SPECIAL ARTICLE

# Ultrasound in critical care

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## ABSTRACT

Ultrasound (US) was introduced in the 1950s and since then its use has increased exponentially. This has been facilitated by significant improvement in the probe technology, increasing access to portable machines and better understanding of lung, heart, abdominal and vascular US. Use of critical care US (CCUS) is now extremely common. It is important for frontline physicians who must make appropriate and timely decisions within seconds. It is safe, convenient and readily available in many centers.  The concept of point of care ultrasound (POCUS) differs from US screening by a radiologist or sonographer. It is, rapid focused and goal-orientated. Despite its major limitation, e.g. operator dependence, bedside CCUS can be used for an ever-increasing range of indications. This narrative review will describe the potential role of CCUS as the replacement for the stethoscope in the 21st century and the limitations which must be overcome to achieve this.

**Key words:** Ultrasound; Critical care; Point of care ultrasound; Diagnosis

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## INTRODUCTION

The stethoscope was invented in France in 1816 by René Laennec in Paris[1] and it revolutionized medical practice as the first non-invasive method of assessing internal organs. Its use remains fundamental to clinical practice in intensive care in many countries of the world. Ultrasound (US) was introduced in the 1950s and since then its use has increased exponentially. In some centers bedside US has virtually rendered the stethoscope obsolete.[2] This transformation of US into the 21st century equivalent of the stethoscope has been facilitated by significant improvement in the probes allowing higher resolution images, increasing access to portable machines and better understanding of lung, heart, abdominal and vascular US imaging.

Critically ill patients require safe, effective and timely interventions. Performing the diagnostic assessments required to achieve this is particularly challenging. In this context, as the technology has improved, the emerging modality of critical care US (CCUS) which combines general ultrasonography with advanced echocardiography has become a game changer. The use of bedside CCUS can accelerate the diagnostic process and enhance decision making which can be lifesaving when seconds count.

The advantages of CCUS include its portability, lack of exposure to ionizing radiation, non-invasiveness and low cost in comparison to other imaging modalities. It is one of the most commonly used imaging techniques in critically ill patients and is considered to be the first line tool for the establishment of many diagnoses worldwide. It can augment the findings on physical examination and increase the efficacy and safety of a wide array of diagnostic and therapeutic procedures. The major advantage of bedside CCUS is that unstable patients have not to be moved; the assessment can be performed at the point-of-care.

## POINT OF CARE ULTRASOUND

Point-of-care US (POCUS) is a sonographic assessment performed to directly answer a clear question relevant to the immediate care of a patient.[3] The main difference between a POCUS assessment and a traditional US scan is that POCUS can be performed rapidly, and is focused and goal-orientated. This approach helps physicians to incorporate anatomical and functional ultrasound findings into their diagnostic and therapeutic algorithms in real time at the bedside. One of the best developed POCUS algorithms incorporates lung ultrasound into the assessment of a patient presenting with sudden onset breathlessness.

## LUNG ULTRASOUND

Bedside sonography provides a unique opportunity to noninvasively explore the lungs of critically ill patients (Figure 1) and lung US has advanced significantly over the last decade.[4] Lung US allows rapid, accurate bedside examinations of most acute respiratory disorders.[4]

However, these principles must be kept in mind when interpreting lung US:[4]

1. Lung ultrasound is performed at best using simple equipment.
2. Standardized areas can be defined as lung is the most voluminous organ.
3. Many signs are artifacts generated from the air tissue interface.
4. In the thorax, gas and fluids have opposite locations so artifacts can be generated easily.
5. Real images allow identification of effusions and consolidation
6. All signs arise from the pleural line.
7. The signs arising from the pleural line are dynamic

There are several potential limitations to the use of lung US in critically ill patients (e.g. subcutaneous emphysema, dressings, and thoracic braces).[4] Although scanning can be difficult, the signs in the superficial lung windows are usually accessible and standardized. Air (the main hindrance for cardiac and abdominal echography) is the main focus of lung US.[4] The deep lung parenchyma cannot be assessed, but it rarely affects immediate management.[4]

Lung US either alone, or in combination with other POCUS assessments, can direct the diagnostic approach to patients with cardiac arrest, respiratory failure, or circulatory failure.[5] Furthermore, CCUS can assess both the lung and heart. This assessment has been protocolized. For example, the BLUE protocol can be used for the management of acute circulatory failure and the FALLS protocol uses lung ultrasound for the early detection of fluid overload.[5]

In patients requiring invasive mechanical ventilation a semi-quantitative bedside assessment of lung aeration (i.e. consolidation and atelectasis) can guide the setting of PEEP, monitor the progression of respiratory disease, assess the efficacy of treatment and direct weaning of support.[6,7] For example, the PINK protocol can be used in patients with acute respiratory distress syndrome.[7]

Lung US can also detect respiratory complications of mechanical ventilation (e.g. pneumothorax, ventilator-associated pneumonia, atelectasis, effusions).[8,9] Lung US can be used to guide interventions such as placement of drainage catheters.

## USG FOR VASCULAR ACCESS & PLACEMENT OF DRAINAGE CATHETERS

Placement of central venous and arterial catheters and chest drain for effusions have traditionally been done with landmark techniques, which depend on knowledge of standard anatomy as well as anatomical variants. These methods are associated with high rates of complications (15%) and failures (35%).[10]

Imaging the selected site of cannulation immediately prior to initiation of the procedure (Figure 2) can alert the physician to anatomical variations and will reduce the number of attempts required for successful cannulation.[10] Whilst this practice reduces complication rates even if US imaging is not used

**Figure 1: Ultrasound image of lung with arrows indicating multiple B lines.**

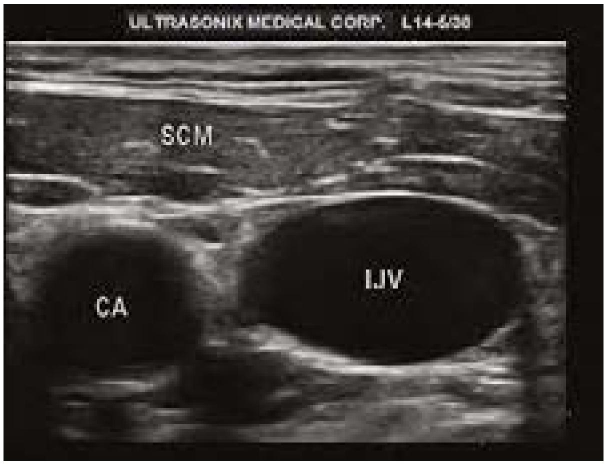


**Figure 2: Ultrasound image of internal jugular vein (IJV) and carotid artery (CA)**

during the procedure; vascular access is safest if real-time US guidance is used to visualize vessels, the introducer needle, guidewire and the catheter during cannulation.

As a result, several authors have recommended the use of sonographic guidance of commonly performed procedures in ICU since 1984.[11] In 2002, the UK's National Institute for Clinical Excellence (NICE) recommended use of two-dimensional imaging US guidance for the placement of central venous catheters.[12] Wigmore et al., (2007) reported an observational study which demonstrated the impact of following NICE guidance on complications from internal jugular vein cannulation.[13] The complication rate was 10.5% before the guideline and 4.6% post-guideline; most post-guideline complications occurred when the anatomical landmark technique was used.[13] The number to treat needed to prevent one complication was 14.5.[13] However, despite substantial evidence supporting US guided placement of central venous catheters and its cost effectiveness, the technique has not yet achieved universal acceptance even in developed countries. The developing countries need many more years to accept it as a standard tool in ICU. Yet this indication is only the tip of the iceberg of the huge potential of CCUS.

## OTHER COMMON USES OF US IN ICU

The list of potential diagnostic and therapeutic applications of CCUS are almost endless. These include detection of arterial and venous flow, screening for arterial or venous thrombosis, identification of pseudoaneurysm, diagnosis of aortic dissection, exclusion of hydronephrosis, volumetric assessment of the bladder, transcranial Doppler etc. Whole body ultrasound can also be used in critically patients with fever of unknown origin to detect a collection. Ultrasound has been used to guide an ever-increasing range of interventions including identification of difficult airway and subsequent management, Confirmation of the correct placement of tracheal tube, tracheostomy, inferior vena cava filter placement, arthrocentesis, and percutaneous nephrostomy placement etc.[14,15]

## LIMITATIONS

New technology often has several benefits but the limitations must also be recognized. Whilst the introduction of bedside CCUS can facilitate care and improve efficiency to fully realize these benefits, the big cost of USG requires significant investment. In the near future healthcare institutions will certainly have to bear the brunt of the financial cost; and the healthcare professionals will have to expend significant resources in terms of time and training to gain mastery of CCUS.

## TRAINING AND COMPETENCY IN CRITICAL CARE ULTRASOUND

The 21st century practice of critical care requires intensivists with expertise in CCUS. However, the training and experience required to achieve this mastery is challenging. The list of competencies must include abdominal, pleural, lung, and vascular ultrasound (i.e. general critical care ultrasonography, GCCUS) as well as critical care echocardiography.

As the interest in CCUS continues to grow with ever-increasing applications of this technology, the teaching of CCUS has not yet been incorporated into the formal training curriculum of critical care medicine or anesthesiology. To date only a few countries have developed specific programs for this purpose. Comprehensive lists of competencies required by intensivists using US has been formulated and published in competence statements from critical care societies.[16,17]

Several other specialties have also expressed great interest in training and gaining expertise in US. Recognizing this the UK Royal College of Radiologists published 'Ultrasound training recommendations for medical and surgical specialties'.[18] This describes how US training should be delivered by radiologists and non-radiologists and when further expert help from radiology department should be sought. The UK College of Emergency Medicine used these guidelines to develop its own curriculum and now US training is part of the core curriculum for all emergency medicine trainees in the UK. There are also guidelines from a joint working party of the Association of Anaesthetists of Great Britain & Ireland, the Royal College of Anaesthetists, and the Intensive Care Society.[19] Yet despite these statements, recommendations and guidelines, it remains difficult for intensivists to gain true mastery of CCUS due to various constraints. Organized training programs and continual practice will help intensive care staff to gain adequate expertise for the benefit of their subjects.

## CONCLUSION

Ultrasound is a versatile tool that has many potential uses. Some consider its usefulness lies in gaining knowledge about the patient while others believe it can facilitate the making of early and lifesaving decisions. To realize the full potential of US as a 21st century replacement for the stethoscope it is important to ensure that intensivists fully master the intricacies of this powerful tool.

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**Authors' contribution:** All authors contributed significantly in the preparation of this manuscript.

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