Point-of-Care Ultrasound and the Rapid Response System

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ABSTRACT

Over the years, the use of ultrasound has moved solely from the domain of the radiologist to that of the intensivist and emergentologist for use in acute care settings. By virtue of its ease of use and rapid learning curve to proficiency, we are now seeing an increased desire by internists to learn the modality and apply it at the patient's bedside. The rapid response system represents a rational starting point for the introduction of point-of-care ultrasound to the inpatient ward setting.

The versatility of ultrasound in the diagnosis of disease lies at the core of the imaging modality. Its use in the point-of-care setting has greatly expanded its utility and truly increased its value by bringing it to the patient's bedside to facilitate real-time diagnosis and decision making. Since its migration from the realm of radiology to intensivists and emergentologists, its versatility has been amplified as a focused point-of-care imaging modality allowing rapid and accurate diagnosis to guide treatment and improve patient safety.

Lead primarily by intensivists, who at some institutions roll cart-based ultrasound machines around while on rounds, ultrasound has been increasingly taking on prominent roles in critical care training programs. Not surprisingly, the American Board of Internal Medicine has taken the first step and added procedural guidance by ultrasound as a core curriculum for central venous access and thoracentesis [1]. In 2009, the Critical Care Network of the American College of Chest Physicians in partnership with La Société de Réanimation de Langue Française developed a consensus statement on core competencies in point-of-care ultrasound [2]. Recently, the journal *Chest* has introduced a new ultrasound series—Ultrasound Corner—aiming to permeate the minds of readers with interesting cases and the impact of ultrasound on diagnosis and management [3].

With the widespread application of point-of-care ultrasound (POCUS) in intensive care units and emergency departments, the low-lying fruit for its broader application in the ward setting is the rapid response team (RRT). RRTs are a relatively new concept in hospital-based medicine and are generally composed of a mix of critical care nurses, respiratory technologists, physician assistants, and physicians. They were implemented for the purpose of responding to acute changes to an inpatient's clinical status (change in vital signs, hypoxia, respiratory difficulty, mental status changes) in order to identify and manage patients at risk for physiologic deterioration or cardiac arrest. With the obvious impetus of improving patient care, evidence is mounting that RRTs decrease out—of—intensive care unit cardiac arrest [4—6] and improve staff satisfaction and hospital safety culture [7], which ultimately translates into healthcare savings. Bearing this in mind, RRTs are primed for the addition of POCUS to their clinical arsenal to facilitate rapid diagnosis and management of these inpatient emergencies.

Though there are several steps required in the implementation of POCUS on RRT, they are not insurmountable. First, a champion for the cause is required; this individual would have managerial oversight of the machine (selection, purchase, and maintenance). An educational curriculum would have to be devised that should include a mix of hands-on and didactic sessions. A formal plan would be needed to operationalize the use of ultrasound during the RRT assessment, goals of the procedure, and how findings should be interpreted and communicated to the team. Finally, a quality assessment process would be required to review RRT

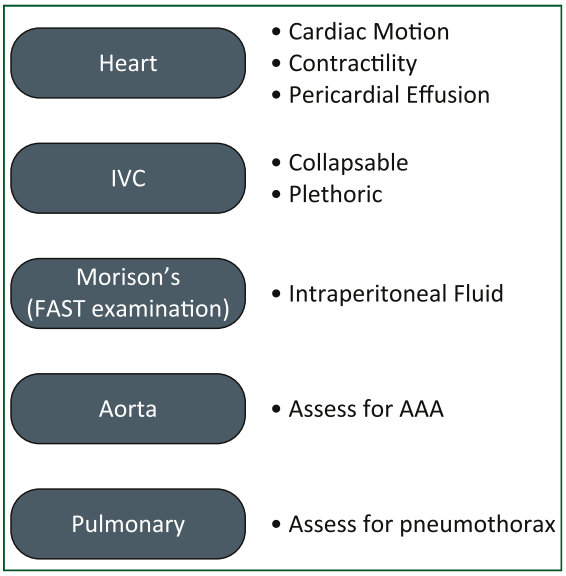

FIGURE 1. HI-MAP. HI-MAP, heart, inferior vena cava, abdomen, thorax, and aorta.

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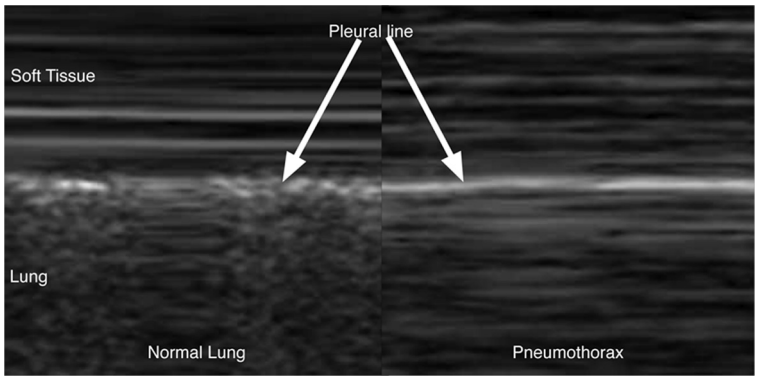

FIGURE 2. Normal lung versus pneumothorax (M-mode).

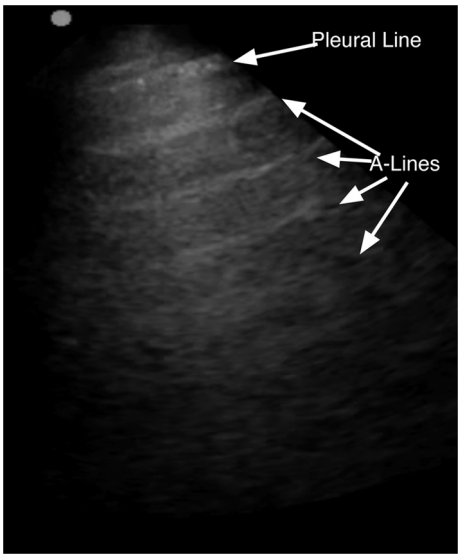

FIGURE 3. Normal lung displaying A-lines (B-mode).

cases (and saved images) to fine-tune its implementation. As well, a continuing education program, such as combined ultrasound rounds with RRT members, intensivists, and emergentologists, to review cases is recommended.

PRACTICAL APPLICATION

The rapid ultrasound for shock and hypotension (RUSH) protocol [8,9] was developed to facilitate rapid assessment of potentially critically ill patients presenting to the emergency department and is very well suited for the type of patients being evaluated by RRTs. The examination leads providers through a comprehensive evaluation of a variety of medical etiologies that could lead to a patient's poor clinical status. Specifically, the examination prompts providers to perform the ultrasound study in an organized manner with required views of the heart, inferior vena cava, abdomen, thorax, and aorta, which can be summarized by the acronym HI-MAP (Fig. 1).

Expanding beyond the rapid ultrasound for shock and hypotension examination, additional diagnoses can be pursued such as pulmonary edema, pneumonia, pleural effusions, and secondary findings of pulmonary embolism. The abdominal examination can also be expanded to evaluate the urinary system for urinary retention and/or hydronephrosis, biliary pathology such as cholelithiasis or cholecystitis, and appendicitis, as well as ascites. Finally, regions of cutaneous erythema can be evaluated for cellulitis and/or abscess.

The following sections provide several illustrative cases.

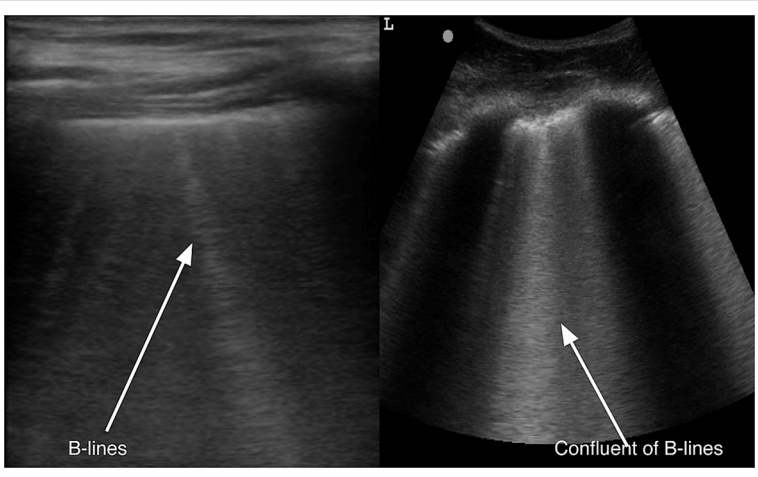

FIGURE 4. Pulmonary B-lines—normal (occasional B-lines) versus confluent.

CASE 1: CHEST PAIN AND SHORTNESS OF BREATH

A 65-year-old woman with a history of newly diagnosed stage III breast cancer (not on chemotherapy) presented with acute onset of shortness of breath over the previous 2 days as well as mild right lower extremity edema. On physical examination, she was afebrile; her pulse was 110 beats/min, blood pressure 120/80 mm Hg, respirations 24 per min, and oxygen saturation 92% on room air. A thoracic ultrasound was performed and was negative for pneumothorax (Fig. 2), pulmonary edema (Figs. 3 and 4), and pleural effusion (Fig. 5). Lower extremity ultrasound demonstrated a deep vein thrombosis (Fig. 6) and echocardiography demonstrated increased right-sided heart pressures (Fig. 7).

Diagnosis: Acute deep vein thrombosis/pulmonary embolism

The differential for this patient included acute pulmonary embolism given a recent diagnosis of malignancy. It would be important to know if this patient received any anthracycline-based chemotherapy, as this can cause acute and delayed cardiotoxicity, putting heart failure on the differential diagnosis. Additionally,

malignant pleural effusion must also be considered in stage IV breast cancer.

The probability for pulmonary embolism is more likely when other etiologies are excluded; therefore, ultrasound can rapidly be employed to exclude pneumothorax, pulmonary edema, and pleural effusion. Then, a 2-region compression test can be done to evaluate for compressibility of the femoral and popliteal vein; noncompressibility of the femoral and/or popliteal vein indicates deep vein thrombosis and would warrant further diagnostic imaging.

CASE 2: HYPOTENSION

A 32-year-old woman with past medical history of obesity who was also a 1-pack-per-day smoker presented with 1 day of pleuritic chest pain and shortness of breath in the setting of fevers and a cough for the previous 4 days. Vital signs included temperature 38.6°C, pulse 115 beats/min, blood pressure 92/64 mm Hg, respirations 20, and oxygen saturation 94% on room air. On physical examination, she was speaking in short sentences, appeared dyspneic, and was unable to lie in a supine position due to worsening dyspnea. Auscultation of her thorax revealed distant heart sounds and clear lungs. The electrocardiograph demonstrated low-voltage complexes. An ultrasound examination of the heart was performed that demonstrated a pericardial effusion (Fig. 8) with right ventricular collapse (Fig. 9), as well as a plethoric inferior vena cava (Fig. 10).

Diagnosis: Pericardial effusion

The differential in this case included pericarditis as well as myocarditis. Pericardial effusion can accompany these diagnoses, and if accumulation is rapid enough, can lead to cardiac tamponade. This was likely a viral pericarditis with effusion as evidenced by the fever and recent upper respiratory infection. Other clinical scenarios where it would be relevant to image the pericardium looking for an

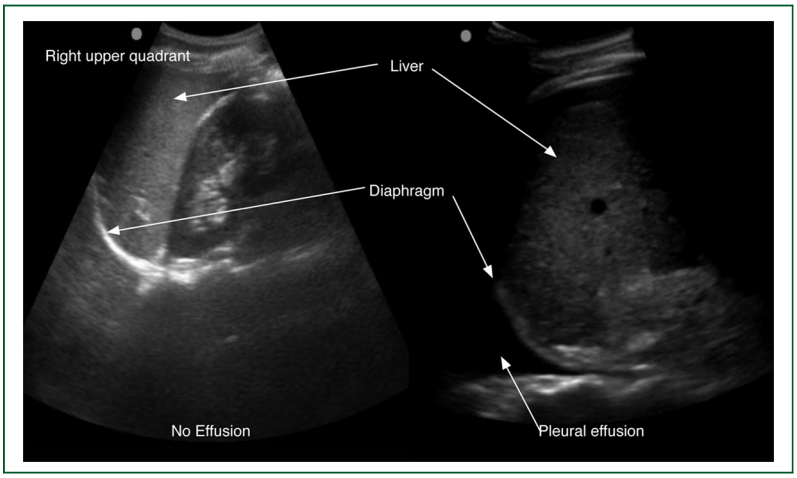

FIGURE 5. Normal lung base versus pleural effusion.

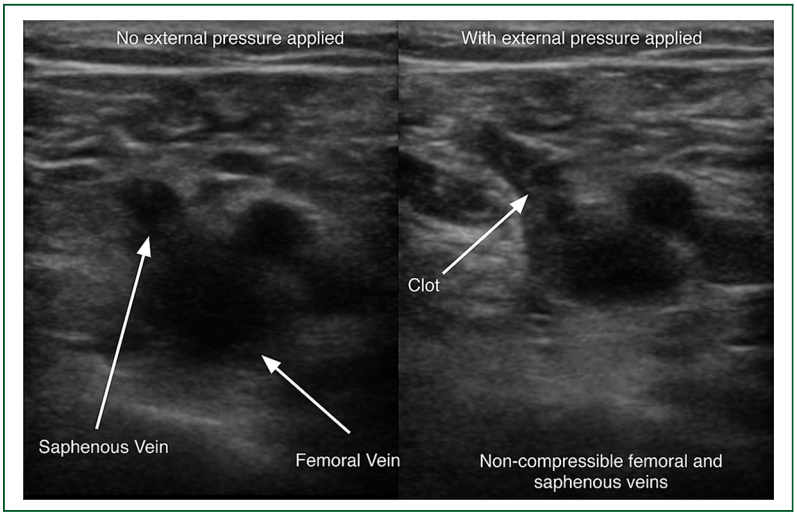

FIGURE 6. Deep vein thrombosis at the femoral vein.

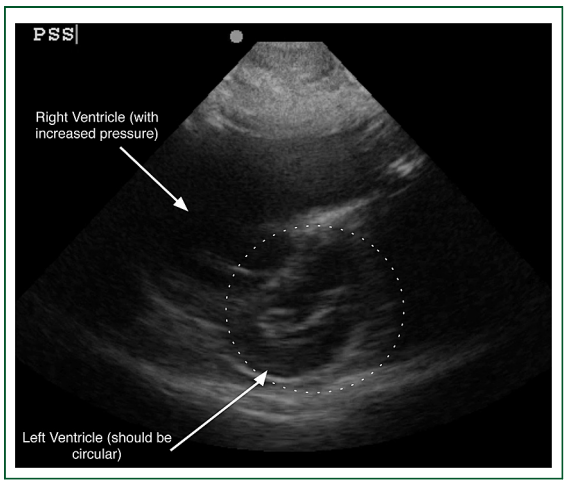

FIGURE 7. Parasternal short view, septal bowing.

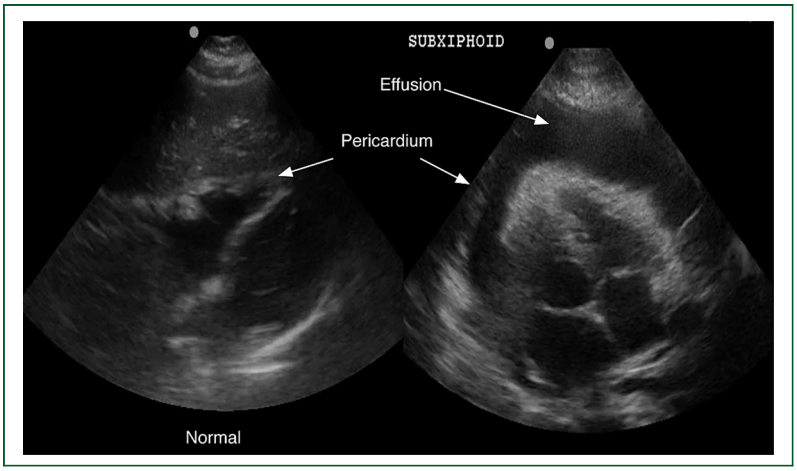

FIGURE 8. Subxiphoid view—normal versus pericardial effusion.

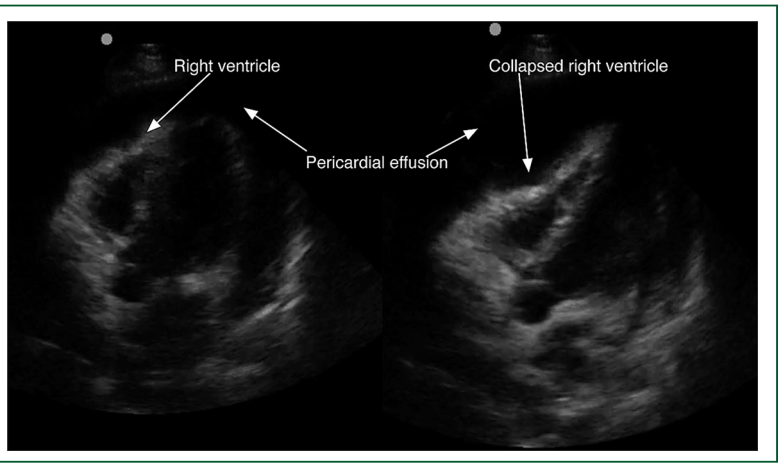

FIGURE 9. Parasternal long view with right ventricular collapse.

effusion include trauma, myocardial rupture complicating myocardial infarction, aortic dissection, autoimmune disease, renal disease, malignancy, and cardiac surgery. Also, patients on anticoagulation would benefit from the imaging of their pericardium. The presence of muffled heart sounds, jugular venous distention, and hypotension clinically represents cardiac tamponade.

CASE 3: FEVER

A 75-year-old man with a history of diabetes had been hospitalized for 1 week on the orthopedics service after an operation for a broken hip. His recovery had been slow due to significant pain. The medical consult resident was called due to delirium, low-grade fever, and tachycardia. On physical examination, his temperature was 38.2°C, heart rate of 110 beats/min, and blood pressure 86/45 mm Hg. Cardiopulmonary examination was unremarkable; however, there was tenderness to palpation in the upper abdomen from epigastrium to the right costal margin.

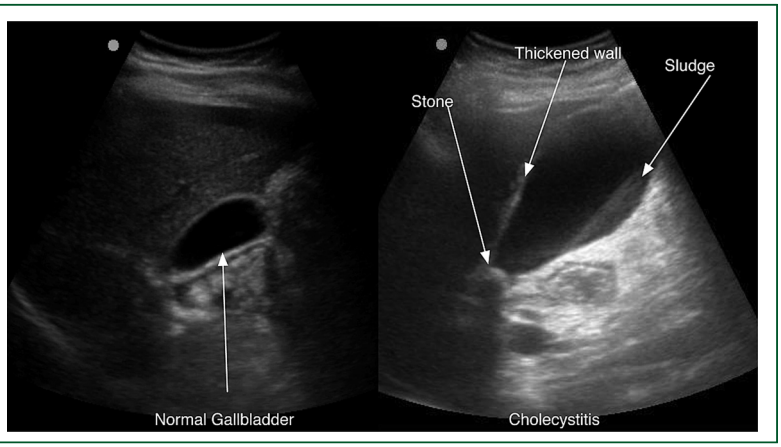

FIGURE 12. Gallbladder—normal versus cholecystitis (gallstone, wall thickening).

FIGURE 10. Plethoric IVC diameter (>2.1 cm and minimal collapse with respirations). IVC, inferior vena cava.

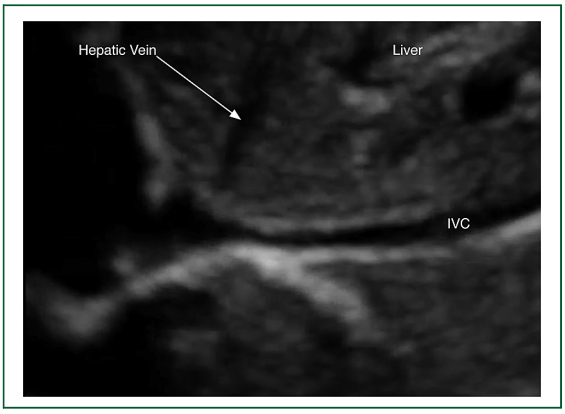

FIGURE 11. IVC—near total collapse. IVC, inferior vena cava.

In addition, there was a 20-cm region of moist skin with erythema, mild breakdown, and tenderness on his sacrum. Ultrasound examination demonstrated a tachycardic and hyperdynamic heart; the lungs were unremarkable; the inferior vena cava was collapsing during respiration (Fig. 11); and the biliary ultrasound did not demonstrate cholecystitis (Fig. 12). The area of sacral erythema was evaluated and demonstrated a cellulitis (Fig. 13).

Diagnosis: Sepsis secondary to cellulitis

Postoperative patients, in particular the elderly with hip surgeries, can be quite complicated and have high mortality rates. Evaluations on these patients must be broad, because not only are they subject to infectious processes, but they are also entirely dependent on others

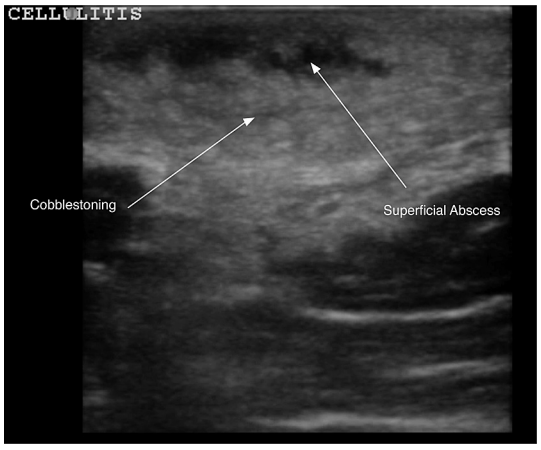

FIGURE 13. Cellulitis with cobblestoning and small superficial abscess.

for activities of daily living. In this case, clinical history, ultrasound, and perhaps a urine dipstick were all that was needed to make a diagnosis, and direct treatment required several liters of intravenous fluids and antibiotics.

CASE 4: ABDOMINAL PAIN

A 73-year-old man with past medical history of hypertension, coronary artery disease, chronic low back pain, and heavy smoking was admitted for an impressive cellulitis. While on the wards, he developed progressive left flank pain. On examination, he was diaphoretic, with a heart rate of 118 beats/min and blood pressure 90/60 mm Hg. His abdomen was diffusely tender, and he had costovertebral angle tenderness. An ultrasound was performed and demonstrated no free fluid in the abdomen, a nondistended bladder (Fig. 14), no evidence of hydronephrosis (Fig. 15), and no evidence of cholecystitis. However, his aorta did demonstrate a sizeable aortic aneurysm (Fig. 16).

Diagnosis: Abdominal aortic aneurysm

Abdominal and flank pain can have quite a broad differential, ever increasing with the age of the patient. Consequently, when there is no obvious diagnosis, a broad evaluation is needed. POCUS allows the provider to rule out infectious processes, urinary retention with consequent hydronephrosis (in this case, possibly secondary to an enlarged prostate, polypharmacy, or even central canal stenosis due to a bulging disc), biliary pathology, and finally aortic aneurysm.

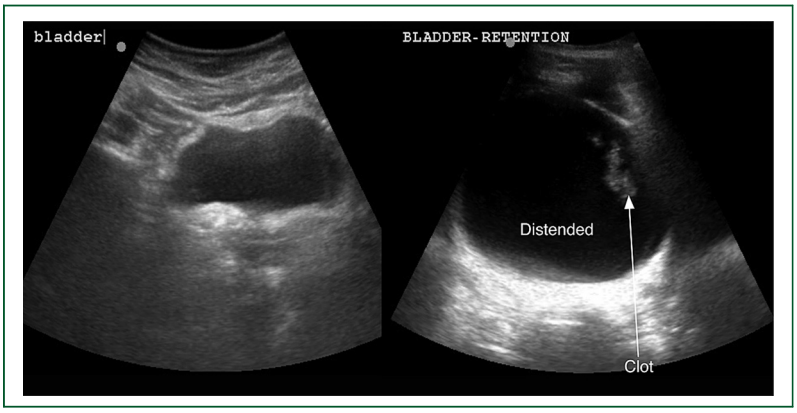

FIGURE 14. Bladder—nondistended versus distended.

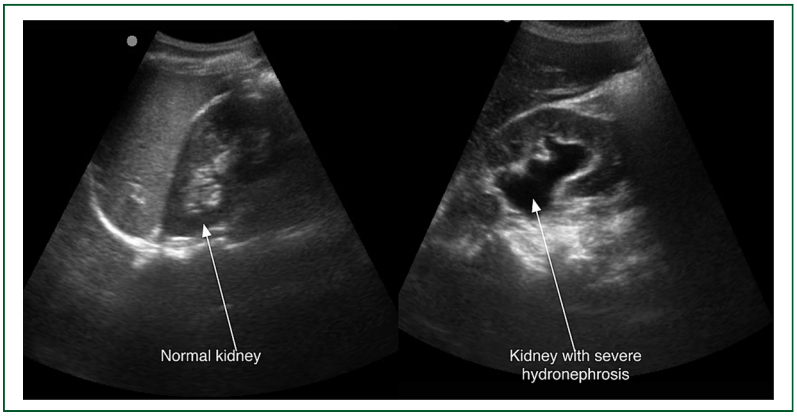

FIGURE 15. Kidney—normal versus hydronephrosis.

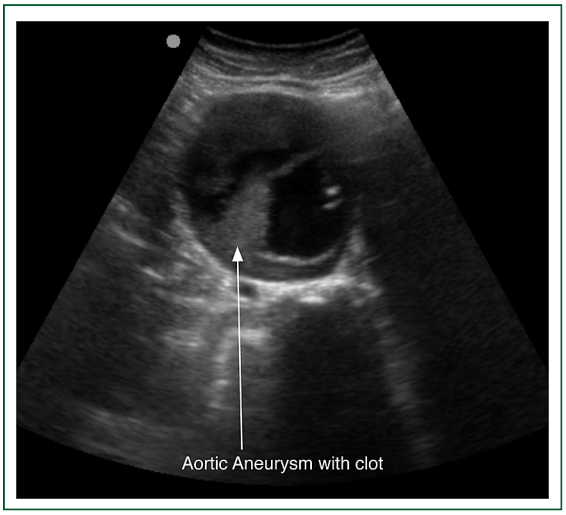

FIGURE 16. Aortic aneurysm with clot.

CONCLUSIONS

As the ultrasound probe ventures to the hands of internists, pediatricians, surgeons, and other subspecialists, patients will have the opportunity to receive quicker, safer, and better care. The RRT is clearly a natural first fit as a mobile acute care team, as internists gain familiarity with the modality as a point-of-care test.

Challenges and barriers do exist on a variety of fronts including implementation of the ultrasound-based RRT programs in hospitals, which require not insignificant capital expenditures, continuous educational programming including didactic and simulation for providers, as well as planning for collaborative rounds specialties.

POCUS is clearly a powerful tool in the management of patients in many clinical settings. With the evolution of handheld devices, its use by a wide variety of practitioners will only continue to grow. With the quality of the devices rapidly improving, and price-points steadily decreasing, patients will come to expect their physicians be facile with the modality and internists will want the tool for the purpose of expediting diagnosis, procedural guidance, and case management.

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