Differential Diagnosis of Cardiovascular Symptoms

Setting the Expectations for the Ultrasound Examination and Medical Education

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ABSTRACT

Within the past several decades, dramatic changes have been made in the field of diagnostic imaging. Many of these changes have been with ultrasound, which has been transformative in the efficiency and accuracy of diagnostics. Emergency physicians, intensivists, and other acute care clinicians are using and relying on critical care ultrasound imaging to better triage and diagnose patients at the point of care. As this new frontier of medicine continues to forge forward using this new and improving technology, we strongly believe in integrating ultrasound training earlier into the medical education curriculum. This paper reviews and discusses the transformation of medical diagnostics within the last few decades and describes changes that should be expected as point-of-care cardiac ultrasound evolves within medical education.

Emergency physicians are often presented with a variety of critically ill patients for whom they are given limited information or have little time to make diagnostic and treatment decisions about. Physicians in the intensive care unit and ward setting similarly deal with acutely ill patients in whom rapid, accurate diagnosis is essential. It is not uncommon to be presented with an altered patient from which a pertinent social, family, medical history cannot be elicited. Decisions often have to be made regardless of the mental capabilities and medical history of the patient, but the more information an emergency department physician has, the more accurate a treatment plan and diagnosis that can be made. Often that additional information comes in the form of medical diagnostic imaging. However, in many cases, imaging is not always the most efficacious and efficient means of gathering information in time-limited scenarios. Radiation, availability and accuracy of portable equipment, and the time it takes for imaging are all factors that can sometimes even make those resources undesirable. However, ultrasound is fast becoming an imaging modality that is rapidly and quickly employed in many of these time-limited and imaging-sensitive scenarios. Several scenarios are discussed herein to illustrate the goals and scope of a cardiac ultrasound evaluation at the point of care.

CHEST PAIN

A number of differentials need to be considered; suppose that further questioning reveals that the pain radiates up the neck, to the back and shoulder, and is associated with shortness of breath. The first impression the emergency physician makes is whether or not the pain is of cardiac, gastrointestinal, musculoskeletal, or respiratory etiology. Often times, the workup for chest pain begins with a chest X-ray and an electrocardiogram and may later require more advanced testing with a computed tomography scan. Simultaneously, lab tests are also typically run to check troponins and other inflammatory and muscle byproduct markers, all of which take time. In theory, a detailed cardiac workup for acute coronary syndromes could take up to 24 h, and the results may still not delineate a clear course of action [1]. However, ultrasound can streamline the workup.

It is possible that a bedside cardiac ultrasound in this patient could gain useful insight into a pericardial effusion [2], with associated tamponade that would have otherwise gone undiagnosed at least initially. By visualizing the aortic outflow tract, the clinician would able be able to note whether a small dissection was a potentially contributing factor. The traditional imaging modality for dissection would be a computed tomography angiogram, which would have taken much longer for diagnostic results and is not ideal in an unstable patient [3]. This fatal diagnosis can be determined more quickly, and disposition arranged more expeditiously, with the use of point-of-care ultrasound [4]. Using ultrasonography, some of the most time-dependent decisions have been shown to reduce morbidity and mortality [5].

SHOCK

A patient in shock has a variety of possible etiologies: neurogenic; cardiogenic; septic; hypovolemic; or anaphylactic. Treating the underlying pathology requires knowing the underlying cause, all of which are time-dependent in a critical shock condition. As Randazzo et al. [6] remarked, the successful outcome of a patient in shock depends more on the hemodynamic management of the patient than on the immediate diagnosis of underlying causality. In the evaluation of a patient in shock, some of the most helpful diagnostic data are the vital signs and presenting physical

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examination of the patient. But a more accurate and rapid diagnosis is made possible using the point-of-care cardiac ultrasonography. Ultrasound is more accurate, more cost-effective, and less invasive than any other diagnostic measurements [6]. Furthermore, the evaluation of hypovolemic and cardiogenic shock can be more accurately assessed by imaging the inferior vena cava and the functional contractility of the heart [7]. This concept of fluid responsiveness has been evolving within the management of emergent patients presenting with shock. This is because only about 40% to 70% of patients in shock will actually respond to volume expansion, leaving at least 30% to 60% who do not respond at all [8]. One of the most effective ways to assess the fluid responsiveness of the heart in shock is by measuring the velocity of blood flow coming out of the aorta [9]. Additionally, fluid responsiveness of the superior vena cava is among the most reliable means by which the functional capacity of the heart can be assessed noninvasively [10]. Thus, ultrasound provides a safer, faster, and more effective means of assessing fluid responsiveness in the setting of shock.

SHORTNESS OF BREATH

When considering the patient who is short of breath in the emergency department, wards, or intensive care unit, a very broad differential can be developed: Is it primarily pulmonary, cardiac, renal, or hepatic in etiology? Often times, patients with shortness of breath present with other chronic conditions, such as congestive heart failure or chronic obstructive pulmonary disease, which can confound an immediate diagnosis [11]. Even with the use of other diagnostic criteria, such as B-type natriuretic peptide lab values, there are still limitations with making accurate diagnoses. However, the use of ultrasonography has been useful in delineating a difference between pulmonary and cardiac contributory pathologies. Through the identification of A-lines and B-lines, congestive heart failure and chronic obstructive pulmonary disease can be differentiated in a matter of moments, allowing for more accurate and efficient treatment of the presenting patient [11,12]. Thus, information provided by a simple bedside cardiac ultrasound can help to differentiate the diagnosis, allowing clinicians to individualize medical treatment for each patient.

LIMITATIONS

Whereas ultrasound has many positive diagnostic implications, there are also limitations to this technology. The most common concern in diagnostic ultrasonography is its operator dependence. Radiologists often express concern for echogenic diagnostics on the basis of the limited experiences and training that some physicians have had with the technology [13]. For point-of-care ultrasound users who are both imagers and medical decision makers, the problem is compounded, as they must both obtain and interpret images. For this reason, it can be argued that ultrasonography, in some cases, is a more subjective screening and diagnostic methodology. Also, in spite of the fact that ultrasound helps gain insight into the functionality of a patient's body, it is also sometimes difficult to determine the difference between acute versus chronic problems of that individual. This can be a confounding finding in an acute setting, in the event that a physician needs to make a treatment decision that could be attributed more to a chronic diagnosis. For example, pulmonary hypertension as a result of an acute or chronic process cannot always be immediately assessed on the basis of echogenic findings. Although limitations such as these are potential problems that may continue to limit ultrasonography's utility throughout medicine, this technology still provides an important insight into the human anatomy, physiology, and pathology that would otherwise be missed purely from the physical examination, laboratory evaluation, and vital signs.

TIMES ARE CHANGING

For centuries, the stethoscope has been a foundational part of the physical examination [14]. Initially, however, its introduction into the realm of medical diagnostics was met with harsh criticism and refute [15]. With time, however, the stethoscope has become among the most iconic symbols and tools of medicine, transforming the way medicine has been practiced [16]. It is apparent that the stethoscope is no longer enough in many emergent cases [17]. Even in the best of hands, with years of training and experience, the question remains: How accurate is the physical examination?

In spite of the impact the stethoscope has had on medicine, studies have shown that it has not been as accurate a tool as once was perceived [15,18]. Simultaneously, the 21st century ushered in a new wave of medical technology allowing for a dramatic leap in diagnosing and treating patients [19]. Included among these modalities are magnetic resonance imaging, computed tomography, and ultrasound imaging [15]. In particular, ultrasound has become increasingly important as a diagnostic imaging modality [20]. Because ultrasound is effective, safe, and portable and it happens in real time, it has the potential to become the "stethoscope of the 21st century" [21]. Siepel and Clifford [22] found that ultrasound has proven to be a valuable imaging modality in the detection and subsequent immediate treatment of cardiac disease, which otherwise would have been limited to the physical examination. In their study [22], they found that cardiac ultrasound was useful in the detection of cardiac disease. Not only is ultrasound more comprehensive and accurate than physical examination, but it also helps with earlier detection of potentially life-threatening conditions, such as cardiac tamponade [23] and confirmation of pulseless electrical activity [2]. Similarly, supporting evidence in the study by Lederle et al. [24] found that compared with traditional physical examination, point-of-care ultrasound was more accurate in detecting abdominal aortic aneurysms. In addition, not only was

ultrasound more accurate than the physical examination, but it was also more reliable in patients who were overweight, when the physical examination failed to detect the abdominal aortic aneurysms [24].

Ultrasound has become among the most ubiquitous imaging devices around the world (Clayman R, Fox JC, unpublished). Traditionally, ultrasound was considered a tool primarily used by obstetric/gynecological physicians [19]. However, over the last several decades, ultrasonography has become indispensable within the emergency department [19]. It is used in hypotensive patients [25], focused assessment with sonography for trauma (or FAST) examinations, ectopic pregnancy diagnoses, and many other instances [19]. Thus, as proficiency with ultrasound has been gaining momentum over the past several decades [19], a foreseeable consequence has been its utility in point-of-care ultrasonography within cardiac imaging to improve diagnostics and treatments. Point-of-care ultrasound for the heart has been adapted within a variety of different venues, including the focused assessment with sonography for trauma examination [18], recognizing congenital cardiac malformations [26], and screening for hypertrophic cardiomyopathy [12]. Additionally, ultrasound provides safer and more immediate results, without introducing radiation to the patient [21]. Thus, it is argued that point-of-care ultrasound should be, rather than optional, an essential part of any examination to help physicians develop and narrow down their differential diagnosis [22]. The differential for cardiovascular and pulmonary complaints is vast and often unclear on presentation. This differential can take time to explore and in the emergency department, ward, or intensive care unit environment, time is a limited commodity.

IMPLICATIONS FOR MEDICAL EDUCATION

Even though ultrasonography has already become the standard of bedside imaging in emergency medicine residency [27], the reality is that it takes years of practice and training to understand its true art [28]. In essence, the level of proficiency required to expertly pilot this device supports a model for ultrasound education earlier within a physician's medical career. This is why, over the last decade, medical education has taken a new interest in ultrasound education [28].

Several medical schools across the nation have recognized the importance of integrating ultrasonography into the medical education curriculum [28,29]. These schools have seen a tremendously positive response among their medical students, and the students' ability to learn and apply their knowledge has been a contagious process [29]. The introduction of ultrasound into medical education has allowed the student to take a more active role in patient care and has transformed the patient-physician relationship (Clayman R, Fox JC, unpublished).

The University of California, Irvine has ultrasound education integrated within the 4-year medical education curriculum [28]. During their first year, students are first taught the basics of ultrasound physics and image acquisition and what normal anatomy and physiology look like on an ultrasound. This foundation is then continually built on during the remaining 3 years of medical school. The curriculum is designed to fuse their knowledge of ultrasound with pathology to synthesize a more tangible grasp on patient care [29]. Additionally, studies have shown that training in ultrasound also leads to an inverse amount of time spent performing a primary ultrasound assessment [30]. Naturally, these facts would prompt the question that if medical students can learn ultrasound, perhaps they would be able to teach it as well? Findings by Knobe et al. [31] suggest that students were not only able to retain ultrasound knowledge, but they were able to apply and disseminate that knowledge to other students.

Additionally, students with ultrasound integrated into their curriculum have reported that they are more likely to retain and understand the physiology and anatomy of the heart (Clayman R, Fox JC, unpublished). Teaching ultrasound in medical school will provide physicians with the comfort, confidence, and skill necessary to effectively implement ultrasound into their patient assessments [29].

Whereas some may question the accuracy and reliability of untrained physicians using ultrasound, Beaulieu [32] remarked that although there are limitations to the extent and completeness of these examinations, there is still an acceptable level of competency that is made possible with the right training. It is with vigorous training that the point-of-care sonographic cardiac examination can become a useful ally in critical care units [33]. Kobal et al. [34] demonstrated this promise in extending ultrasound education into the medical school curriculum. Their study compared the physical examinations done by trained cardiologists to the diagnostic accuracy of ultrasounds done by medical students. They concluded that not only were students capable of capturing images of cardiac pathology on patients, but their diagnostic skills were far superior in detecting valvular disease, left ventricular hypertrophy, and cardiac dysfunction than those of trained cardiologists performing physical examinations. Similarly, Brennan et al. [35] found that residents with limited training in point-of-care cardiac ultrasound were able to more frequently and accurately determine an elevated right atrial pressure on the basis of the inferior vena cava measurements they obtained from ultrasound images, compared with the use of traditional means of measuring the jugular venous pulsations within the physical examination. It is becoming increasingly apparent that training our medical students to use ultrasound earlier in their careers can allow them to develop diagnostic skills that far exceed the traditional examination that physicians have been taught for centuries [36].

Thus, it is impossible to ignore the impact ultrasound has made within medical education. Ultrasound has played an essential role in point-of-care cardiac diagnostics, and implementing ultrasound training into medical education is the next logical step to enable the progression of point-of-care ultrasonography.

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