

# Ten Influential Point-of-Care Ultrasound Papers: 2021 in Review

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## Abstract

The ongoing rapid expansion of point-of-care ultrasound (POCUS) and its corresponding supporting literature leaves the front-line clinician in a difficult position when trying to keep abreast of the latest developments. Our group of POCUS experts has selected ten influential POCUS-related papers from the past twelve months and provided a short summary of each. Our aim is to give to emergency physicians, intensivists, and other acute care providers key information, helping them to keep up to date on rapidly evolving POCUS literature.

## Keywords

ultrasound, point-of-care ultrasound (POCUS), medical education

## Introduction

Neither the clinical developments nor the academic literature surrounding point-of-care ultrasound (POCUS) showed any signs of slowing in the year 2021. Whether you prefer terms like critical care ultrasound (CCUS) or resuscitative ultrasound, or the broader POCUS terminology, the use of clinician-performed ultrasound to aid in the care of acutely ill patients continues to expand in the intensive care unit (ICU), the emergency department (ED), and beyond.

This rapid clinical growth has been coupled with a corresponding increase in academic literature. While this phenomenon speaks to a healthy process of discovery and refinement of the POCUS skill set, it does leave the frontline clinician in a difficult position when trying to keep abreast of new developments. To provide some slight assistance here, our group of POCUS experts has selected ten influential papers from the last twelve months and provided a short summary of each.

For the sake of efficiency our group settled on an informal methodology, rather than attempting a more formal systemic review. Each expert brought forth a list of 4-6 articles that had influenced their clinical practice over the past 12 months, with a focus on their particular area of expertise. During a subsequent conference call, each expert presented their list and thereafter all participants voted to create the final collection of ten articles. Each expert was thereafter charged with summarizing two articles, and one author (SJM) provided final editing. Our overall objective is to give emergency physicians, intensivists, and other acute care providers some sense of recent development in the broader POCUS literature, even though the year was dominated by the COVID-19 pandemic.

Hemodynamic Profiles of Shock in Patients With COVID-19: Hollenberg et al, *Am J Cardiol*, vol. 15, no. 153, pp. 135-9, 2021.

The COVID-19 pandemic dominated much of the medical landscape in 2021, and POCUS-related literature was no different. While much of the emphasis was placed on lung ultrasound (LUS), this retrospective study<sup>1</sup> reported the hemodynamic profiles of 160 COVID-19 patients admitted to the ICU with vasopressor-dependent shock. Left ventricular (LV) ejection fraction (EF) and cardiac index (CI) were estimated by transthoracic echocardiography, and patients were thereafter classified by type of shock. Most patients (approximately 48%) had both a normal EF and CI and were considered as vasoplegic/distributive shock. A smaller number (10%) had low CI and EF, a pattern consistent with cardiogenic shock. An even smaller group (5%) had a low EF and a normal CI, which was classified by the authors as compatible with a septic cardiomyopathy.

Finally, and perhaps most interestingly, roughly 36% of patients had a preserved EF but a low CI. This was hypothesized by the study authors to be related to hypovolemia, but could equally have been the result of right ventricular (RV) failure related to severe acute respiratory distress syndrome (ARDS). Interestingly, in this phenotype, high PEEP was associated with a lower CI as would be expected with RV

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dysfunction. This study serves to re-emphasize that critical care echocardiography (CCE) can be of help to physicians caring for patients with COVID-19, just as in septic shock or non-COVID ARDS, both to determine the hemodynamic phenotype and to adapt treatment.

Lung ultrasound for the early diagnosis of COVID-19 pneumonia: an international multicenter study: Volpicelli et al, *Intensive Care Med*, vol. 47, no. 4, pp. 444–54, 2021.

The current global pandemic has yielded many studies and review articles focused on the efficient and accurate radiologic diagnosis of COVID-19 pneumonia. Regardless of clinical setting, the diagnosis (or identification of an alternative illness) is best accomplished by imaging that provides high sensitivity, has the capability to identify alternative diseases, and allows for minimal provider contact and patient transport.

This multi-center international observational study<sup>2</sup> compared LUS findings in patients who presented to the hospital with symptoms and signs compatible with a diagnosis of COVID-19 pneumonia. 1462 patients were categorized by both LUS pattern and clinical phenotype. Ultrasound patterns consisted of: 1) High probability [bilateral, multifocal clusters of B-lines with a hyperechoic pleural line (a “light beam”), with areas of consolidation alternating with normal A-line patterns], 2) Intermediate probability (unilateral isolated clusters of B-lines and light beams or focal multiple B-lines, with or without small areas of consolidation), 3) Low probability (normal or near normal A-line pattern with lung sliding), and 4) Alternative diagnosis (findings of a large alveolar consolidation pattern with or without dynamic air bronchograms, a large pleural effusion, or a homogenous B-line pattern). Clinical phenotypes included mild (patients without dyspnea or hypoxemia), mixed (patients with pre-existing lung disease), and severe (signs and symptoms of respiratory failure).

Combining LUS patterns with clinical phenotypes allowed the researchers to examine test performance characteristics for the diagnosis of COVID-19 pneumonia, using RT-PCR as a gold standard comparison. A high probability LUS with a severe phenotype had a positive predictive value (PPV) of 97%, for example. Even a mild clinical phenotype with a high probability LUS had a PPV of 88%. In both cases, it would seem wise to assume a working diagnosis of COVID-19 pneumonia while awaiting the result of confirmatory PCR testing. In contrast, a low probability LUS had a much lower likelihood of COVID-19 infection (sensitivity of 99.3% even in the severe clinical phenotype). Here an alternate diagnosis should be sought, even if isolation protocols are maintained until the result of PCR testing becomes available. Further study is required to fully understand how to operationalize these results, but it is undoubtedly useful for the clinical provider to better understand the likelihood of COVID-19 disease at the time of the first encounter without need for patient transport.

Ultrasound assessment of pulmonary fibroproliferative changes in severe COVID-19: a quantitative correlation study with histopathological findings: de Almeida Monteiro et al, *Intensive Care Med*, vol. 47, no. 2, pp. 199–207, 2021.

Severe COVID-19 pneumonia can evolve to include fibroproliferative changes and eventually permanent fibrosis in some cases. In this prospective Brazilian study,<sup>3</sup> the association between LUS parameters and histopathological images was evaluated. LUS was performed immediately after death, both to acquire ultrasound images and to guide subsequent minimally invasive autopsy via lung biopsy. A standardized description of LUS findings was used, focusing on the pleural line, the presence of A- and B-lines, and the presence lung consolidation. Each abnormality was scored as 1 when present or 0 when absent. The authors included 28 patients who died after a median time between symptoms onset and death of 18 days, and a median of 10.5 days of invasive mechanical ventilation.

A positive correlation between the fibroproliferative phase on biopsy and both peripheral and pulmonary consolidation on LUS was discovered. By computing the sum of lung regions with these two specific abnormalities, they propose a new LUS severity score which was independently associated with the extent of fibroproliferative damage. This finding raises the possibility of monitoring the evolution of lung damage as it advances towards fibrosis in severe COVID-19 disease using LUS, and helping physicians identify at-risk cases, and perhaps prevent irreversible injury.

Surveillance or no surveillance ultrasonography for deep vein thrombosis and outcomes of critically ill patients: a pre-planned sub-study of the PREVENT trial: Arabi et al, *Intensive Care Med*, vol. 46, pp. 737–46, 2021.

In this sub-study<sup>4</sup> of a larger multicenter trial, it was discovered that twice-weekly deep vein thrombosis (DVT) surveillance ultrasound studies in critically ill patients led to the earlier detection of more occult DVTs. While increased testing leading to more DVT diagnoses is not surprising, the mortality benefit in the surveillance group is the most provocative finding here.

That earlier treatment may mitigate morbidity and mortality from ensuing pulmonary emboli with such magnitude as to offset the perils of overtreatment and the hazards of anticoagulation resulting from such surveillance could – if replicated - be practice changing for intensivists. The volume of ultrasound studies required to support this surveillance model could, however, challenge the resources of imaging departments. Given the ease and accuracy of 2-zone, point-of-care DVT sonography,<sup>5,6</sup> a pragmatic implementation of this surveillance model – with ultrasound performed by the ICU clinicians - would form the most interesting follow-up study to this work.

Doppler Echocardiographic Indices Are Specific But Not Sensitive to Predict Pulmonary Artery Occlusion Pressure in Critically Ill Patients Under Mechanical Ventilation: Mercado et al, *Crit Care Med*, vol. 49, no. 1, pp. e1–10, 2021.

The intensivist is challenged by the patient on ventilatory support with bilateral B-lines on LUS and bilateral opacities on chest radiography. Does the patient have airway disease from primary lung injury, pulmonary edema from elevation of left atrial pressure (LAP), or both? The American Society of Echocardiography/European Association of Cardiovascular Imaging (ASE/EACI) recommendations on assessment of

diastolic function includes an algorithm to estimate LAP as either normal or elevated ( $>18$  mm Hg),<sup>7</sup> but this process has limited utility for acute care providers as some of the required measurements are not realistically achievable in unwell patients. This article proposes an alternative approach.<sup>8</sup>

The authors attempted to apply the ASE/EACI algorithm to 98 critically ill patients on ventilatory support using pulmonary artery occlusion pressure (PAOP) as a surrogate for LAP, and found that only 50 of 98 patients could be classified. Of the 24 patients with an ASE/EACI predicted elevated LAP, only 17 (71%) had a high measured PAOP, and 20 of the 26 patients (77%) with a normal predicted LAP had a measured PAOP of less than 18 mm Hg. The sensitivity and specificity of the ASE/EACI algorithm were therefore both 74% in this cohort.

The data set allowed the authors to propose a simpler approach to estimation of LAP in critically ill patients: The best echocardiographic predictors of a normal pulmonary artery occlusion pressure were a lateral  $e'$ -wave greater than 8 or an E/A ratio less than or equal to 1.5 (both assuming a left ventricular ejection fraction  $> 45\%$ ). This study provides the acute care provider with a simple algorithm that utilizes measurements that are readily obtainable in most critically ill patients, and may eventually replace the impractical ASE/EACI algorithm in this patient population should further studies confirm these results.

Lung Ultrasound for Detection of Pulmonary Complications in Critically Ill Obstetric Patients in a Resource-Limited Setting: Pisani et al, *Am. J. Trop. Med. Hyg.*, vol. 104, no. 2, pp. 478–86, 2021.

In resource limited settings where frontline clinicians do not have the luxury of chest radiography let alone computerized tomography, ultrasonography offers a low cost, portable, radiation-free, and multipurpose imaging modality that can be used at the point-of-care to provide immediate diagnostic information and, with serial application, to track the course of the disease process. This study clearly demonstrates this point.<sup>9</sup> The authors focused on the diagnostic utility of LUS in pregnant patients who were admitted to a high-dependence obstetrical unit (HDU) in Sierra Leone. The investigators performed a standardized 12-zone LUS examination on 166 patients within 6 h of admission and repeated it at 24 and 48 h. The primary outcome was the identification of one or more pulmonary complications including pleural effusion, atelectasis, consolidation, or ARDS; such complications were identified in 21% of patients. If the examination was normal but associated with respiratory distress, the cause was either anemia or metabolic acidosis. Respiratory distress in association with an abnormality detected with LUS was associated with poor clinical outcome.

The study, although prospective in design, was observational and based on a non-serial sample of convenience. It did not include echocardiography or venous examination, nor did it report the effect of LUS on patient management or outcome. The authors acknowledge these weaknesses of study design, which are understandable given the operational challenges in a resource limited HDU. The important message of the study is that LUS should be the “go to” modality for

use in the obstetrical population in both under- and well-resourced medical systems. The addition of other elements of ultrasonography such as cardiac, abdominal, and vascular imaging would have added value in this population.

Systematic review and literature appraisal on methodology of conducting and reporting critical-care echocardiography studies: a report from the European Society of Intensive Care Medicine PRICES expert panel: Huang et al, *Ann. Intensive Care*, vol. 10, no. 49, pp. 49–62, 2020.

Clinical providers depend, at least in part, on well performed studies that can be integrated with patient-specific information to help with clinical judgment. CCE proliferation has often outstripped production of supporting trial data, and the literature that does exist has yet to conform to a standardized methodology and reporting standard.

This timely paper<sup>10</sup> aims to improve CCE research data reporting, such that clinical providers may more easily use data to support their clinical decision making when caring for critically ill patients. A critical appraisal of the existing literature from 2000–2017 was conducted, and recommendations were provided as how to best report CCE findings in a standardized fashion. In total, 209 articles were reviewed, focusing on common topics encountered in the critical care arena such as LV and RV function, LV diastolic function, fluid management, and advanced echocardiographic techniques. Their analysis revealed a pattern of suboptimal reporting of research items that could result in bias when analyzing study results, potentially leading to inaccurate interpretation of study findings. Importantly, this methodology attempts to help future researchers in the development of CCE studies and in the reporting of results. Hopefully this standard will be widely adopted, allowing researchers to build off each other’s work and helping clinical providers to accurately interpret the literature.

Assessing Competence in Critical Care Echocardiography: Development and Initial Results of an Examination and Certification Processes: Panebianco et al, *Crit Care Med*, vol. 49, no. 8, pp. 1285–92, 2021.

Debates around the assessment of POCUS competency and the provision of certification are as old as the tool itself. While all agree that POCUS providers must be supervised until they are competent, there is a dearth of validated assessment tools to achieve this purpose and any such assessment would be expected to be an onerous endeavor for any individual POCUS expert. With respect to certification, the situation is even more complex: While certification seems, at first glance, to be an unquestioned positive, there are potential downsides. Certification may serve as an obstacle to the growth of POCUS, depriving patients of this useful tool. Requiring certification, especially for basic applications, threatens the status of ultrasound as a core skill for many acute care specialties. The absence of certification may be used as a weapon to deny individuals or groups the ability to use POCUS, rather than as a tool to ensure competence or excellence. North American physicians have not had access to CCUS certification, whereas the process in Europe is well established for advanced CCE.<sup>11</sup>

Into this debate wades the examination of Special Competence in Critical Care Echocardiography (CCEeXAM), and a description of its first iteration in 2019.<sup>12</sup> Under the supervision of the National Board of Echocardiography (NBE), the longstanding provider of certification for comprehensive (cardiology) and peri-operative (anesthesia) echocardiography, the process supports both an assessment of competency (the exam) as well as formal certification (requiring successful exam completion coupled with a supervised ultrasound portfolio).

The paper describes the successful launch of an examination of competency and pathway for formal certification which attempts to straddle these difficult issues. The process is specific in its intention to avoid restricting current providers or limiting the appropriate use of POCUS. A new (North American) paradigm, with basic POCUS applications built into residency training programs and advanced skills vetted by a formal certification pathway, is now a possibility.

Analysis of lawsuits related to diagnostic errors from point-of-care ultrasound in internal medicine, paediatrics, family medicine and critical care in the USA: Reaume et al, *Postgrad Med J*, vol.97, pp. 55–8, 2021.

While highly jurisdiction dependent, perceived medico-legal risks loom over all POCUS-related decisions. Fear of adverse legal action can serve as a deterrent to clinicians as they contemplate learning and using POCUS, and such concerns are sometimes wielded by traditional ultrasound providers in an effort to discourage new users.

Helping to alter this perception significantly, the American POCUS landscape was examined,<sup>13</sup> taking advantages of the Westlaw legal database which comprehensively catalogs lawsuits and other legal documents. Building on older literature<sup>14</sup> which failed to identify any successful lawsuits in the ED, this updated effort reviewed cases from 1939 through 2019 and identified 70 cases of successful litigation. In all 70 cases, the ultrasound study in question had been performed by a traditional ultrasound provider (within the cardiology or radiology departments); there were no cases of physicians in critical care medicine (or internal medicine, pediatrics, or family medicine) being sued for using POCUS.

POCUS providers, physicians contemplating ultrasound training, hospital administrators, and medical societies should all be very encouraged by this result. The threat of litigation should not be used as a deterrent here; if anything the primary medico-legal risk related to POCUS appears increasingly to involve a failure to provide it in a timely fashion.<sup>14</sup>

Utility of a Deep-Learning Algorithm to Guide Novices to Acquire Echocardiograms for Limited Diagnostic Use: Narang et al, *JAMA Cardiology*, vol. 6, no. 6, pp. 624–32, 2021.

Despite the clear diagnostic value of POCUS in general, access to training continues to be a consistent bottleneck to adoption.<sup>15,16</sup> As such, there has been rising momentum toward artificially intelligent (AI) solutions that may increase access to POCUS by allowing novices to take advantage of its utility without need for as much training in image acquisition

and/or interpretation. Here an AI-based echocardiographic guidance system<sup>17</sup> was deployed prospectively in two ICUs in the United States.

Through the use of a “turn by turn” GPS-like guidance system, novice ICU nurses without echocardiography training could generate limited study images, suitable for the 2D evaluation of pathology such as ventricular dysfunction or pericardial effusion in more than 90% of the 240 patients studied. While the scope of these exams was limited and the paper was (understandably) industry funded, the signal sent from these results is that the future is bright for AI-enabled, disseminated access to the most essential critical care ultrasound techniques.

## Conclusion

While far from an exhaustive list, the ten articles selected by our expert group represent important articles published over the past twelve months, each one of which has influenced our daily clinical practice.

## Author Contributions

All authors contributed equally to the creation of the manuscript, including selecting articles, writing, and proofreading.

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