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REVIEW ARTICLE

Perioperative Ultrasonography Review

[1]Nicholas J Schott, [2]Christopher K Schott

ABSTRACT

Point-of-care ultrasonography (POCUS) has become increasingly utilized in modern medicine. Advancements in device technology and ease of use have dramatically broadened its clinical applications. The role in acute care specialties of a point-of-care device has allowed increased opportunities for patient assessment and management. The specialties of emergency medicine and critical care medicine have accepted POCUS in many aspects of clinical use as well as trainee education. Anesthesiology has begun to implement the use of POCUS, specifically transthoracic echocardiography, in the perioperative setting. Many elements of patient care can be addressed and modified using this as an assessment tool. This has led to in growth in ultrasonography training and the potential to be a staple of future anesthesiology care. Point-of-care ultrasonography may become vital to the forefront of management for improving perioperative patient care.

Keywords: Perioperative ultrasound, Point of care, Transthoracic.

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BACKGROUND

Technology has advanced tremendously in medicine while concurrently allowing the ease of application for the end user. In the case of ultrasound equipment technology, this has been exceptionally true. In many situations, the cost, portability, and the extent of applicability for contemporary ultrasound devices have appreciably made leaps and bounds over the past 20 years.[1,2] Today, devices are able to be pocket-sized while allowing good visual image quality. The days of transporting potentially unstable patients to radiologic suites for sonographic studies has transitioned to bringing devices to the patient. The discipline of using a sonographic device for patient assessment, or point-of-care ultrasonography (POCUS), has blossomed in numerous specialties.

Point-of-care ultrasonography in the acute care settings has evolved over time from a niche modality to expanded clinical use and influenced practice guidelines.[3-5] The specialties of emergency medicine (EM) and critical care medicine (CCM) have utilized POCUS for urgent patient care. In EM, the scope of POCUS is wide. In the trauma setting, the use of POCUS for the focused assessment with sonography for trauma (FAST) examination has become prominent and even replaced former invasive procedures, such as the diagnostic peritoneal lavage.[6,7] This also has allowed rapid, focused cardiac assessment in patients presenting with undifferentiated shock physiology. Other uses of POCUS have grown to being able to perform focused assessments of the gallbladder, aorta, kidneys, lungs, lower extremities for deep vein thrombosis, soft tissue, musculoskeletal, obstetric/gynecologic, ocular, and even more advanced hemodynamic measurements.[4,5] It has also been utilized for direct visualize guidance during invasive bedside procedures. Newer studies have shown that POCUS for endotracheal intubation can be used as an adjunct for confirmation of placement in the emergency medicine setting.[8]

In a critical care setting, POCUS has gained importance as a compliment to patient examinations from emergent diagnostic use to guiding daily care.[9-11] Examples of this include serial cardiac and pulmonary examinations to diagnosis shock or guide resuscitation and fluid management. Additionally, it can be used for venous mapping for deep vein thrombosis for risk assessment in a hypoxic patient suspected of pulmonary embolism, arterial, and venous vascular access for invasive monitoring, as well as procedures including thoracentesis and paracentesis.[3,5,12-15] Focused cardiopulmonary assessment, in particular, has evolved substantially. The pulmonary evaluation using ultrasound historically was not assessed as air is a nonconductor for ultrasonic energy waves, yet this too has changed dramatically.[13] Using proper windows and modes, viewing of the sonographic artifacts created by the lungs has led to the ability to evaluate thoracic parenchyma and pleural structures.

[1]Resident, [2]Assistant Professor

[1]Department of Anesthesiology, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, USA

[2]VA Pittsburgh Healthcare System, Department of Critical Care Medicine and Emergency Medicine, University of Pittsburgh Medical Center, Pittsburgh Pennsylvania, USA

Corresponding Author: Christopher K Schott, Assistant Professor, VA Pittsburgh Healthcare System, University Drive C, Pittsburgh, Pennsylvania, USA, Phone: +4123603718, e-mail: schottck@upmc.edu; Christopher.Schott@va.gov

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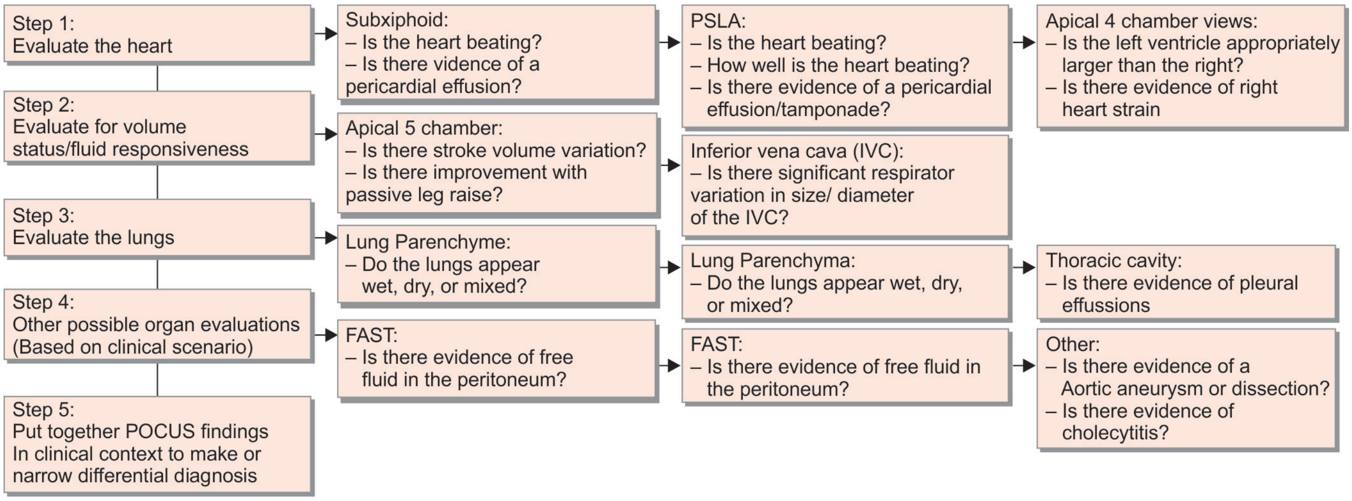
Flow Chart 1: This algorithm is derived from other validated protocols and provides a structure on how to approach an acutely hypotensive or hypoxic patient with POCUS. Included are the focused the clinical to begin building or refining a differential diagnosis based on the clinical scenario



Examples of these applications include the determination of pulmonary edema, pneumothorax, atelectasis, pneumonia, and pleural effusions.[13] Real-time viewing of anatomy with POCUS greatly assists in guiding treatment and intervention, such as chest tube placement, dieresis, or endotracheal intubation in critically ill patients.[8,12]

Cardiopulmonary assessment using POCUS has allowed rapid assessment in critically ill patients. Numerous differential diagnoses can be excluded, included or narrowed on POCUS echocardiography. In order to facilitate examinations and allow training, multiple examination protocols have been used. Some examples include focused assessment for transthoracic echocardiography (FATE), rapid ultrasound for shock and hypotension (RUSH), and bedside lung ultrasound in emergency (BLUE).[9,12,16] Each protocol may differ in terms of recommended views to specific diagnostic questions to ask, the inclusion of calculations of cardiac function, the inclusion of pulmonary assessment, and time intended to complete examinations. However, they all provide similarities in views obtained in order to narrow the potentially broad differential diagnoses in an acutely hypotensive or hypoxic patient. Flow Chart 1 provides a broad overview of the windows utilized and clinical questions that may be answered in a goal-directed POCUS examination of a critically ill patient.

The goal of these protocols is for a rapid, targeted assessment of cardiopulmonary function with the acquisition of information to direct care in urgent or emergent settings.[7,9,11] These examinations were created to not be fully comprehensive and supersede formal transthoracic or transesophageal echocardiographic (TEE) examinations, but as a segue way for further workup and management. This is the defining factor that separates these examinations as "point-of-care" or focused examinations, where the provider is attempting to answer simple "yes or no" findings to rule in or out potential diagnoses. Additionally, use of POCUS has been established in many teaching institutions where bedside ultrasonography provides additional acute care education and feedback.[17-19]

In the specialties of EM and CCM, POCUS had become integrated into the core medical residency training as well as including fellowships to develop ultrasound expertise. Numerous studies have shown how acute care residency programs have introduced and utilized POCUS in various settings.[18-23] The maturation of this component to their training has grown to the development of requirements issued by the accreditation council for graduate medical education (ACGME) and other specialty governing bodies.[18,24,25] With the evolving use of POCUS in these related specialties, it is merely a matter of time before it becomes more fully integrated into anesthesia and the perioperative care environment.

PERIOPERATIVE TRANSTHORACIC ULTRASOUND WINDOWS

Specific windows are critical to understanding and implementing perioperative transthoracic echocardiography (TTE). Each view gives specific insight into the patient's anatomy and physiology while contributing to the overall examination at hand. The most commonly acquired perioperative views will be briefly summarized.

Subcostal (Subxiphoid) Four-chamber Window

The subcostal four-chamber view has the benefit of grossly visualizing the entire four chambers of the heart including pericardium and venous inflow from the inferior portion of the patient's body. The ultrasound

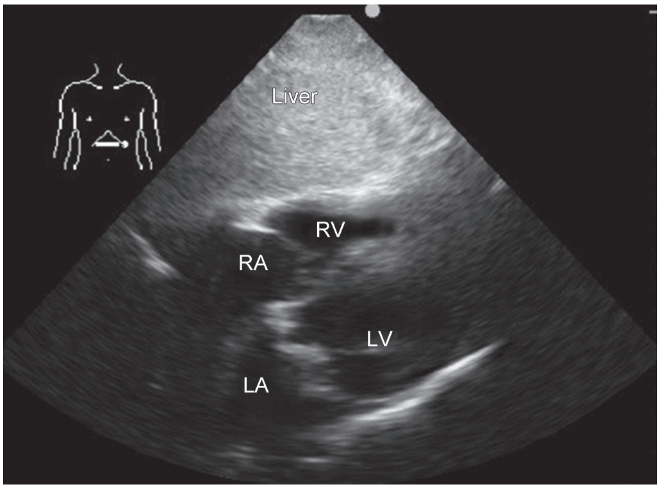


Fig. 1: Subcostal four-chamber view. RV: Right ventricle; RA: Right atria; LV: Left ventricle; LA: Left atria

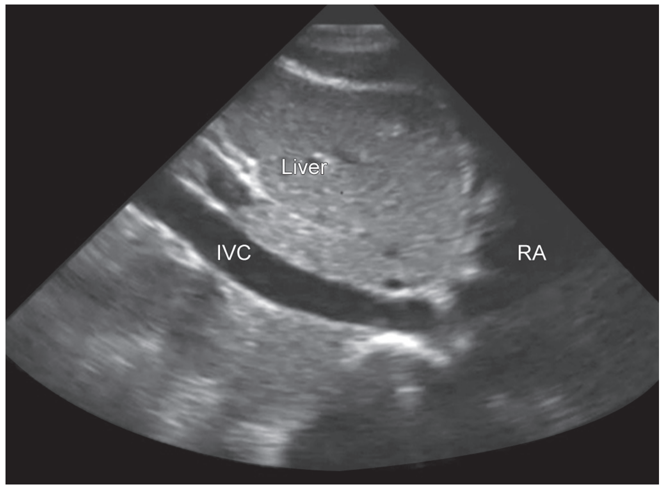


Fig. 2: Subcostal IVC view. RA: Right atria; IVC: Inferior vena cava

probe is placed under the xiphoid process with the probe marker directed toward the patient's left side, using traditional cardiology orientation and presets (Fig. 1). This will bring the heart in view with the right ventricle closest to the probe and therefore most superficial/superior on the ultrasound screen. In this view, the heart is in the dependent position, allowing view of potential fluid collections around the heart. In this same region, the ultrasound probe may be adjusted to obtain views of the inferior vena cava (IVC). This view can be accompanied by rotating the probe in longitudinal fashion while observing the venous inflow into the right atrium. This allows observation of the IVC as it travels through the liver (Fig. 2). Studies have shown that this may be helpful in assessing volume status (i.e., estimating a central venous pressure) in a spontaneously breathing patient using IVC dynamic variation with respirations.[26]

Parasternal Long-axis

The use of the parasternal long-axis (PSLA) view is useful for assessing the left side of a patient's heart, particularly in terms of identifying a pericardial or pleural effusion and gross estimation of left ventricular systolic function. The PSLA view is obtained by placing the cardiac probe at the 3rd to 4th intercostal space on the left sternal border with the probe indicator facing to the patient's right shoulder (Fig. 3). In this view, the inflow and outflow to the left ventricle can be seen including the mitral and aortic valves, which allow assessment of valve pathology, such as regurgitation when using color Doppler processing. Overall left ventricle morphologic appearance and function can be assessed with particular focus on left ventricular septal and posterior walls.

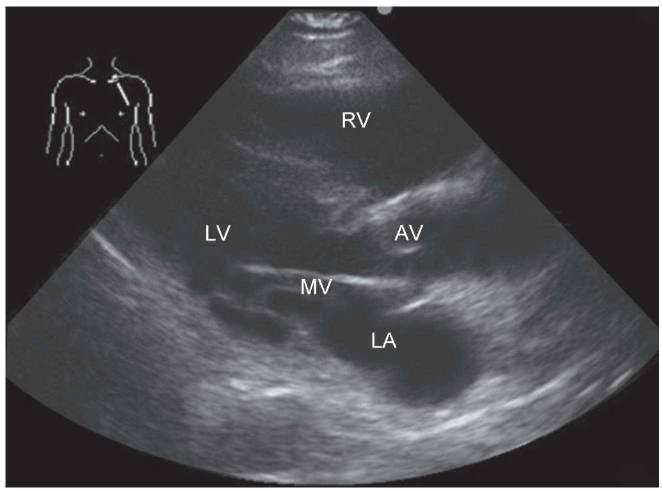


Fig. 3: Parasternal long-axis view. RVOT: Right ventricular outflow tract; LV: Left ventricle; LA: Left atria; MV: Mitral valve; AV: Aortic valve

Parasternal Short-axis Window

The parasternal short-axis view is obtained by rotating the PSLA view 90° clockwise, toward the patient's left shoulder. This provides a view of the heart in cross-section, which allows visualization of the left ventricle at multiple levels depending on angle of the probe and intercostal space (Fig. 4). The three main levels of view include a cross-sectional aortic valve, mitral level, and mid-papillary views. This window provides visualization of the aortic and mitral valves as well as comparison of right-to-left ventricular size. Additionally, regional wall motion abnormalities may be assessed in this view through the 360° cross-sectional appearance of the left ventricle that is seen.

Apical Four- or Five-chamber Window

The apical views may be obtained at the point of maximum amplitude of cardiac contraction, typically inferiolateral

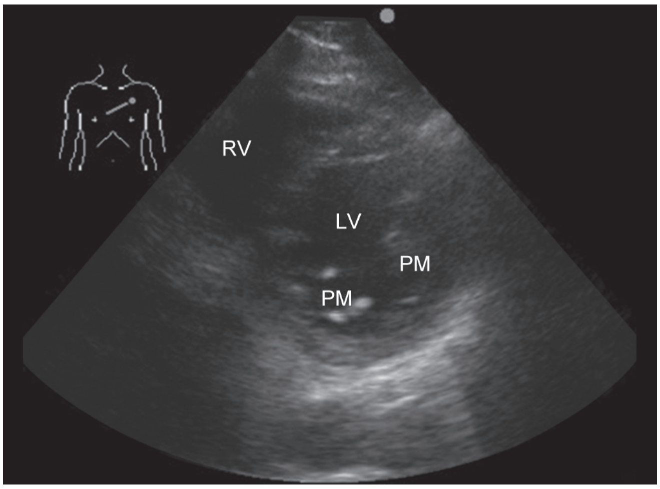


Fig. 4: Parasternal short-axis mid-papillary view. RV: Right ventricle; LV: Left ventricle; PM: Papillary muscle

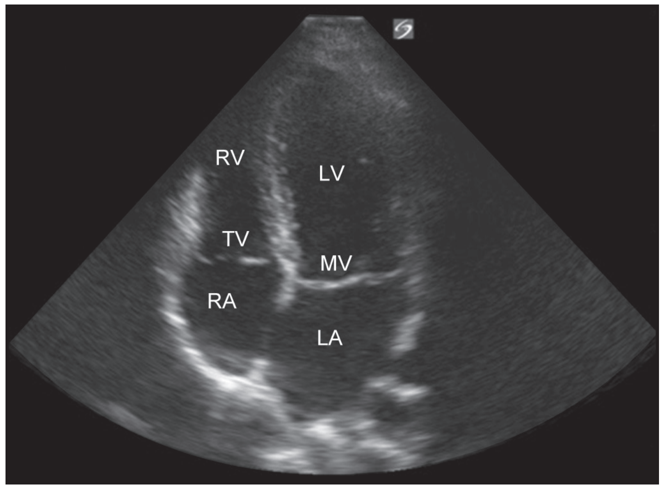


Fig. 5: Apical four-chamber view. RV: Right ventricle; RA: Right atria; LV: Left ventricle; LA: Left atria; MV: Mitral valve; TV: Tricuspid valve

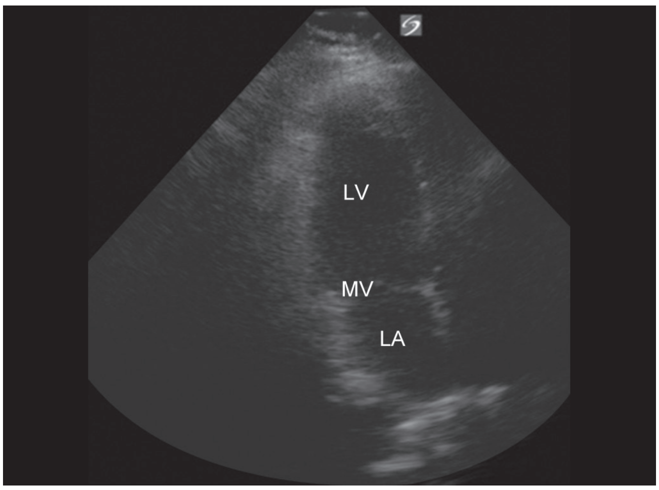


Fig. 6: Apical two-chamber view. LV: Left ventricle; LA: Left atria; MV: Mitral valve

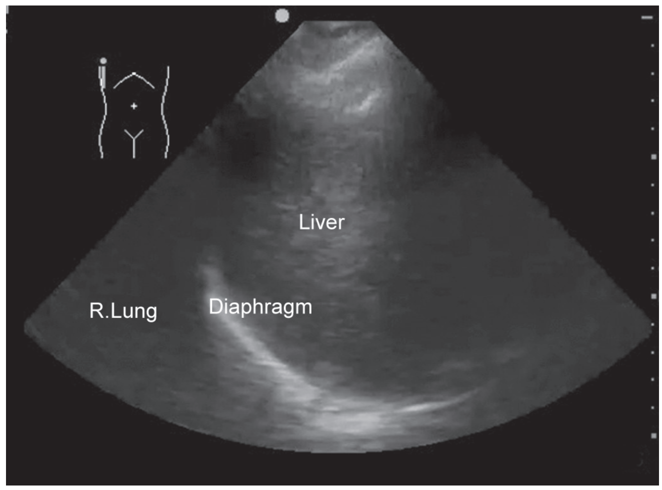


Fig. 7: Pulmonary base view at right costodiaphragmatic junction

to the patients left nipple with the probe marker aiming toward the patients left axillae. This may be a challenging view for beginners and image acquisition may be augmented by having the patient role into a left lateral decubitus position, bringing the heart closer to the anterior thoracic wall. This view shows cross-section of all four chambers of the heart and allows direct visualization of the mitral and tricuspid valves for a more intricate assessment of stenosis or regurgitation (Fig. 5). The five-chamber view is a modification of angulation of the four-chamber view with respect to bringing the aortic valve into the center of the window. With direct alignment of the aortic valve and Doppler imaging, this information can be used to calculate cardiac output, stroke volume variation, and aortic stenosis or regurgitation.

Apical Two-chamber Window

Rotating the probe 90° counterclockwise so that the marker is now orientated toward the patient's right axillae, while still in the apical window, produces the apical two-chamber view. This orientation brings the left ventricle, atrium, and mitral valve into a cross-sectional view, allowing assessment of the anterior and inferior walls of the left ventricle (Fig. 6).

Pulmonary Windows

The phased array probe, used in the cardiac evaluation, can then be used to assess the thoracic pleura and pulmonary parenchyma by looking through intercostal spaces. Of note, this may require changing the preset on the ultrasound machine from a cardiac to a lung or superficial preset. When looking superficially, lung sliding can be seen to rule in or out a pneumothorax at the specific point being investigated. With more imaging depth, one can begin to assess for the presence and location interstitial or alveolar edema. At dependent portions of the thorax, the diaphragm is seen (Fig. 7) and potential pleural effusions may be seen. Of note, one may switch to a higher frequency linear probe to obtain better resolution of more superficial aspects of the pleural in evaluating lung sliding to assess for a pneumothorax.

CURRENT ANESTHESIOLOGY USES

Use of POCUS in anesthesiology in the perioperative setting is developing at a rapid pace.[13,27] The application of ultrasound guidance for placement of invasive monitoring devices, including arterial and central venous access, has been occurring more and more, particularly with its recommended use in current practice guidelines.[28] Anesthesiologists have already had exposure to intraoperative POCUS through TEE with training in this procedure as a critical aspect of any practice setting.

Recently, many anesthesiology residency programs have begun expanding ultrasound use in other perioperative settings.[29,30] A recent publication has described anesthesiology residency training in POCUS with application in many specific areas, such as in cardiovascular, neurological, thoracic, and venous examinations.[31] Some programs have included perioperative TTE in the preoperative anesthesiology clinic.[27] With increasing use, POCUS for TTE in the perioperative period will be addressed in terms of indications and training considerations.[32]

INDICATIONS

The indications for POCUS in the perioperative setting are very similar to those for the critically ill patient.[9-11] These indications are derived from the need for rapid diagnosis and potential immediate medical or surgical management. Applications of use are directed into various categories: (a) Initial diagnosis, (b) therapy-directed guidance, (c) intermittent monitoring, and (d) follow-up.

Initial Diagnosis

With a clinical suspicion of a potential cardiovascular or pulmonary abnormality, use of diagnosis algorithm for a specific concern may easily be incorporated into the initial patient assessment of a patient with acute hypoxia or hypotension. Examples of published protocols include the RUSH, FATE, and BLUE examinations.[12-14,32,33] Use of one of these validated protocols incorporates systematic viewing of all sonographic windows with notation normal and abnormal findings. Findings during these focused examinations may lead to immediate therapeutic interventions or further evaluations, such as other imaging modalities, electrocardiogram, or specialty service consultation. Flow Chart 1 provides a broad overview and summation of recommended sonographic views utilized and clinical questions that may be answered in a goal-directed POCUS examination of a critically ill patient.

Therapy-directed Guidance

Treatment and timely intervention can be managed using perioperative echocardiography. Changes, such as responsiveness to a fluid bolus infusion or, conversely, the cardiopulmonary response to diuresis can be visualized in real time. The finding of pericardial effusions to suggest tamponade during a cardiac arrest may lead to pericardiocentesis. Lack of lung pleural sliding may suggest a pneumothorax in the right clinical setting, prompting intervention with needle decompression or tube thoracotomy. Additionally, procedures, such as chest use insertion or vascular access may be aided by direct visualization through the use of POCUS in the operating room, postanesthesia care unit (PACU), or after transfer to an intensive care unit (ICU). Goal-directed management with focus on the visualization changes in physiology is the greatest benefit of POCUS.

Intermittent Monitoring

After management has begun and the patient is stabilized, continued monitoring utilizing POCUS and perioperative TTE may be critical. Longer-term response and management with ongoing adaptations may serve as a bridge until other invasive monitoring is achieved or a desired end point is obtained. For example, serial evaluations will help guide continued assessment of a hypotensive patient's volume status to guide further fluid or pressor administration until a goal blood pressure is restored. These intermittent examinations could be scheduled or performed as frequently as changes occur. Documentation of images obtained and documentation of interventions during POCUS allow continuity of care other service care teams provide for the patient, such as admission to the ICU.

Follow-up

Postoperatively, a follow-up examination may give ongoing insight into the providers, patient, and families to the current and future medical plan. Recovery of the initial event may clinically occur. However, observations on POCUS may visualize any residual effects. An example of this would be a patient with a hypertensive episode resulting in pulmonary interstitial edema. Treatment may provide adequate oxygenation and extubation of a patient in the PACU or ICU. However, follow-up in the days after may show ongoing disease process or other change not able to be acutely seen but contributing to the original event. The convenience of the bedside examination allows the anesthesiologist to gain insight without exposure to radiation, invasive procedures or costly testing that may occur.

Recently, the appropriate use of POCUS and TTE in the critically ill patient has been analyzed and published.[9,11] These criteria have been reviewed and modified to continually adapt and improve patient care. Overall, the process of POCUS and TTE in the perioperative period allows the anesthesiologist to have real-time feedback with open communication to all possible teams involved.

DECISION AND TREATMENT ALGORITHMS

At present, there have been many validated protocols in the use of POCUS to evaluate patients following trauma, during a cardiac arrest and the acute onset of hypoxia or hypotension. Each of these protocols has many similar elements, with slight changes in recommended views to obtain for the particular clinical question or scenario at hand. For example, the BLUE protocol was developed to rapidly determine the cause of hypoxia or respiratory distress.[12-14] In patients experiencing acute hypotension, or even during pericardiac arrest scenarios, POCUS protocols, such as the FATE examination or RUSH may be utilized to identify cause and initiate specific therapeutic interventions.[32,33]

FUTURE CONSIDERATIONS AND SUMMARY

The use of focused POCUS has evolved greatly in recent years. Its presence in anesthesiology continues to spread in use and practicality. There are clear applications for potential preoperative, intraoperative, and ongoing postoperative assessments. Many centers and residency programs have begun utilizing POCUS as part of a didactic and clinical program throughout training.[31] Potential for cross-specialty use may aid in transitions of care and management. It is easy to foresee POCUS growing in anesthesiology residency programs through curriculum development. It is not unreasonable to predict the general understanding and competency of perioperative ultrasound becoming a standard for residency requirements or maintenance certification. In anesthesiology, potential use of ultrasound may be implemented and tested in board examinations in the near future for possible standardized clinical examinations scenarios.[34] Given the history and projected evolution of POCUS in anesthesiology, it is critical for providers to be familiar with its application to the care of perioperative patients.

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