been a part of the gross anatomy course since 2006 [47]. Cadaveric dissections are supplemented by cardiac and vascular ultrasound modules to demonstrate dynamic, "live" functional anatomy. The introductory physical examination course includes sessions on ultrasound imaging of the heart, gallbladder, aorta, and thorax. For example, the cardiac examination session includes training in palpation, auscultation, and insonation of the heart. Medical students complete a structured assessment of their physical examination and basic ultrasound skills on standardized patients as part of their final examination in this course.

The Ohio State University College of Medicine undergraduate medical curriculum includes assessment of ultrasound anatomy of multiple organ systems in concert with the gross anatomy course [52]. This curriculum extends through the rest of the undergraduate experience in the pre-clinical and clinical years.

SUMMARY

Dramatic technology advancements continue to change the face of medicine. In the first several decades of medical ultrasound use, machine cost, size, and significant training requirements meant the technology was used mainly by radiology, obstetrics, and cardiology departments. As machines evolved into less expensive, portable devices and other specialties demonstrated the value of qualitative point-of-care assessments, there has been an explosion of specialties using ultrasound. Focused cardiac ultrasound, performed in real time by treating clinicians has the advantage of being inexpensive, repeatable, and intimately tied into the overall clinical picture of the patient. It is very often employed as part of a multiorgan system assessment and guided by discrete clinical questions related to the presence of tamponade and likelihood of fluid overload, for example. The need for comprehensive sonographic assessments by specialist consultants is unlikely to wane with the advent of point-of-care ultrasound. As our healthcare system becomes increasingly interested in cost-effective and evidence-based care, we are likely to see clinician-performed focused examinations complemented by comprehensive specialist studies with clear clinical indications.

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