

# How we do Multiorgan Integrated Critical Care Ultrasonology (MICCUS): An Approach for Patient Evaluation

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## ABSTRACT

The point-of-care ultrasonography (POCUS) has become integral for physicians working in critical care set-ups. It has been used for acute and crisis management, ongoing care of the patient, real-time guidance for performing procedures, diagnostic and screening aids, etc. Interestingly, the use of POCUS is increasing daily, and intensivists and critical care physicians are routinely scanning the lung, heart, vascular structure, abdomen, optic nerves, etc. Presently, literature for the routine and emergency use of ultrasound for protocolized assessment for differentiating and diagnosing acute respiratory failure, acute shock, and undifferentiated shock is available. Although there is some overlap, most of the protocolized approach primarily aims at respiratory or circulatory failure.

On the other hand, the respiratory and cardiovascular system is well integrated. Moreover, critically ill patients also suffer other organ insufficiencies because of cardiorespiratory insufficiencies or vice versa. Nevertheless, POCUS is now considered the visual stethoscope of critical care physicians. Therefore, a multiorgan integrated approach is justified for assessing the patient right from the first clinical evaluation on admission. This article is intended to provide brief information related to the use and current practice of ultrasonology for critical care patient management by the residents and provide a technical framework for multiorgan integrated critical care ultrasonology (MICCUS) approach for evaluating patients having a new or ongoing acute cardiorespiratory insufficiencies with particular emphasize on the respiratory, cardiac, and vascular systems and integrating the evaluation of the abdomen and urological system. Nevertheless, the MICCUS is just an approach (how critical care ultrasonology can be integrated), not a protocol. It is developed by using existing and validated protocols on topics.

## Keywords

Critical Care; Emergency Department; Respiratory Disease; Shock; Trauma; Point-of-Care Ultrasound; Clinical Evaluation

## INTRODUCTION

Despite being user-dependent, ultrasonology is widely accepted and recognized for clinical use beyond the radiological suite for non-radiologists and even in primary care<sup>1,2</sup>. The portable nature of the ultrasound device, lack of radiation hazard, point-of-care user interface, and the easy learning curve have made it an essential armamentarium for anaesthesiologists and critical care physicians and has been used as a clinical assessment tool<sup>3,4</sup>. The European Society of Intensive Care Medicine even recommends ultrasound use and training as core competency-based training<sup>5</sup>. It can even be regarded as part and parcel for critical care physicians as it can aid and supplement the clinical examination, establish differentials, and even confirm the diagnosis with good reliability and efficiency. Anaesthesiologists, actively involved in perioperative and critical care, often use transthoracic point-of-care echocardiography for diagnosing cardiac

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problems and hemodynamic measurements<sup>6</sup>.

Further, bedside ultrasound by the critical care physician can reduce the need for other radiological investigations, patient transfer to radiological suit, and related complications. Many works of literature for the routine and emergency use of ultrasound are available; even protocolized assessment using point-of-care ultrasonography (POCUS) for differentiating acute respiratory failure and undifferentiated shock is described<sup>7</sup>. The present article is intended to provide brief information related to the use and current practice of ultrasonology for critical care patient management by the residents and provide a technical framework for a multiorgan integrated critical care ultrasonology (MICCUS) approach for evaluating patients with a special emphasize on acute cardiorespiratory insufficiencies. The integrated approach is developed from the validated protocols for acute respiratory failure, fluid assessment, shock, and trauma. It integrates the evaluation of the respiratory, cardiac, vascular, abdomen, and urological systems. Nevertheless, the MICCUS is just an approach (how critical care ultrasonology can be integrated), not a protocol.

### **Opinion: Why a Multiorgan Integrated Approach?**

The critically ill patient often suffers from multiple organ insufficiencies at admission or throughout the critical illness. Therefore, the evaluation and management of such patients are also multi-dimensional and well-understood. Although most critically ill patients suffer from either respiratory failure or shock, most protocols like Basic Lung Ultrasound Examination (BLUE)<sup>8</sup>, Fluid Administration Limited by Lung Ultrasonograph (FALLS)<sup>9</sup>, Focused Assessment with Sonography for Trauma (FAST) and extended Focused Assessment with Sonography for Trauma (eFAST)<sup>10,11</sup>, SIMPLE<sup>12</sup>, Rapid Ultrasound for Shock and Hypotension (RUSH)<sup>13</sup>, etc., primarily target a section of these common problems. On the other hand, the cardiovascular and respiratory systems are well integrated and often affect each other or suffer together. Therefore, using revolutionary technology, i.e., ultrasonology as POCUS as an adjunct to patient management at the bedside in a multiorgan integrated way, is more justifiable. The use of multiorgan integrated POCUS for acute pulmonary oedema has been pointed out earlier. Still, no or limited such approach exists for POCUS to assess and manage a patient with cardio-respiratory insufficiencies.

The BLUE protocol is intended to pick up the common

lung pathologies in line with clinical examination, auscultation, and chest x-rays. The protocol provides an algorithmic approach to diagnose pneumonia, pneumothorax, pulmonary oedema, pulmonary embolism, COPD, and Asthma. It is based on the ultrasonographic findings of BLUE points of the lung, Posterior and/or Lateral Alveolar and/or Pleural Syndrome (PLAPS) point, and sequential venous analysis. Based on the presence of A-lines, B-lines, and lung sliding, the protocol defines profiles and thereby hints towards possible diagnosis and rules out a few. However, the protocol does not explicitly point toward the ALI and ARDS nor touch the cardiac evaluation and shock<sup>8</sup>.

Unexplained shock and its management can also be assisted using POCUS, which the FALLS addresses. While it can be considered a product or adaptation of BLUE protocol, it uses the underlying ability of the lung ultrasound to detect interstitial syndrome, which is also a marker of clinical volume. The FALLS protocol is primarily intended for the hemodynamic management of shock and can differentiate obstructive, cardiogenic, distributive, and hypovolemic shock. The protocol starts with scanning the heart for pericardial tamponade and right ventricular dilatation to suggest pulmonary embolism and then steps into the BLUE protocol. It also incorporates the fluid administration and evaluation of its response<sup>9</sup>.

The FAST and its extended version, i.e., eFAST, is well known and currently regarded as fundamental for trauma care. It primarily intends to find the collection of blood in the different potential spaces and cavities after trauma and causing hemodynamic instability. The FAST uses four windows viz.: pericardial (subxiphoid), hepatorenal, splenorenal, and suprapubic (pelvic). A bilateral lung window is added to FAST to make it eFAST, which can detect pneumothorax and hemothorax<sup>10</sup>. FAST and eFAST assessments should be done in patients with shock but not responding to fluid resuscitation<sup>11</sup>.

A mnemonic-based 'SIMPLE' approach for cardiac ultrasound has also been suggested for cardiac scanning and etiological evaluation in shock patients<sup>12</sup>. The SIMPLE approach also helps diagnose abdominal aortic aneurysms by assessing the aorta size in the epigastrium. The RUSH protocol also intends to diagnose and differentiate the different types of shock. In this protocol, the cardiovascular system is considered

in three segments, i.e., pump (heart), tank (IVC and abdominal and thoracic cavities), and pipes (aorta and lower extremity veins). The heart is evaluated on the left parasternal long axis and subxiphoid view. The same probe in the subxiphoid view can be used for assessing the IVC, followed by FAST windows for abdominal and thoracic cavities. The RUSH protocol, however, scans the abdominal aorta across the length at four points (infracardiac, suprarenal, infrarenal, and right at the iliac bifurcation) <sup>(13)</sup>.

### **The Proposed Approach: MICCU - Multiorgan Integrated Critical Care Ultrasonology**

We propose an integrated algorithm for critical care patients' management in Figure 1.

The proposed algorithm is not intended to replace any established protocols validated for their diagnostic utility but to be used as a clinical decision-making tool during patient assessment and management. We do not claim that MICCUS is a new idea. However, based on our preliminary search of the literature, we believe that the algorithm provided by us is the first of its kind, which is an advancement and innovation of existing literature and protocols that will allow the use of POCUS as an adjunct to the physical examination in an integrated way. The MICCUS approach presented here has used the BLUE points described for the BLUE protocol<sup>14</sup>.

Further, we have used established left parasternal long and short axis, apical four-chamber and two-chamber view, and subcostal four-chamber view for a focussed cardiac ultrasound. While the inferior vena cava (IVC) can be examined using a subcostal cardiac view after rotating the probe anti-clockwise towards the liver or even from a PLAPS point, we find using a curvilinear probe over the epigastrium more practical. Further, we suggest using a colour Doppler for venous (DVT) screening to study the flow and compression test as per the recommendation of a multidisciplinary team, which has shown better results<sup>15</sup>.

### **The Practical Application and Scope of MICCUS**

As mentioned above, the main idea of the MICCUS is the application of POCUS right at the time of patient admission in critical care as a part and visual adjunct of patient examination. However, the approach applies whenever a patient develops a new cardio-respiratory insufficiency or deterioration. It can even be used as an assessment protocol for finding the disease progression, abdominal collection, hydronephrosis, urinary bladder

condition, etc. From our experience, applying the MICCUS approach takes 10-15 minutes for a patient with a relatively good ultrasound window. However, it is common to find poor windows in critically ill patients. While it is not inclusive, we propose to use the algorithm in two slightly different sequences based on the predominant signs and symptoms, i.e., desaturation and shock. While both sequences start from the upper BLUE points, lower BLUE point assessment can be kept towards the later part of the sequence for patients having shock as the predominant presentation. However, given that the whole MICCUS evaluation takes only a few minutes, it is unlikely to impact therapeutic decision-making significantly. The probe position and movement sequences are shown in Figure 2.

The MICCUS approach is intended to diagnose and decide significant cardiopulmonary, abdominal, and acute urological problems, as presented in Table 1.

**Table 1** describes the MICCUS probe points and intended diagnosis or pathologies.

Probe points	Window description	Intended findings/pathologies
1 and 2 -	BLUE upper point	r/o pneumothorax
3 -	PLAPS (right)	r/o pneumonia and pleural effusion
3a -	PLAPS (right) extended	Hepato-renal pouch – r/o fluid collection, hydronephrosis, cholecystitis, liver abscess, liver injury
4 -	Sub xiphoid	r/o cardiac tamponade, hypovolemia
5 -	PLAX/PSAX	r/o hypovolemia, RWMA and valvular pathologies
6 -	A4C	r/o hypovolemia, ventricular contractility, RWMA, MI
7 -	PLAPS (left)	r/o pneumonia and pleural effusion
7a -	PLAPS (left) extended	Splenorenal pouch – r/o fluid collection, splenic injury, splenic infarct.
8 -	AA slide	r/o abdominal aortic aneurysm
9 a, b, c, d -	(a) LFV, (b) RFV, (c) RPV, (d) LPV	r/o deep vein thrombosis
10 -	Suprapubic window	r/o free fluid in rectovesical (in a male) or rectouterine and vesicouterine space (in a female), urine in the bladder/catheter position or obstruction

**The table needs to be used as an adjunct to**

**Figure 2.** (A4C- apical four-chamber, AA slide- Abdominal aorta slide, BLUE- Basic lung ultrasound examination, LFV- left femoral vein, LPV- left popliteal

vein, MI- myocardial infarction, MICCUS- Multiorgan Integrated Critical Care Ultrasonology, PLAPS- posterolateral alveolar and/or pleural syndrome, PLAX- parasternal long-axis view, PSAX- parasternal short-axis view, RFV- right femoral vein, RPV- right popliteal vein, RWMA- regional wall motion abnormality, r/o- rule out.)

## DISCUSSION

Ultrasound use has increased far from a mere diagnostic aid, which is more valid for critical care practice. Lung and thoracic ultrasonology is now pointed as a visual stethoscope<sup>16,17</sup>. Studies have shown it has better sensitivity and specificity in detecting lung pathologies like pleural effusion, alveolar consolidation, and AIS over X-rays<sup>18</sup>.

### Uses of POCUS/MICCUS

For descriptive purposes, the use of POCUS in critical care can be categorized as below, although overlapping uses are often expected.

#### *For Acute and Crisis Management*

These include Basic Lung Ultrasound Examination (BLUE) protocol for acute respiratory failure, Focused Assessment with Sonography for Trauma (FAST), and extended Focused Assessment with Sonography for Trauma (eFAST) for trauma patients, Fluid Administration Limited by Lung Ultrasonography (FALLS), Rapid Ultrasound for Shock and Hypotension (RUSH), SIMPLE, etc. for patients with shock including differentiation of shock types.

#### *For Ongoing Care*

These include real-time procedural aid (direct visualization of the procedure) for central venous catheterization, peripherally inserted central line, arterial cannulation, even deeper peripheral vein catheterization, tapping of fluids from pleural, pericardial and abdominal cavities, airway management, etc.; screening and clinical assessment adjunct: screening for deep vein thrombosis (DVT), central compartment fluid status, optic nerve sheath diameter (ONSD) assessment, pulmonary edema, kidney echotexture and morphology, hepatic vein assessment, etc.; diagnostic use for diagnosing pneumothorax, pleural effusion, pericardial effusion, pulmonary thromboembolism, oesophageal intubation; therapeutic aid - use for regional analgesia technique, positive end-expiratory pressure (PEEP) adjustment, drainage of

unwanted body collections, etc.; monitoring purpose - optic nerve sheath diameter (ONSD), papilledema, pneumonic patch or consolidation progression, fluid responsiveness; increasing patient safety by reducing radiation exposure from multiple x-rays; outcome predictive utility - diaphragmatic excursion assessment weaning difficulty and failure; screening of abdomen for collection or abscess, detecting hydronephrosis, etc. Studies indicate that PoCUS can be used in high-risk pregnant women for determining fetal status by using umbilical artery Doppler velocimetry, which has shown similar sensitivity and specificity to non-stress tests<sup>(19)</sup>. Furthermore, bedside assistance for managing liver abscesses and subsequent follow-up is also feasible<sup>20</sup>.

#### *Investigational Use*

POCUS has recently been used for PEEP adjustment, management, and prognostication during cardiopulmonary resuscitation, antibiotic de-escalation, etc.

The efficacy and usability of POCUS in critical care, emergency department, and anesthesiology settings are beyond doubt. A systematic review analyzing the effect of POCUS in association with clinical information for diagnosing diseases found an increase in diagnostic accuracy from 45-60% to 80-89% compared to the standard of care<sup>21</sup>. Although the evidence from observational and retrospective studies for routine focused echocardiography in anesthesiology and critical care has not shown a clear outcome benefit, it was noted that focused echocardiography could modify the diagnosis and change the management of patients frequently<sup>22</sup>. The real-time use of ultrasonography in critical care patients is well known. It bears more importance while performing a procedure near or on the vascular structures or critical organs, as well as while performing the procedures in the pediatric population where the structures are relatively more minor and delicate. Using ultrasonography for vascular access procedures reduces the number of attempts, increases the success rate at the first pass, and reduces complications. Some patient care authorities recommend it as the standard of care<sup>23</sup>. Recent studies indicate that the non-availability of ultrasound led to delayed initiation of intervention and optimization of critically ill patients<sup>(22)</sup>. The learning curve of ultrasound for vascular access is also brief; as many as 30 procedures under guidance give good competency<sup>24</sup>.

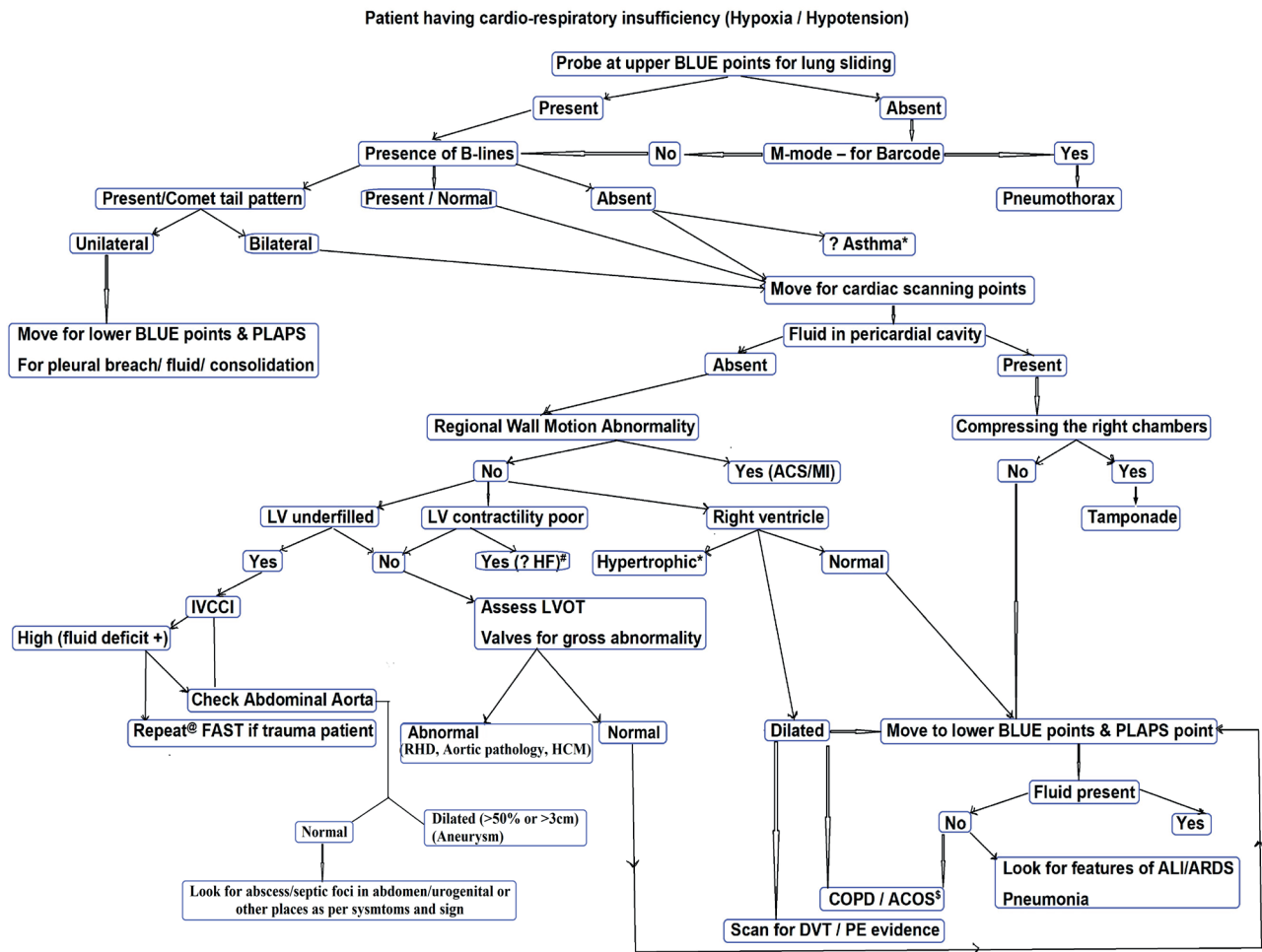


## LIMITATIONS

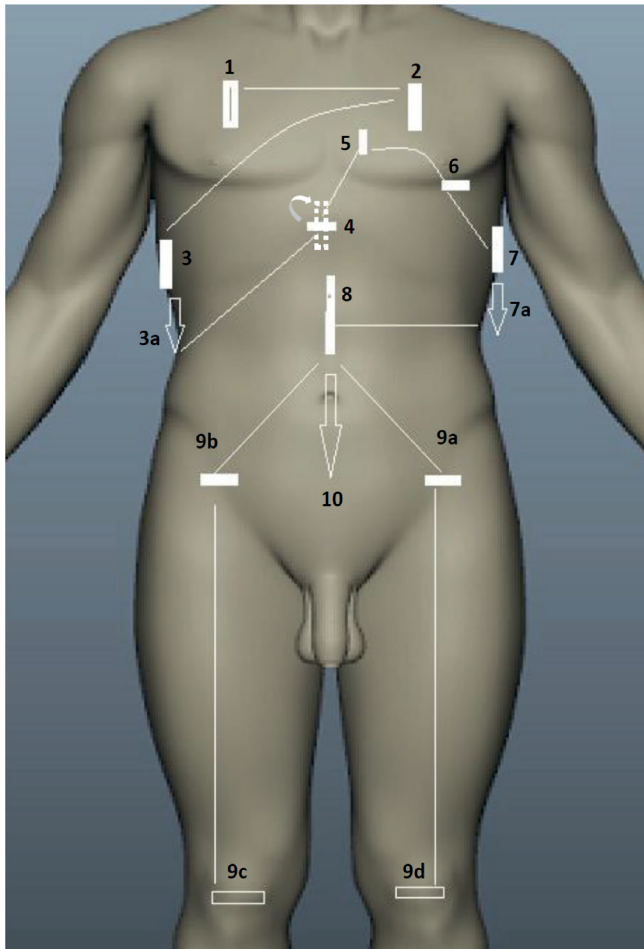
As the MICCUS is just a suggested approach to POCUS, the inherent technical and patient-related limitations of POCUS will also apply to MICCUS. User dependency, variation, competency, and the learning curve will impact the MICCUS performance. However, because POCUS is recommended as a core competency for critical care training and regular workshops worldwide on POCUS, critical care residents are expected to achieve the required proficiency quickly. Such training,

however, still needs to remove the limitation of the non-availability of the device, especially in developing countries<sup>24</sup>. Although it is easy to learn, the knowledge and skill are expected to deteriorate after training unless practised.

Further, MICCUS is just an adaptation or amalgamation of the different POCUS approaches into one. Therefore, it is also expected to work like the BLUE, FALLS, FAST, etc. Nevertheless, future research will be required to confirm the same.



**Figure 1:** The Multiorgan Integrated Critical Care Ultrasonology algorithm for decision-making on possible pathologies in patients with hypoxia and/or shock. (ACS - Acute Coronary Syndrome, ACOS- Asthma-COPD Overlap Syndrome, ALI- acute lung injury, ARDS- Acute Respiratory Distress Syndrome, BLUE- Basic Lung Ultrasound Examination, COPD- Chronic Obstructive Pulmonary Disease, DVT- deep vein thrombosis, FAST- Focused Assessment with Sonography for Trauma, HCM- hypertrophic cardiomyopathy, HF- heart failure, IVCCI- inferior vena cava collapsibility index, LV- left ventricle, LVOT- left ventricular outflow tract, MI- myocardial infarction, PE- pulmonary embolism, PLAPS- Posterior and/or Lateral Alveolar and/or Pleural Syndrome, RHD- rheumatic heart disease)



**Figure 2:** The Multiorgan Integrated Critical Care Ultrasonology approach: probe points and movement sequences.

## CONCLUSIONS

To conclude, ultrasonology and its application in the critically ill has revolutionized patient management. It has even value as a clinical evaluation tool like a stethoscope for heart and lung and has an additional visual advantage. The broad spectrum of applications for assessment, diagnosis, therapeutic aid, and even as a predictive tool makes it necessary to have and use clinical armamentarium in critical care training and patient management. A multiorgan integrated approach for applying ultrasonology (e.g., MICCUS) for patient examination and evaluation is worth evaluating for possible usefulness.

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