

Competencies for Point-of-care Ultrasonography in ICU: An ISCCM Expert Panel Practice Recommendation

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Received on: 07 March 2022; Accepted on: 12 April 2022; Published on: 29 October 2022

Keywords: Central venous catheter, Competencies, Critical care, Deep vein thrombosis, Echocardiography, e fast, Lung ultrasound, Optic nerve sheath diameter, Point-of-care, Point-of-care ultrasound.

Indian Journal of Critical Care Medicine (2022): 10.5005/jp-journals-10071-24199

INTRODUCTION

Point-of-care ultrasonography (POCUS) refers to performing scans on the bedside and real-time interpretation of images and its incorporation into a clinical pathway. Over the last two decades, POCUS has been found to have unparalleled use in intensive care unit (ICU) and has demonstrated an indisputable positive effect in influencing decision making at the bedside.¹ It helps the bedside clinician to acquire rapid and reliable answers for the deranged physiology and pathology and is rapidly becoming an integral part of ICU protocols worldwide.

India has over 7,500 registered critical care practitioners. With ever increasing use of point-of-care ultrasound in critical care for diagnostic, monitoring, and therapeutic purpose; it is imperative to develop a standardized training structure with well-defined core competencies to enable rapid and reliable image acquisition and interpretation. Use of critical care sonography (CCS) and critical care echocardiography (CCE) has made substantial progress in day-to-day use for diagnostic and therapeutic purposes in intensive care units.

To achieve competency, ICU clinician should have clinical knowledge and skills to perform an examination of airway, lungs, heart, abdomen, vascular structures, optic nerve, and brain. The clinician should also have proficiency in anatomy of the structures examined, associated pathologies, and their interpretation to have a correct clinical correlate of point-of-care imaging.

A core group of leaders practicing point-of-care ultrasound (POCUS) of Indian Society of Critical Care Medicine was formulated to define various competencies, in order to standardize training and certification. The group discussed various aspects of POCUS and defined the competencies based on consensus.

The aim of the document is to elaborate on the desirable competencies that are expected in a clinician to appropriately use point-of-care ultrasonography in the ICU.

The document does not summarize the evidence for the use of sonography in various pathological states nor does it evaluate the available evidence for various sonographic interpretations of diseased state rather it simply provides a framework of various competencies needed to comprehensively evaluate the patient from head to toe using point-of-care ultrasound.

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General Principles for Any Ultrasound Examination and Procedures

For examination of any organ or region of the human body, the clinician should have a sound knowledge on anatomy of that organ and region as well as sonoanatomy. Prior to performing the scan the patient should be explained about the procedure and its potential benefits to his or her care and that the scan may have to be repeated to guide therapy.

The clinician should be familiar with various probes required for image acquisition and optimal patient position needed for optimal image acquisition and patient as well as user comfort. For a complete competency, the clinician should exhibit proficiency in various indications and limitations of ultrasound examination of various regions and organ systems.

For any ultrasound-guided procedure, proper selection of probe, adjustment of gain, depth settings, identification of site of needle puncture, angle of inclination, and underlying depth for a safe needle penetration is vital and the clinician should have a sound clinical knowledge and skills for real-time guided procedure. The clinician should also show proficiency in maintaining sterility during examination and procedure and decontamination of probes after every examination.

Physics Governing the Ultrasound and Image Acquisition

Prerequisite for any good ultrasound examination is a sound knowledge and an understanding of the basic principles governing the sound waves.² For competency in POCUS, the clinician should have the proficiency, knowledge, and clinical command on the following principles of physics:

- Propagation of sound waves, interaction of ultrasound waves with various tissues, concept of acoustic impedance, attenuation, reflection, refraction, scatter, and transmission
- Knowledge and proficiency about pulse frequency, pulse duration, pulse length, pulse repetition period, duty factor, and concept of aliasing
- Knowledge and command over the use of focus, depth, gain, and automated gain compensation
- Clinical command over various modes of ultrasound (gray scale, M mode, Doppler)
- Principles governing the Doppler and various Doppler modalities including pulsed wave, continuous wave, color, tissue, and power Doppler
- Resolution and processing power of the system
- Understanding of various artifacts, their clinical and pathological significance, and limitations of ultrasound examination
- A sound understanding of various probes used and their uses and limitations

Airway Ultrasound

Ultrasonography of airway and neck has a wide range of clinical applications and can be used in the assessment of vocal cords, airway size, postprandial state, and also guide bedside procedures like endotracheal intubation and tracheostomy.³ For a competency in airway ultrasound, the clinician should exhibit comprehensive knowledge and skills on the following:

- Sonoanatomy of floor of mouth, thyroid, and cricoid cartilage
- Identification of cricothyroid membrane
- Identification of tracheal rings and deviation of trachea

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How to cite this article: Srinivasan S, Kumar PG, Govil D, Gupta S, Kumar V, Pichamuthu K, *et al.* Competencies for Point-of-care Ultrasonography in ICU: An ISCCM Expert Panel Practice Recommendation. *Indian J Crit Care Med* 2022;26(S2):S7–S12.

Source of support: Nil

Conflict of interest: None

- Identification of thyroid gland along with isthmus
- Demonstration of vocal cord movements and vocal cord palsy
- Assessment of prandial status
- Performance of ultrasound-guided endotracheal intubation, including confirmation of tube position and identification of esophageal intubation
- Performance of ultrasound-guided cricothyroidotomy and percutaneous tracheostomy

Lung Ultrasonography

The use of ultrasound to detect deranged physiology and pathology of the lungs is perhaps the most potent use of point-of-care ultrasound in critically ill patients with the increasing evidence of superiority of lung ultrasound compared to chest radiography in the identification of various lung pathologies in intensive care.^{4,5} The functional utility of lung ultrasound is not restricted to identification of pathological states; it is now used as a routine respiratory monitoring tool and is also used to perform invasive pleural procedures. For a competency in lung ultrasound, the clinician should exhibit comprehensive knowledge and skills in the following:

- Clinical significance of various sonographic zones of lungs
- Sonoanatomy, demonstration, and significance of pleural line and sliding: A lines, B lines, E lines, and Z lines
- Demonstration of lung pulse and its clinical significance
- Cognizance of various sonographic signs to diagnose pneumothorax, consolidation, atelectasis, pulmonary oedema, and acute respiratory distress syndrome at bedside
- Cognizance of sonography-guided lung recruitment strategies and their limitations
- Semi-quantification and monitoring of lung aeration and de-aeration and semi-quantification of extravascular lung water
- Identification, characterization, and quantification of pleural effusion and ultrasound-guided drainage of effusion
- Clinical command on the sonographic assessment of acute respiratory failure and fluid administration limited by lung sonography
- Prediction of weaning success and failure from ventilator in integration with diaphragmatic and cardiac sonography
- Understanding the limitations of lung ultrasound in context of the current evidence available
- Competency in ultrasound-guided percutaneous chest tube insertion

Ultrasound of Diaphragm

Diaphragm is easily assessable by ultrasound, and sonographic assessment of diaphragm is increasingly used as a monitoring tool in intensive care.⁶ For a competency in diaphragm ultrasound, the

clinician should exhibit comprehensive knowledge and skills in the following:

- Qualitative assessment of diaphragmatic movement
- Objective assessment of diaphragmatic excursion and thickness
- Prediction of weaning success and failure from ventilator in integration with lung and cardiac sonography

Ultrasound of Abdomen

Point-of-care ultrasound of abdomen is a propitious modality in critical care units. From being an integral part of evaluation of trauma patients^{7,8} to being an adjunct in diagnosis of multiple intra-abdominal pathologies,⁹ its wide range of applications has led to increased use on the bedside. For a competency in abdominal ultrasound, the clinician should exhibit comprehensive knowledge and skills in the following:

- Demonstrate and identify structures in right upper quadrant, left upper quadrant, pelvic view, subxiphoid, parasternal long axis, and thoracic views, and enumerate the significance as a part of eFAST (extended Focused Assessment with Sonography in Trauma) examination
- Identification of ascites in nontrauma settings, and clinical proficiency in real-time ultrasound-guided drainage of peritoneal fluid
- Identification and demonstration of normal anatomy of liver and gall bladder and abnormal presentations including hepatic abscess, cholelithiasis, and acalculous cholecystitis
- Identification and demonstration of normal anatomy of kidney and abnormal presentations including nephrolithiasis, various grades of hydronephrosis, gross renal mass and cyst
- Identification and demonstration of normal anatomy of bladder, identification of Foley's bulb and quantitative assessment of urine in the bladder. Also, identification of abnormal presentations including urolithiasis and mass
- Identification of bowel motility and signs of ileus
- Demonstration of clinical skills to perform ultrasound-guided suprapubic catheter insertion
- Identification of both thoracic and abdominal aorta and identification of specific pathologies like aneurysm and dissection

CARDIAC ULTRASOUND OR ECHOCARDIOGRAPHY

Echocardiography is an indispensable bedside tool in the critical care units for assessment of patients with circulatory and respiratory failure. Between Focused Cardiac Ultrasound (FOCUS), which is limited goal directed assessment and a detailed cardiac assessment, bedside echocardiography has infinite applications in intensive care.^{10,11} For a competency in echocardiography, the clinician should exhibit comprehensive knowledge and skills in the following:

- In-depth knowledge about anatomy of heart and proficiency in sonoanatomy
- Clinical efficiency on various movements of cardiac probe, which includes tilting, rocking, sliding, rotating, angling, and sweep
- Identification and demonstration of structures in various echocardiographic views, which includes:
 - Parasternal long axis (PLAX)
 - Parasternal short axis (PSAX) (at level of aortic valve, mitral valve, papillary muscle, and apex)

- Apical four, five, two, and three chambers
- Subcostal view with visualization of inferior vena view
- Suprasternal view with demonstration of aortic arch and its branches

PLAX View

- Right ventricle (RV) subjective enlargement and free wall motion
- Left ventricle (LV) measurement—formal 2D
- E-point septal separation (EPSS) by M-mode across tip of mitral leaflets for estimation of ejection fraction
- Left atrium (LA)/left ventricular outflow tract (LVOT)/aortic root measurement—2D
- LVOT diameter measurement
- Aortic Valve/Mitral Valve—valve morphology, vegetations, color Doppler (CD) for identification of regurgitation and stenosis jets
- LVOT—color Doppler for identification of turbulence
- Descending aorta: size/appearance for identification of dissection flaps, true and false lumen, thrombus, rupture, color Doppler for identification of flows in true and false lumen
- Pericardial effusion/features of tamponade; recognizing pleural effusion, and differentiating it from pericardial effusion
- RV PLAX view to appreciate RV, RA, passage, and checking position of pacing wire, positioning of veno venous (VV) ECMO cannulas

PSAX View

Aortic Valve Level

- Aortic valve CD
- Tricuspid valve—CD, Continuous Wave Doppler (CW)
- Pulmonary valve—CW, Pulse Wave Doppler (PW) for calculating RVOT VTI (right ventricular outflow tract velocity time integral) and PAT (pulmonary acceleration time for estimating pulmonary pressures), CD
- RVOT (distal)—2D, identification of main pulmonary and branch pulmonary arteries

Mitral Valve Level

- LV measurements
- Segmental wall motion abnormalities (SWMA)
- Identification of mitral regurgitation jet

Papillary Muscle Level

- LVEDA: RVEDA (EDA = end-diastolic area)
- Paradoxical septal motion
- Eccentricity index
- Fractional area change (FAC)
- Segmental wall motion abnormalities
- Assessment of hypovolemia
- Assessment of LV contractility

Apical Level

- Segmental wall motion abnormalities (SWMA)
- Identifying movement of cardiac apex

Apical 4-chamber/Apical 5-chamber

Left Atrium and Ventricle

- Chamber volumes—LV/LA
- LV Contractility—EF (eyeballing and preferably modified Simpson's method), SWMA
- Mitral inflow pattern—E/A

- Tissue Doppler Imaging mitral annulus—septal/lateral E'/A/S'
- Pulmonary vein inflow pattern preferable—identification of S, D, A waves with atrial duration and reversal

Left Ventricle Outflow Tract

- 2D, CD, PW, CW
- Recognize SAM
- Measurement of stroke volume and cardiac output by LVOT velocity time integral
- Assessment of fluid responsiveness by using swings in LVOT VTI in response to passive leg raising, end expiratory occlusion, fluid challenge

Right Atrium and Ventricle

- Size—RV/RA [right ventricular end-diastolic area (RVEDA): left ventricular end-diastolic area (LVEDA) ratio]; RV/RA dimensions
- RV free wall motion
- RV contractility subjective
- Tricuspid Annular Plane Systolic Excursion (TAPSE), Tissue Doppler Imaging (TDI) tricuspid annulus S'
- Calculation of right ventricular systolic pressure and pulmonary artery systolic pressures by tricuspid regurgitation jet, correct positioning of central line, pacing wire, ECMO cannulas

Valves

- Mitral valve—2D, CD, PW, CW
- Tricuspid valve—2D, CD, CW
- Aortic valve—CD, PW (LVOT), CW
- Pulmonary valve—CD, PW, CW (for pulmonary regurgitation jet)

Apical 2-chamber

- Chamber size—LV/LA volume
- Contractility—EF (eyeballing and modified Simpson's), SWMA
- Mitral valve—2D, CD, PW, CW

Apical 3-chamber

- Essentially the PLAX view with visualization from a different angle
- Appreciate SWMA, posterior pericardial effusion, eccentric mitral regurgitation jets. Also, to eyeball the descending aorta for dissection

Subcostal View

- All chambers—size, ventricular contraction (eyeballing)
- Right ventricular free wall thickness
- SC-SAX views, if PLAX SAX is suboptimal
- Inter Atrial Septum—CD for patent foramen ovale (PFO)/atrial septal defect (ASD); identification of pericardial effusion and tamponade
- Use during cardiopulmonary resuscitation for identifying reversible causes
- IVC view—M-mode/2D measures identifying IVC collapsibility/distensibility, positioning of ECMO cannula, transhepatic view of IVC
- Hepatic vein flow—CD, PW, and its utility and limitations
- Assessment for volume responsiveness by left ventricular outflow tract velocity time integral
- Identification and characterization of pericardial effusion and tamponade. Demonstration of clinical skills to perform sonography-guided pericardiocentesis

- Clinical skills to perform echocardiography-guided temporary venous pacing catheter insertion
- Assessment of circulatory shock and respiratory failure in integration with lung and abdominal ultrasound
- Identification of cause of cardiac arrest in pulseless electrical activity
- Clinical skills to differentiate pulseless electrical activity from false electromechanical dissociation
- Clinical knowledge and skills to demonstrate various step-wise approaches for use of echocardiography in cardiac arrest

Ultrasound for Deep Vein Thrombosis and Pulmonary Thromboembolism

The reported incidence of deep vein thrombosis in the intensive care unit is 5–33% and close to 10–50% patients with deep vein thrombosis may develop pulmonary embolism.¹² Thromboembolism is associated with significant morbidity and early detection by limited bedside ultrasound is shown to improve outcomes.¹³ For a competency in detection of venous thrombosis, the clinician should exhibit comprehensive knowledge and skills in the following:

- Sound clinical knowledge about vascular anatomy of upper and lower extremity
- Demonstration of techniques of assessment of venous thrombosis by identification of spontaneous flow and variation with respiration, compression sonography, color Doppler method, and distal augmentation technique
- Demonstration of echocardiography findings of pulmonary embolism by assessment of right atrial and ventricular size, tricuspid jet and assessment of pulmonary artery pressures, right ventricular systolic function and other signs of significant pulmonary embolism like McConnell sign, D-shaped septum, and paradoxical septal movement

Optic Ultrasound

Optic ultrasound has evolved as a bedside noninvasive monitoring tool for intracranial pressure.¹⁴ Assessment of optic nerve sheath diameter, identification of papilledema, and pupillary reaction have a short learning curve and good reproducibility. For a competency in optic ultrasound, the clinician should exhibit comprehensive knowledge and skills in the following:

- Identification and demonstration of normal anatomical structures
- Measurement of optic nerve sheath diameter, identification of papilledema, and clinical interpretation
- Identification and demonstration of various pathologies like dislocation or subluxation of lens, vitreous hemorrhage, and retinal detachment
- Measurement of pupillary size and demonstration of pupillary reactions
- Understanding of potential complications of optic ultrasound

Brain Ultrasonography

Sonography of the brain is a noninvasive bedside technique of neuromonitoring with reliable and reproducible assessment of cerebral vascular flow and hemodynamics and bedside assessment of midline shift.¹⁵ Unlike optic ultrasound, brain sono-imaging, including transcranial Doppler and midline shift assessment, has a longer learning curve. For a competency in ultrasound of brain,

the clinician should exhibit comprehensive knowledge and skills in the following:

- Sound clinical knowledge of brain anatomy, especially vascular anatomy and sonoanatomy
- Demonstration of technique of transcranial Doppler through temporal window and identification of structures, including temporal bones, third ventricle and anterior, middle and posterior cerebral arteries
- Demonstration of technique to measure peak systolic, end diastolic, and mean flow velocity of middle cerebral artery and calculation of pulsatility index
- Assessment of signs of brain death, vasospasm and cerebral hyperemia

Ultrasound for Vascular Access

Vascular access is one of the most frequently performed procedures in intensive care units. Use of ultrasound for aiding vascular access has shown to reduce the incidence of all potential complications (like arterial puncture, pneumothorax, hematoma formation, failed cannulation, assessing venous anomalies and thrombus) and also improved first-time cannulation rates.¹⁶ The principles governing the use of ultrasound for vascular access are uniform irrespective of site and type of cannulation, and the clinician should have a sound knowledge about the local vascular anatomy and also have a strong hand eye coordination for a successful procedure. For a competency in ultrasound image-guided vascular access, the clinician should exhibit comprehensive knowledge and skills in the following:

- Demonstration of internal jugular vein cannulation by transverse, longitudinal, and oblique approach
- Use of Doppler and color to differentiate between artery and vein
- Demonstration of infraclavicular and supraclavicular approach of subclavian vein cannulation and infraclavicular axillary vein cannulation by longitudinal approach
- Demonstration of femoral vein cannulation by transverse and longitudinal approach
- Demonstration of insertion of peripherally inserted central cannulas
- Demonstration of radial and femoral arterial cannulation by both longitudinal and transverse approach

CONCLUSION

Using a consensus method, we defined the core competencies in point-of-care ultrasound in critical care, and are most illustrative of all competencies defines till date. Albeit, the use of ultrasound in critical care is an evolving field with new indications ever expanding, this document will set a foundation for training standards for point-of-care ultrasound in critical care.

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