Definitive Advantages of Point-of-Care Ultrasound: A Case Series

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INTRODUCTION

Point-of-care ultrasound (POCUS) is performed by bedside clinicians to answer specific questions in diagnosis and management. Although not without pitfalls, POCUS can shorten the time to diagnosis and perhaps improve outcomes.[1,2] The specialties of emergency medicine, critical care medicine, and anesthesia have embraced POCUS as part of their training and practice, although numerous other specialties also use POCUS, including cardiology.[3] As utilization of POCUS has increased, many specialties have integrated POCUS into their training programs and routine practice.

We highlight some cases where POCUS performed by noncardiologists resulted in improved diagnosis or management and elaborate on the scope, practice, and training of POCUS.

CASE PRESENTATION 1

A 34-year-old man, unvaccinated for COVID-19, presented to the emergency department with dyspnea. The patient was tachycardic and tachypneic and required 5 L/min of supplemental oxygen to maintain SpO_2 above 90%. White blood cell count was $13.7 \times 10^3/\mu L$, and alkaline phosphatase was 206 U/L; the remainder of labs were unremarkable. Chest x-ray demonstrated extensive infiltrates with areas of nodularity, which were thought to represent COVID-19 pneumonia. POCUS was performed as part of the evaluation for suspected COVID-19 and revealed an extracardiac mass adjacent to the left ventricular (LV) apex and multiple echogenic circumscribed structures noted in the liver parenchyma (Videos 1 and 2, Figures 1 and 2). Comprehensive echocardiography confirmed the findings. Computed tomography revealed innumerable nodules and masses in the lung and liver, consistent with metastatic disease. Testicular exam revealed a large mass. The patient underwent scrotal ultrasound and biopsy, which confirmed metastatic testicular cancer. The liver and pulmonary opacities in the POCUS were metastases. SARS-2-CoV testing was negative. Over the next month, the patient progressively worsened and died in hospice care.

CASE PRESENTATION 2

A 60-year-old man presented to the emergency department with progressively worsening chest pain, shortness of breath, and lightheadedness. History was significant for coronary artery disease and hypertension. On arrival, the patient was tachycardic and required 2 L O_2 by nasal cannula to keep SpO_2 above 90%. Chest x-ray demonstrated no acute pathology. Electrocardiogram revealed ST-segment depression in leads II, III, and aVF. Troponin and B-type natriuretic peptide were elevated. The initial diagnosis was suspected non-ST-elevation myocardial infarction (NSTEMI) from plaque rupture. The patient rapidly went into shock and was admitted to the intensive care unit (ICU), where POCUS was performed to evaluate alternative causes of shock. POCUS revealed severe right ventricular (RV) dilation and severely reduced RV systolic function with an underfilled, hyperdynamic left ventricle assessed by visual estimate (Video 3, Figure 3). Further investigation revealed thrombus in the inferior vena cava (IVC) and a noncompressible left popliteal vein, indicating deep venous thrombosis (DVT; Videos 4 and 5, Figure 4). ICU management was adjusted to treat suspected obstructive shock from pulmonary embolism rather than cardiogenic shock from NSTEMI. Pulmonary embolism was later confirmed by computed tomography angiography. On further history, it was also noted that a prior IVC filter had been placed 10 years ago, which was never removed. After a multidisciplinary team meeting, the patient underwent IVC filter removal and aspiration thrombectomy with resolution of symptoms.

CASE PRESENTATION 3

A 34-year-old man presented for elective sigmoid colectomy for recurrent diverticulitis. Surgery was uneventful, but on postoperative day 2, he left against medical advice. The patient returned to the emergency department several days later with severe abdominal pain and was noted to have an acute abdomen on examination requiring emergent surgery where fecal peritonitis was found. After intestinal resection and irrigation, the patient was brought to the ICU in severe shock on high-dose vasopressors, presumed to be septic in origin. Bedside POCUS was performed to evaluate ventricular function and assess volume status and revealed thrombus in transit throughout the right atrium, right ventricle (RV), and main

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Conflicts of Interest: None.

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VIDEO HIGHLIGHTS

Video 1: Apical 4-chamber view with extracardiac mass noted near apex.
Video 2: Subcostal 4-chamber view with hyperechoic masses in liver and lung B lines.
Video 3: RV-focused apical 4-chamber view demonstrating hyperdynamic left ventricle, RV and right atrial dilatation, reduced RV systolic function, and echogenic structure in the inferior cavoatrial junction.
Video 4: Subcostal view of the IVC in the long axis with thrombus protruding into the right atrium.
Video 5: Left popliteal vein compression ultrasound, demonstrating noncompressible vein (*right, black arrow*), while the popliteal artery is compressed (*left, white arrow*), consistent with DVT.
Video 6: Parasternal short-axis view at the level of the great vessels, with focus on the aortic valve, demonstrating thrombus in transit displayed in a slow-motion cine loop.
Video 7: Parasternal short-axis view at the level of the great vessels, with focus on the pulmonic valve, showing pulmonary embolism (*white arrow*) in the main pulmonary artery (PA) and displayed in a slow-motion cine loop. The aorta (Ao) and RV outflow tract (RVOT) are labeled.
Video 8: Parasternal long-axis view prior to cardiac arrest (*left*) and after cardiac arrest (*right*), demonstrating echogenic opacity in the left ventricle. Both images demonstrate abnormal septal motion.
Video 9: Parasternal view of the aortic valve in the short axis prior to cardiac arrest (*left*) and after cardiac arrest (*right*), demonstrating echogenic opacities in the right atrium and RV.

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pulmonary artery (Videos 6 and 7, Figure 5). The clot could be traced into the IVC. After a multidisciplinary discussion, thrombolytics were administered. Despite administration of thrombolytics, the patient developed progressive shock and died.

CASE PRESENTATION 4

A 53-year-old man underwent heart transplantation due to ischemic heart disease. Medical history included lupus, antiphospholipid syndrome, and prior placement of LV assist device and percutaneous RV assist device. The postoperative course was complicated by multiple DVTs, chylothorax, and cardiac tamponade requiring pericardiocentesis and subsequent surgical drainage due to purulent pericarditis. Subsequent medical course further worsened with respiratory failure requiring intubation, bowel ischemia requiring exploratory laparotomy, and refractory septic shock. The patient was scanned with POCUS daily to monitor cardiac function and volume status while in shock. Although not clinically appreciated at the time, the POCUS images demonstrated abnormal septal motion, suggestive of pericardial constriction. The patient then experienced cardiac arrest overnight with successful return of spontaneous

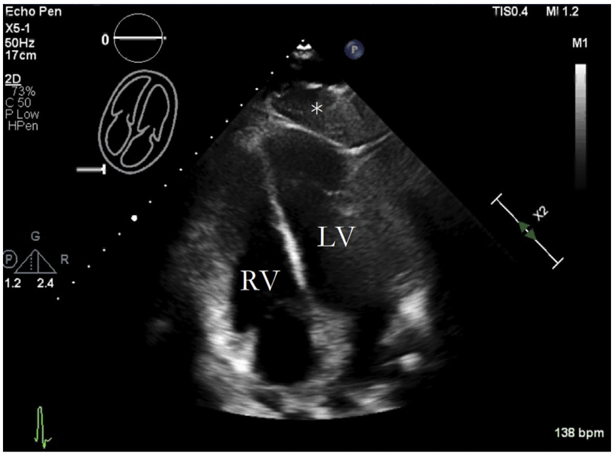

Figure 1 Still image of Video 1. Apical 4-chamber view with extracardiac mass noted near apex, marked with an *asterisk*. *LV*, Left ventricle.

circulation. Following the event, another POCUS was performed, which revealed new echogenic structures in all 4 chambers of the heart not seen during the preceding day (Videos 8 and 9, Figure 6). Based on the timing, the clinical team believed these structures to be acute thromboses consistent with catastrophic antiphospholipid syndrome. Given the patient's poor prognosis, the family elected to withdraw life-sustaining treatment, consistent with what they believed were the patient's wishes.

DISCUSSION

These cases all involved integration of POCUS with clinical presentation of an acutely ill patient to expedite diagnosis and management when comprehensive imaging was either infeasible or impractical. In case 1, the clinical team had a strong but erroneous suspicion that the lung opacities and clinical presentation were consistent with COVID-19. POCUS was performed as part of an evaluation for COVID-19, as cardiac dysfunction can occur in COVID-19.[4] The POCUS study revealed a completely unexpected diagnosis that changed the initial management for this patient. In case 2, the clinical team suspected NSTEMI in a person with acute chest pain and dyspnea. POCUS was performed to evaluate alternative diagnoses such as pneumothorax, pulmonary embolism, or tamponade, among others. In both of the above cases, POCUS shortened the time to correct diagnosis and changed the initial presumptive management. Similarly, case 3 describes a patient with presumed septic shock. POCUS is commonly performed in patients in shock to evaluate for alternative diagnoses. POCUS revealed echo findings consistent with an acute pulmonary embolism as the cause for shock and resulted in a major change to the therapeutic approach, despite the death of the patient. In case 4, POCUS was performed daily to evaluate changes in clinical status, including assessment of intravascular volume, which provided a fortuitous daily record of the heart function, antecedent to the cardiac arrest and discovery of severe pathology. Although POCUS did not change management in this patient, daily imaging offered insight into the acuity of the pathology.

These cases illustrate multiple advantages of POCUS. In the emergency room or the ICU, the ability for a clinician to rapidly identify pathologies is invaluable. Second, the ability for the bedside clinician

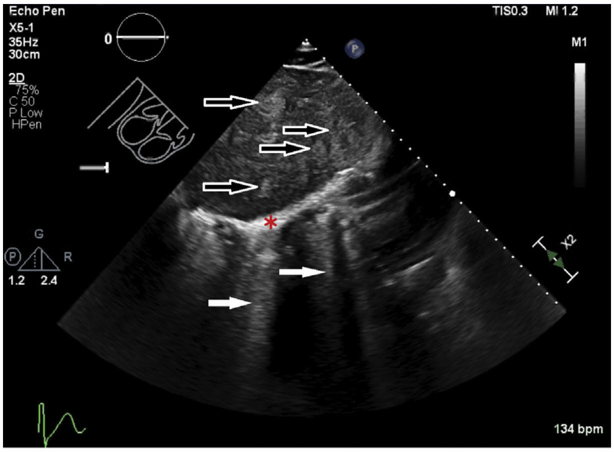

Figure 2 Still image of Video 2. Subcostal 4-chamber view with hyperechoic masses in liver (*black arrows with white outline*). Lung B lines (*solid white arrows*), commonly seen with pulmonary edema, are seen cephalad to diaphragm (*asterisk*).

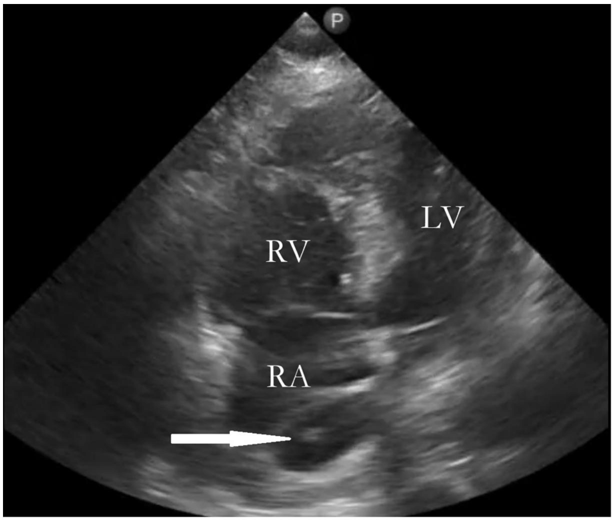

Figure 3 Still image of Video 3. Right ventricle–focused apical 4-chamber view demonstrating RV and right atrial (RA) dilatation and echogenic structure in the inferior cavoatrial junction (*arrow*). *LV*, Left ventricle.

to monitor changes over time is an aspect of POCUS that is easier and more cost-effective than comprehensive echocardiography. Third, POCUS can identify abnormalities that augment consultation with local experts. Fourth, POCUS is not confined to a single organ, hence the bedside clinician can rapidly assess multiple organ systems using POCUS to improve diagnostic accuracy by corroborating the pathophysiological relationship between different organ systems that are simultaneously altered in the disease process.[5] Last, POCUS incorporates the clinician's knowledge of the patient to answer targeted diagnostic or management questions. Although data are scarce, the potential harms of POCUS are mainly those of misdiagnosis or identification of incidental findings of unclear significance, prompting further unnecessary workup.

Scope of Practice of Diagnostic POCUS

POCUS is not a replacement for comprehensive echocardiography. The American Society of Echocardiography has published international evidence-based guidelines for the scope of practice of POCUS.[6] POCUS is a goal-directed, limited-scope ultrasound assessment performed by the bedside clinician. POCUS is typically simplified, time-sensitive, and repeatable. It is impractical and expensive to perform comprehensive echocardiography in patients with low-pretest probabilities for cardiac abnormalities. Conversely, treatment delays while awaiting comprehensive echocardiography in a patient in cardiorespiratory failure are harmful. POCUS can diagnose common causes of cardiorespiratory failure and thus facilitate timely treatment. While comprehensive echocardiography would have been indicated in case 2 due to the suspected cardiac abnormalities, POCUS was performed immediately and resulted in a real-time change in management. The use of POCUS does not obviate a need for a comprehensive echocardiogram. Abnormal findings in POCUS should be followed up with confirmatory assessments.

Regarding diagnostic cardiac POCUS, the usual scope of practice includes qualitative and quantitative assessments of chamber size and function and evaluation for severe pathologies that could contribute to shock, such as tamponade, acute cor pulmonale, or hypovolemia. By way of example, over half of patients with septic shock also have ventricular hypokinesia.[7,8] POCUS can often identify these pathologies rapidly and cheaply compared with traditional echocardiography. POCUS is also well suited to be performed repeatedly with any change in hemodynamic status, including after an initial comprehensive echocardiogram, to detect these dynamic changes. While POCUS can occasionally identify valvulopathy, quantification and valvular assessments are often excluded from the domain of basic POCUS due to low sensitivity for identification of even severe valvular disease.[6,9] While POCUS and critical care echocardiography omit some areas of comprehensive echocardiography, they also include areas outside of comprehensive echocardiography, including extracardiac ultrasound and specific assessments of fluid responsiveness.[10]

A subset of POCUS practitioners have pursued additional training, including certification by the National Board of Echocardiography in

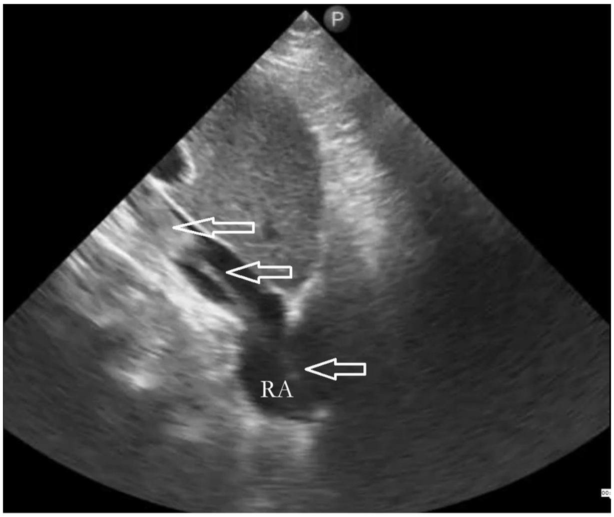

Figure 4 Still image of Video 4. Subcostal view of the IVC in long axis with thrombus (*arrows*) protruding into the right atrium.

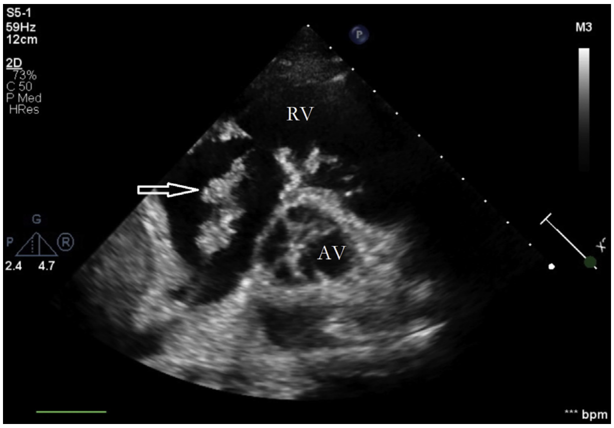

Figure 5 Still image of Video 6. Parasternal short-axis view at the level of the great vessels, with focus on the aortic valve (AV), demonstrating thrombus in transit (*arrow*).

Critical Care Echocardiography.[11] These practitioners may incorporate more detailed quantification or valvular assessments in examinations beyond that of basic POCUS. While many of the vocal proponents of POCUS have this knowledge, we specifically selected POCUS cases that likely would have been identified as abnormal by early adopters of POCUS.

Sensitivity of Diagnostic POCUS

Diagnostic POCUS, by design, is aimed to diagnose life-threatening emergencies in a timely manner. Practitioners are taught imaging protocols to screen for common diagnoses, but the sensitivity of POCUS exams is still expected to be less than that of comprehensive echocardiography, especially for valvular pathology and subtle abnormalities. Both the American College of Emergency Physicians policy statement and the Society of Critical Care Medicine's Ultrasound training course emphasize the limitations of basic POCUS.[9] When a cardiac POCUS does not identify an abnormality, the practitioner should understand that the POCUS does not completely exclude all cardiac pathology. In the last case, serial POCUS was performed. It is possible that valvulopathy or subtle wall motion abnormality might have been missed during these examinations. The abnormal septal motion seen in these images is suggestive of pericardial constriction, which was not clinically diagnosed by the POCUS practitioner. However, the goal of the POCUS exam for that patient was gross ventricular assessment and fluid responsiveness. One should not rely on POCUS examinations to exclude the possibility of subtle disease. Additionally, while diagnostic POCUS is designed to detect severe abnormalities, it is not immune to suboptimal implementation or practice. Just as with any other diagnostic test, lack of institutional standardization or clinical oversight or a perfunctory approach to diagnosis can result in errors.

Training Standards

Emergency medicine, critical care medicine, and anesthesia have formalized training expectations for POCUS practitioners.[12-14] All 3 of these specialties have clear training guidelines and include basic POCUS on their board examinations. POCUS training may emphasize different aspects between specialties, just as a physical examination might differ between a dermatologist and a neurologist. While emergency medicine residency includes POCUS training, some physicians pursue an additional year of dedicated ultrasound and echocardiography training. Understanding the level of training of a POCUS practitioner can facilitate dialogue between consultant echocardiographers and POCUS practitioners.[15]

Within the field of POCUS, there exists a multispecialty standard for certification in critical care echocardiography, which requires performing and interpreting 150 transthoracic echocardiograms under appropriate expert supervision and passing the National Board of Echocardiography examination.[11]

The Role of Serial Measurements and Extracardiac Imaging

Although our cases used diagnostic POCUS, one can also use POCUS for monitoring or management. An advantage of POCUS is the ease with which it lends itself to serial measurements, when daily comprehensive echocardiography would be impractical or wasteful. POCUS practitioners might calculate changes in stroke volume before and after interventions in a patient in shock or assess extravascular lung water daily in a patient with acute respiratory distress syndrome. Although unanticipated, the daily assessments in case 4 were useful in differentiating the chronicity and, by extension, the origin of the

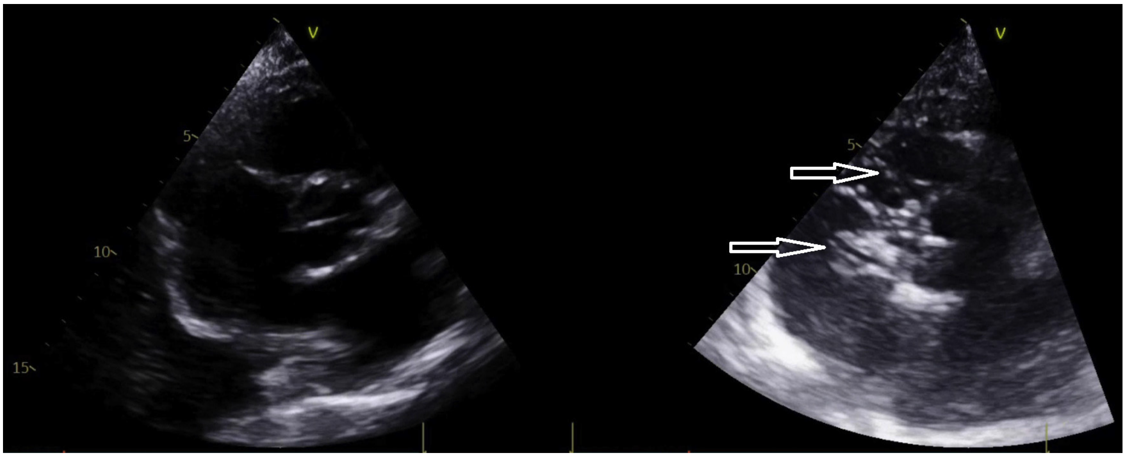

Figure 6 Still image of Video 9. Parasternal short-axis view at the level of the great vessels, with focus on the aortic valve, prior to cardiac arrest (*left*) and after cardiac arrest (*right*), demonstrating echogenic opacities in right atrium and RV (*arrows*).

echogenic lesions. POCUS image recording is supported by International Societal Guidelines.[6]

Another advantage of multiorgan POCUS over echocardiography is the ability to image multiple organs to help answer a focused question. In case 2, the identification of RV failure could have been observed with a right-sided infarct, but imaging the popliteal vein at bedside increased the likelihood of pulmonary embolism as the cause.

Collaboration with Local Experts

POCUS frequently improves communication with consultants and reduces the time to achieve the correct diagnosis.[1] The American Society of Echocardiography has issued guidelines informing on how echocardiography labs can augment POCUS training.[16] During the COVID-19 pandemic, resource and personnel limitations propelled the use of POCUS forward, typically in conjunction with expert cardiologists.[4,17] The American Society of Echocardiography and many cardiologists have championed POCUS education in recognition of its benefit to patient care.[15,18] In many of the cases described herein, diagnosis was achieved in collaboration with cardiology or with follow-up formal echocardiography. In the example of the first case, the POCUS practitioner recognized the image as abnormal but was unsure of the diagnosis and sought local expertise. In the example of the second case, POCUS changed the direction from cardiology consultation for ischemic workup to the more appropriately directed consultation of the multidisciplinary pulmonary embolism response team for management of massive pulmonary embolism.

Potential Pitfalls

POCUS is not without harm. Misdiagnosis can occur, even among highly trained practitioners. Despite emphasis on the limitations of POCUS in formal training, it can still mislead. Ultrasound provides a real-time graphical representation of internal structures, which can instill inexperienced clinicians with false confidence and may result in management that ignores other key clinical information. The Dunning-Kruger effect, where incompetent individuals lack the skill and insight to recognize their own incompetence, can occur in POCUS as it can with any other area of medicine. Clinicians accustomed to the comprehensive nature of formal transthoracic echocardiography and ultrasound may erroneously assume that a POCUS exam will have the same sensitivity as formal comprehensive imaging studies. Similarly, a clinician may overestimate a basic POCUS practitioner's level of training, which can result in miscommunication or mismanagement.

Much like auscultation or interpretation of electrocardiograms or chest x-rays by nonexperts, we rely on a long history of clinical experiences when we incorporate that information into our conceptual framework. Many of these pitfalls will resolve as POCUS becomes more established. In the meantime, these pitfalls can be minimized by implementing robust quality assurance processes, which include image archiving, documentation, secondary retrospective image review, and timely expert feedback. These processes enable monitoring of effective and responsible use of POCUS with an aim of continual improvement.

CONCLUSION

As these cases illustrate, POCUS remains a powerful tool for timely diagnosis and management and improved consultation. We advocate for high-quality POCUS training and implementation developed in collaboration with experts in comprehensive echocardiography and ultrasonography.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.case.2022.05.008.

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