Lung ultrasound for organ donation and transplantation

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Abstract

Lung ultrasound (LUS) has emerged as a valuable, non-invasive imaging modality that enhances bedside clinical assessment without exposing patients to ionising radiation. Despite its current widespread use, LUS was historically met with considerable scepticism, with many clinicians sharing the view expressed in authoritative texts such as Harrison's *Principles of Internal Medicine*, which noted the thorax was unsuitable for Ultrasound (US) evaluation due to the air-filled lungs acting as a barrier for US (Fauci et al., 1997). This sentiment was encapsulated by Daniel Lichtenstein, who reflected on the prevailing attitudes of the 1990s with the phrase: *"Ultrasound, not us. Lung ultrasound, impossible"* (Lichtenstein, 2016, pp. 265).
Nevertheless, work by innovators such as Dr. Jos Roelandt, a Dutch cardiologist, demonstrated the potential of thoracic ultrasound as early as 1978 (Roelandt et al., 1978) His pioneering efforts influenced subsequent generations of clinicians, including Lichtenstein, who in 1993 published one of the earliest studies applying LUS within the Intensive Care Unit (ICU). Here, D. Lichtenstein & Axler (1993) demonstrated the effectiveness of LUS in confirming diagnoses and altering treatment plans in patients. These early findings directly challenged longstanding assumptions about the limitations of US in thoracic imaging. Today, the diagnostic relevance of LUS in a variety of clinical contexts continues to affirm the validity of those initial insights.

Historical perspectives and advancements in lung ultrasound technology

While X-rays became a cornerstone of medical diagnostics in the late 19th century, ultrasound (US) has seen substantial advancements over the past five decades, establishing itself as a vital and rapidly evolving imaging modality. In the early 1990s, clinicians began recognising the potential of US for broader clinical applications, including thoracic imaging. However, early US machines were bulky, heavy, and difficult to manoeuvre into restricted spaces such as ICUs.

To address this, the United States government supported the development of compact, portable, and durable ultrasound devices for use in austere or resource-limited environments (Noble, 2023). This initiative culminated in the creation of the first battery-powered portable US device in 1998

(Noble, 2023), a significant technological milestone that occurred one year after *Harrison's Principles of Internal Medicine* dismissed the viability of LUS (Fauci et al., 1997).

In low-resource healthcare settings, where access to advanced imaging devices such as computed tomography (CT) or magnetic resonance imaging (MRI) scanners is limited, US offers a cost-effective and informative alternative. Advancements in medical technology have led to the development of smaller, higher-resolution US devices, making LUS increasingly feasible in remote or austere environments. Creation of handheld devices that integrate with smartphone devices, have progressed US utility and accessibility for clinicians (Fryman & Mayo, 2023). These innovations have been tailored to meet the diverse clinical demands across various healthcare settings, as highlighted by the European Respiratory Society's 2021 statement on LUS, which emphasised that one size certainly does not fit all when it comes to US imaging (Laursen et al., 2021).

Another notable advancement is the use of remote telementored ultrasonography (RTMUS), which has enabled real-time diagnostic support in geographically isolated locations. Enhanced communication systems now allow US images to be interpreted remotely through two-way audio-visual systems, expanding diagnostic capabilities in extreme environments. The most striking example is the use of RTMUS aboard the International Space Station, where US serves as the primary diagnostic imaging modality for space medicine (Demi et al., 2023).

The emerging role of lung ultrasound in critical care

LUS has become increasingly recognised as a crucial tool in ICUs, particularly due to the risks and logistical challenges associated with transporting ventilated or hemodynamically unstable patients to radiology departments for diagnostic imaging. Such transfers require significant preparation, staffing, and time, often resulting in delays to diagnosis and potential clinical deterioration. In contrast, Point-Of-Care ultrasound (POCUS), including LUS, can be performed at the bedside, allowing for rapid and real-time evaluation without the need for patient transport. Beyond its convenience, LUS offers superior diagnostic performance compared to traditional imaging modalities in specific contexts. For instance, LUS has demonstrated greater sensitivity than chest X-rays (CXR) in detecting pneumothorax and pleural effusions (Laursen et al., 2021; D. A. Lichtenstein, 2014) and has shown comparable diagnostic accuracy to CT scanning in the detection of pneumonia (Ferrari et al., 2023; D. A. Lichtenstein, 2016). Importantly, LUS provides dynamic, real-time imaging capabilities allowing clinicians to assess lung aeration, evaluate diaphragmatic excursion, monitor recruitment during ventilation, and track patient responses to therapeutic interventions. These attributes make LUS not only a diagnostic tool but an essential component of ongoing clinical decision-making. Considering these advantages, LUS has become an integral imaging modality in ICU, offering immediate, bedside insights that can guide and optimise patient management in real time.

Rationale for the Review

LUS as an evolving imaging modality in pulmonary assessment

Given its high sensitivity and specificity, LUS is increasingly being recognised as a essential imaging modality in pulmonary evaluation. One of its emerging applications is the assessment of diaphragmatic function, particularly in the context of Ventilator-Induced Diaphragmatic Dysfunction (VIDD), which can inform clinical decisions regarding the timing of extubation (Dario & Carvajalino, 2025). While preliminary evidence supports its use in this setting, further research is required to establish the validity and standardisation of this application.

LUS enables accurate and timely assessment of fluid status, allowing for earlier detection of fluid overload when compared to traditional imaging methods. Moreover, it aids in distinguishing between cardiogenic and non-cardiogenic pulmonary oedema, facilitating more precise clinical management. The modality has demonstrated efficacy in identifying US features consistent with pneumonia, supporting prompt initiation of antibiotic therapy. Importantly, its use may enhance antibiotic stewardship by contributing to more targeted prescribing practices.

In the assessment of acute respiratory distress syndrome (ARDS), LUS gained increased attention during and following the COVID-19 pandemic due to its ability to diagnose disease, monitor progression and guide management strategies (Demi et al., 2023).

The integration of LUS with echocardiography (ECHO) and vascular imaging, supports a comprehensive, systems-based approach to patient evaluation. Given the physiological interdependence of the heart and lungs, a cardiopulmonary ultrasound assessment reflects the holistic nature of clinical examination and decision-making in ICUs. This holistic approach to clinical assessment and US not only broadens the diagnostic scope for clinicians but enhances treatment planning, contributing to improved patient outcomes.

The relevance of lung ultrasound in donor and post-retrieval lung evaluation

LUS is gaining recognition as a valuable diagnostic modality in the context of lung transplantation, with applications spanning from donor lung assessment prior to retrieval through to post-transplant monitoring. Its value lies in its capacity to provide real-time, bedside evaluation of lung aeration, pleural pathology, and parenchymal abnormalities without the need for ionizing radiation or transportation of critically ill patients. Which is part of the rational why US is key modality which can be utilised as part of the process for donor assessment (Kukreja et al., 2025) LUS can be utilised whilst the donor is on life support or when the lungs have been placed on Ex Vivo Lung Perfusion (EVLP), enabling ongoing monitoring of lung recruitment, consolidation, and fluid status. These assessments allow for real-time optimization of donor lung management, potentially improving the likelihood of successful transplantation. However, current evidence supporting LUS in this setting is limited, largely comprising of observational studies with small sample sizes. Rigorous, prospective research is needed to validate its effectiveness, to define standardized protocols for use during EVLP and donor management.

The recently published International Consensus Recommendations on Anaesthetic and Intensive Care Management of Lung Transplantation (Marczin et al., 2021) underscores the importance of anaesthesiologists in optimizing ventilation and perfusion strategies during EVLP. While LUS is not directly referenced here, it emphasizes the need for interventions that prevent atelectasis and consolidation whilst supporting adequate gas exchange, objectives that align with the diagnostic strengths of LUS. Given the increasing reliance on EVLP in marginal donor lung evaluation, there is potential to consider integration of into future guidelines as a standard component of donor lung assessment and monitoring.

Challenges and limitations of LUS

Operator dependency

Training requirements

The expansion of LUS across various clinical specialties has led to the emergence of multiple training pathways. Originally governed by radiologists, US has increasingly been adopted by emergency physicians, intensivists, anaesthetists, nurses, and physiotherapists. A key development in non-radiology LUS education was the publication of the Emergency Ultrasound Guidelines by the American College of Emergency Physicians (ACEP) in 2001, later revised in 2009 (American College of Emergency Physicians, 2009) Subsequently, various discipline specific training guidelines have emerged, including the The College of Emergency Medicine (2009) and Association of Anaesthetists (2011). This prompted the development of International Consensus Guidelines on LUS in 2012, which following the rapid expansion of its use during the COVID-19 pandemic were updated in 2022 (Demi et al., 2023). Yet, the British Medical Ultrasound Society (British Medical Ultrasound Society and Society of Radiographers, 2023) has highlighted the lack of unified, comprehensive guidelines, instead placing responsibility on local healthcare organizations to establish training standards based on current evidence. This fragmented approach underscores the urgent need for standardisation across disciplines, specialties and regions.

LUS is increasingly embedded in undergraduate medical curricula, often described as the "next-generations' stethoscope" due to its ability to enhance the visual and practical understanding of anatomy and pathology in real time (Demi et al., 2023) Medical education has evolved from traditional didactic methods to embrace multimodal learning with, LUS offering a bridge between theoretical knowledge and bedside application (Demi et al., 2023) In Canada, focused US was formally introduced into undergraduate training in 2020, setting a precedent for broader curricular adoption (Ma et al., 2020). The International Guidelines and Consensus on the use of Lung Ultrasound (2023) recommend that LUS should be taught with the same rigour as other imaging modalities, given its clear impact on understanding physiological and pathophysiological processes.
The demand for LUS proficiency now extends beyond physicians. In the United Kingdom (UK), it is increasingly included in specialist nurse job descriptions and is being utilized by allied health professionals (British Thoracic Society, 2023). This expansion emphasizes the need for universal standards in training and certification.

Despite its clinical utility, tensions have arisen between radiologists and non-radiologist clinicians referred to as "turf wars" relating to concerns of crossing professional boundaries, quality assurance, and decreasing opportunities for radiology trainees (British Society of Interventional Radiology, 2023; Ferrari et al., 2023). While the Royal College of Radiologists has acknowledged the necessity of out-of-hours imaging services (The Royal College of Radiologists, 2017) resource constraints in the UK's National Health Service (NHS) limit the availability of dedicated radiology

staff during these times. This is further compounded by national shortages of radiologist and sonographers (The Royal College of Radiologists, 2012). As a result, non-radiology clinicians have increasingly acquired LUS competency to ensure timely, high-quality patient care.
Healthcare organisations seeking to implement or expand LUS services must engage in careful service planning. This includes assessing clinical need, ensuring logistical feasibility, and establishing robust educational and governance frameworks to maintain standards and accountability (Rovida et al., 2023).

Competency in LUS requires structured training program incorporating three essential components. Firstly, students must undertake a theoretical component which can be delivered remotely, or self-directed. Following completion a practical skill-based course should be undertaken to offer hands on practice. Finally, students must have a qualified mentor to oversee clinical supervision whilst collecting a logbook of performed scans (Rovida et al., 2023)

Two key elements that clinicians need to master when learning LUS are image acquisition and image interpretation. LUS relies heavily on the recognition of artefacts, such as A-lines and B-lines, rather than the direct visualization of anatomical structures. This makes proficiency highly dependent on hand stability, optimal probe positioning, and familiarity with dynamic lung patterns. Even minor probe movements can significantly alter the displayed image, which underscores the importance of repetitive practice and guided supervision during the initial learning curve (D. A. Lichtenstein, 2016) Clinicians with previous US experience (e.g., in vascular access or echocardiography), the learning trajectory may be shorter, however the transition to interpreting LUS findings still requires dedicated training and adaptation.

Despite clear benefits for the clinical and educational applications of LUS, the lack of a universally accepted curriculum remains a significant limitation. Standardising LUS education would ensure consistent skill sets and clinical application across disciplines. Furthermore, robust governance structures are required to support ongoing professional development, quality assurance, and patient safety. This includes the development of accreditation pathways and access to qualified mentors and supervisors, which are essential for sustaining high standards in clinical practice (Rovida et al., 2023).

Interobserver variability

LUS is a highly specific and sensitive imaging modality however it remains highly operator dependent despite advances in technology (The Royal College of Radiologists, 2012). The ability to achieve the high specificity and sensitivity recorded within the literature is based on the premise that the images obtained are of sufficient quality and that the clinician can accurately interpret the information from them. Inexperienced clinicians or students learning LUS, may misinterpret anatomical landmarks, mistaking the liver with lung consolidation, or misinterpret US signs for example a Z-line for a B-line. These errors can result in misdiagnosis, missed opportunities for appropriate treatment, or the inappropriate initiation of interventions.

As with any newly acquired clinical skill, it is essential that clinicians receive appropriate supervision and training. Clinicians need to be aware that they are exposed to the legal and ethical ramifications if they have not undertaken appropriate training and supervision (The Royal College of Radiologists, 2012). To ensure patient safety, governance strategies should be implemented at the organisational level, regulating the competence of clinicians performing LUS. Furthermore, both learners and qualified practitioners should engage in Continuing Professional Development (CPD) activities related to LUS, incorporating reflective practices to maintain high standards of care.

When considering governance, hospitals may consider standardizing the protocols employed by clinicians performing LUS. A standardized approach would facilitate the interpretation of reports and images by learners whilst ensuring consistent imaging zones for assessment, enabling ongoing monitoring of interventions crucial for evaluating changes in clinical status (Demi et al., 2023). However, this may not be possible due to the diverse range of areas where LUS is applied.

Technical Limitations

Difficultly in imaging certain lung regions

As with any imaging modality there are technical limitations with LUS that require consideration to ensure its appropriateness and effectiveness. The process of patient assessment for LUS suitability should be as thorough as for traditional imaging modalities and based on the need to answer a specific clinical question.

Factors influencing the suitability of LUS include accessibility of imaging zones, patient's body habitus, and the presence of surgical emphysema. Various protocols exist to image the different regions of the lungs based on varying clinical indications, with the intercostal space serving as the acoustic window for the probe. This space is generally accessible and provides an optimal area for imaging. However, for intubated and ventilated patients in ICUs, accessing the posterior regions of the chest can be challenging. While non-ventilated patients can alter their positioning to enable access to these regions, critically ill ICU patients are often sedated, haemodynamically unstable and may be receiving inotropic or vasopressor support, complicating access. In patients receiving Mechanical Circulatory Support (MCS) or those with stented chests, the ability to access posterior lung fields is significantly limited.

Interference from obesity and subcutaneous emphysema

The increasing prevalence of obesity, particularly in Western populations, poses additional challenges for LUS. Obesity not only complicates ventilation management in ICU patients but limits the effectiveness of US imaging. The challenge lies in the balancing the penetration of US waves, required for visualising deep structures against the resolution of the image.

The increased thickness of subcutaneous tissue results in significant attenuation of US waves before they can reach the thoracic cavity, often leading to poor-quality images or unusable images altogether. Furthermore, clinicians must be highly skilled to distinguish between abdominal fat and lung consolidations, as failing to do so may result in diagnostic inaccuracies (D. A. Lichtenstein, 2016).

As previously mentioned, historically held opinions were that air-filled spaces were considered a significant obstacle US, an opinion which has since been refuted. However, the presence of air directly beneath the US probe, as in surgical emphysema, can severely limit or entirely obscure imaging. As in cases of pneumothorax, LUS cannot effectively penetrate air-filled spaces, meaning that patients with surgical emphysema, typically are not suitable for LUS examination. (D. A. Lichtenstein, 2016) notes that while skilled clinicians may attempt to manoeuvre the surgical emphysema out of the probe's view, the resulting images would likely be of poor quality and prone to misinterpretation. In such cases, alternative imaging modalities should be considered. Additional factors such as dressings can obstruct views however, the US probe can be repositioned around dressings, or scans performed during dressing changes. Still clinicians must pay attention to maintaining the sterility of both the probe and the wound to prevent infection (D. A. Lichtenstein, 2016).

Research gaps and future directions

Need for standardised protocols in lung retrieval

LUS has become a cornerstone of bedside imaging, with a range of well-established protocols to guide clinicians in various clinical contexts, each with specific diagnostic goals. The most widely known is the Bedside Lung Ultrasound in Emergency (BLUE) protocol, developed by Daniel Lichtenstein in the 1990s, which set the foundation for the systematic assessment of acute respiratory failure using LUS. Additional protocols include the Focused Assessment with Sonography in Trauma (FAST) protocol, designed to expedite the identification of intrathoracic and intra-abdominal bleeding in trauma patients, and the Fluid Administration Limited by Lung Sonography (FALLS) protocol, utilising LUS to guide fluid management in shock ((D. A. Lichtenstein, 2016). Additionally, the Posterolateral Alveolar and/or Pleural Syndrome (PLAPS) point extends the BLUE protocol to improve the detection of posterior consolidations and pleural effusions (Lichtenstein, 2016). Though these protocols are well-validated and widely used in emergency and ICU environments, they were not designed to account for the individual physiological challenges that come with donor lung assessment.

Within lung transplantation, there is a direct need for a specifically tailored protocol that accounts for the pathophysiological conditions of donor lungs which can be affected by brain death, mechanical ventilation, and systemic inflammation (Marczin et al., 2021). Donor lungs may be placed on Ex Vivo Lung Perfusion (EVLP) systems to optimize function, a true advancement for lung transplantation (Kukreja et al., 2025) During this period, LUS can provide valuable insight into lung aeration and fluid status. A more targeted approach is exemplified by the recently described direCt Lung Ultrasound Evaluation (CLUE) protocol, which aims to systematize LUS in donor lungs and guide decision-making regarding organ viability (Ayyat et al., 2019). The AATS, noted that when assessing donor lungs a diverse range of parameters need to be considered incorporating a multimodal approach to imaging and assessment. The management of Extra Vascular Lung Water (EVLW) is an important consideration when transplant teams discuss discarding lungs (Kukreja et al., 2025) hence there is potential scope for LUS to play an important role here. Presently there is lack of standardisation in lung procurement and variations exist within the assessment and management of donor lungs (Kukreja et al., 2025) hence, the development and validation of specialized protocols represent a key step toward standardizing LUS in lung retrieval, ensuring its effective integration into transplant workflows.

It is essential that transplant and ICU teams have a robust understanding of available protocols and are trained to select and apply the most appropriate one for the clinical context. The future of LUS in transplantation may lie in the development protocols that combine elements of established frameworks with the specific requirements of donor lung assessment. Though further work will need to be done in this area given that the predominant data is from retrospective studies with limited numbers of randomised controlled trials (Kukreja et al., 2025).

Potential for AI-assisted LUS interpretation

The integration of Artificial Intelligence (AI) and Machine Learning (ML) into medical imaging is transforming medical care, and LUS is no exception. Many modern US devices are now equipped with AI-driven features, such as automated border detection, B-line quantification, and image enhancement algorithms, which facilitate more rapid and consistent image interpretation (Fryman & Mayo, 2023). AI has been shown to detect subtle pathological features often overlooked by the human eye, reduce inter-operator variability, and enhance diagnostic confidence (Fryman & Mayo, 2023). These advantages are particularly relevant in LUS, where interpretation can be highly subjective and operator dependent. Preliminary studies suggest that AI can be trained to detect lung pathologies such as interstitial syndrome, consolidation, and pleural effusion with high sensitivity and specificity With certain AL algorithms being applied for donor lungs on EVLP alongside biomarkers, however these are not presently used within clinical practice (Kukreja et al., 2025).

However, it is important to consider that the effectiveness of AI systems is directly dependent on the quality and representativeness of the data input during the systems training. A mismatch between the standardized datasets used to develop AI programs and the often suboptimal images obtained in clinical practice could compromise performance leading to diagnostic errors. Hence, the integration of AI into LUS should be approached with caution acknowledging its limitations.

The application of AI in the evaluation of lungs on EVLP has also garnered attention, with the aim of automating assessments of perfusion, aeration, and injury severity to optimize organ selection. Given the persistent shortage of donor lungs, such innovations could improve organ utilization and outcomes. The International Thoracic Organ Transplant Registry reported over 4,400 lung transplants worldwide in with double-lung transplants accounting for 81% of cases (Chambers et al., 2019). However, these figures do not reflect the substantial number of lungs discarded during the selection process. There perhaps is scope to consider optimizing AI specifically for donor LUS assessment to help address the gap between supply and demand in transplantation.

Integration with other bedside monitoring tools

Further encouraging work lies in integrating LUS with other bedside US modalities, to facilitate a comprehensive assessment of the patient. This holistic US examination allows clinicians to evaluate cardiac function, volume status, and pulmonary pathology in a single, non-invasive assessment. Such a multimodal approach can enhance care of ICU patient and within transplantation aid donor assessment, guide intraoperative management whilst support early identification of complications.

The collaboration between LUS and point-of-care echocardiography is particularly valuable, as right and left ventricular dysfunction can influence graft viability and perioperative risk. Similarly, vascular US can help assess fluid responsiveness and detect vascular complications post-transplant.

References

American College of Emergency Physicians. (2009). POLICY STATEMENT Policy Statement Emergency Ultrasound Guidelines. *Annals of Emergency Medicine*, *53*, 550–570. https://doi.org/10.1016/j.annemergmed.2008.12.013

Association of Anaesthetists, T. (2011). *Ultrasound in Anaesthesia and Intensive Care: A Guide to Training Membership of the working party*.

Ayyat, K. S., Okamoto, T., Niikawa, H., Itoda, Y., Dugar, S., Latifi, S. Q., Lebovitz, D. J., Moghekar, A., & McCurry, K. R. (2019). DireCt Lung Ultrasound Evaluation (CLUE): A novel technique for monitoring extravascular lung water in donor lungs. *Journal of Heart and Lung Transplantation*, *38*(7), 757–766. https://doi.org/10.1016/j.healun.2019.03.005

British Medical Ultrasound Society and Society of Radiographers. (2023). *Guidelines for Professional Ultrasound Practice*. https://www.bmus.org/media/resources/files/_2023_SoR_and_BMUS_guidelines_8th_Ed_FINAL_CphWPoK.pdf

British Society of Interventional Radiology. (2023). *Provision of Interventional Radiology Services 2023*. https://www.bsir.org/media/resources/files/BSIR_2023_IRProvisions_32ppA4_March24_v1.pdf

British Thoracic Society. (2023). *Respiratory Nurse Specialist - Pleural Disease*. https://www.brit-thoracic.org.uk/media/456312/respiratory-nurse-specialist-pleural-disease-banding_march-2023.pdf

Chambers, D. C., Cherikh, W. S., Harhay, M. O., Hayes, D., Hsich, E., Khush, K. K., Meiser, B., Potena, L., Rossano, J. W., Toll, A. E., Singh, T. P., Sadavarte, A., Zuckermann, A., & Stehlik, J. (2019). The International Thoracic Organ Transplant Registry of the International Society for Heart and Lung Transplantation: Thirty-sixth adult lung and heart–lung transplantation Report—2019; Focus theme: Donor and recipient size match. *The Journal of Heart and Lung Transplantation*, *38*(10), 1042–1055. https://doi.org/10.1016/j.healun.2019.08.001

Dario, R., & Carvajalino, M. (2025, March). *Ultrasound Assessment of Respiratory Physiology: Lungs, Diaphragm, and Cardiopulmonary Interaction*. Society of Mechanical Ventilation. https://societymechanicalventilation.org/wp-content/uploads/2025/03/Cardio-Pulmonary-Ultraound-Ruben-Dario-Mesa-Carvajalino.pdf

Demi, L., Wolfram, F., Klersy, C., De Silvestri, A., Ferretti, V. V., Muller, M., Miller, D., Feletti, F., Wełnicki, M., Buda, N., Skoczylas, A., Pomiecko, A., Damjanovic, D., Olszewski, R., Kirkpatrick, A. W., Breitkreutz, R., Mathis, G., Soldati, G., Smargiassi, A., … Perrone, T. (2023). New International Guidelines and Consensus on the Use of Lung Ultrasound. In *Journal of Ultrasound in Medicine* (Vol. 42, Issue 2, pp. 309–344). John Wiley and Sons Ltd. https://doi.org/10.1002/jum.16088

Fauci, A., Braunwald, E., Isselbacher, K. J., Wilson, J. D., Martin, J. B., Kasper, D. L., Hauser, S. L., & Longo, D. L. (1997). *Harrison's Principles of Internal Medicine* (14th Edition). McGraw-Hill Companies.

Ferrari, G., Cammarota, & Gianmaria. (2023). Fundamentals of Lung and Diaphragmatic Ultrasound. In H. Soliman-Aboumarie, M. Haertel Miglioranza, L. Gargani, & G. Volpicelli (Eds.), *Cardiopulmonary Point of Care Ultrasound*. Springer International Publishing. https://doi.org/10.1007/978-3-031-29472-3

Fryman, C., & Mayo, P. H. (n.d.). Future Applications of Handheld POCUS. In H. Soliman-Aboumarie, M. Haertel Migiloranza, L. Gargani, & G. Volpicelli (Eds.), *Cardiopulmonary Point Of Care Ultrasound* . Spinger International Publishing.

Kukreja, J., Campo-Canaveral de la Cruz, J. L., Van Raemdonck, D., Cantu, E., Date, H., D'Ovidio, F., Hartwig, M., Klapper, J. A., Kelly, R. F., Lindstedt, S., Rosso, L., Schaheen, L., Smith, M., Whitson, B., Saddoughi, S. A., & Cypel, M. (2025). The 2024 American Association for Thoracic Surgery expert consensus document: Current standards in donor lung procurement and preservation. *Journal of Thoracic and Cardiovascular Surgery*, *169*(2), 484–504. https://doi.org/10.1016/j.jtcvs.2024.08.052

Laursen, C. B., Clive, A., Hallifax, R., Pietersen, P. I., Asciak, R., Davidsen, J. R., Bhatnagar, R., Bedawi, E. O., Jacobsen, N., Coleman, C., Edey, A., Via, G., Volpicelli, G., Massard, G., Raimondi, F., Evison, M., Konge, L., Annema, J., Rahman, N. M., & Maskell, N. (2021). European Respiratory Society statement on thoracic ultrasound. *European Respiratory Journal*, *57*(3). https://doi.org/10.1183/13993003.01519-2020

Lichtenstein, D. A. (2016). *Lung Ultrasound in the Critically Ill*. Springer International Publishing. https://doi.org/10.1007/978-3-319-15371-1

Lichtenstein, D., & Axler, O. (1993). Intensive use of general ultrasound in the intensive care unit - Prospective study of 150 consecutive patients. *Intensive Care Medicine*, *19*(6), 353–355. https://doi.org/10.1007/BF01694712

Ma, I. W. Y., Steinmetz, P., Weerdenburg, K., Woo, M. Y., Olszynski, P., Heslop, C. L., Miller, S., Sheppard, G., Daniels, V., Desy, J., Valois, M., Devine, L., Curtis, H., Romano, M. J., Martel, P., Jelic, T., Topping, C., Thompson, D., Power, B., … Tonseth, P. (2020). The Canadian Medical Student Ultrasound Curriculum: A Statement From the Canadian Ultrasound Consensus for Undergraduate Medical Education Group. *Journal of Ultrasound in Medicine*, *39*(7), 1279–1287. https://doi.org/10.1002/jum.15218

Marczin, N., de Waal, E. E. C., Hopkins, P. M. A., Mulligan, M. S., Simon, A., Shaw, A. D., Van Raemdonck, D., Neyrinck, A., Gries, C. J., Algotsson, L., Szegedi, L., von Dossow, V., Burrell, A., Carmona, P., Greenhalgh, D., Höchter, D., Kachulis, B., King, C. S., Licker, M. J., … Senturk, M. (2021). International consensus recommendations for anesthetic and intensive care management of lung transplantation. An EACTAIC, SCA, ISHLT, ESOT, ESTS, and AST approved document. *Journal of Heart and Lung Transplantation*, *40*(11), 1327–1348. https://doi.org/10.1016/j.healun.2021.07.012

Noble, V. E. (2023). The Evolution of Point of Care Ultrasound . In H. Soliman-Aboumarie, M. H. Miglioranza, L. Gargani, & G. Volpicelli (Eds.), *Cardiopulmonary Point of Care Ultrasound* . Springer.

Roelandt, J., Wladimiroff, J. W., & Baars, A. M. (1978). Ultrasonic Real Time Imaging With A Hand-Held Scanner: Part II Initial Clinical Experience. *Ultrasound in Medicine and Biology*, *4*, 93–97.

Rovida, S., Martinelli, G., & Fletcher, N. (2023). Teaching and Accreditation in Cardiopulmonary POCUS. In H. Soliman-Aboumarie, M. H. Miglioranza, L. Gargani, & G. Volpiceli (Eds.), *Cardiopulmonary Point of Care Ultrasound*. Springer.

The College of Emergency Medicine. (2009). *THE COLLEGE OF EMERGENCY MEDICINE Core (Level 1) Ultrasound Curriculum*. https://rcem.ac.uk/wp-content/uploads/2021/10/1.14.5-RCEM-EMUS-booklet-3.pdf

The Royal College of Radiologists. (2012). *Ultrasound training recommendations for medical and surgical specialties Second edition*.

The Royal College of Radiologists. (2017). *Standards Standards for providing a 24-hour interventional radiology service Second edition*. www.rcr.ac.uk