

Ten Influential Point-of-Care Ultrasound Papers: 2023 in Review

Scott J. Millington, MD¹ , Mangala Narasimhan, MD², Paul H. Mayo, MD², and Antoine Vieillard-Baron, MD³

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Abstract

In an effort to help keep busy clinicians up to date with the latest ultrasound research, our group of experts has selected 10 influential papers from the past 12 months and provided a short summary of each. We hope to provide emergency physicians, intensivists, and other acute care providers with a succinct update concerning some key areas of ultrasound interest.

Keywords

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

Introduction

The rate of growth for point-of-care ultrasound (POCUS) academic literature seems to have continued at a blistering pace. The year 2023 saw fewer articles related to the COVID-19 pandemic, but many new forays into areas such as artificial intelligence, lung ultrasound, and the right ventricle (among many other topics). The use of clinician-performed bedside ultrasound to aid in the care of acutely ill patients continues to expand in the intensive care unit (ICU), the emergency department (ED), the operating room, and beyond.

Keeping abreast of new developments in the academic literature is always challenging. To provide some modest assistance here, our group of POCUS experts has selected 10 influential papers from the last 12 months and provided a short summary of each, as we did for 2021¹ and 2022.² 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 four to six 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 10 articles. Each expert was thereafter charged with summarizing two or three articles, and one author (SJM) provided final editing.

Is Left Ventricular Systolic Dysfunction Associated with Increased Mortality Among Patients with Sepsis and Septic Shock?

The question of whether (and how) changes in left ventricular (LV) systolic function may alter prognosis in patients with septic shock is still debatable.³ There are contradictory studies, many especially limited by a small sample size. This retrospective cohort analyzed 3151 adult patients admitted to

the ICU for sepsis (n = 1254) or septic shock (n = 1897) who underwent echocardiography within 3 days of ICU admission (median time 16 h). LV ejection fraction (EF) was evaluated either using the biplane Simpson method or estimated visually, and separated in five categories: <25% (severely reduced, n = 133, 4.2%), ≥25% but <40% (moderately reduced, n = 305, 9.7%), ≥40% but <55% (mildly reduced, n = 568, 18%), ≥50% but <70% (normal, n = 1792, 56.9%), and ≥70% (hyperdynamic, n = 353, 11.2%). Logistic regression was adjusted based on age, sex, APACHE II, history of chronic dialysis, cirrhosis, COPD, diabetes, immunosuppression and malignancy, maximum lactate level within 24 h, total IV fluid administration at the day of echocardiography, and time to antibiotics administration.

The authors found a U-shape relationship between LVEF and in-hospital mortality with an odds ratio (OR) of 2.30 (95% CI 1.52-3.49) for severely reduced LVEF (in-hospital mortality 51.1%) and 1.42 (95% CI 1.07-1.87) for a hyperdynamic left ventricle (in-hospital mortality 41.9%) compared to normal. In the subgroup of patients with septic shock, this increased mortality was only observed in patients with norepinephrine requirements >0.5 µg/kg/min. Right ventricular (RV) systolic function tended to decrease in tandem with LVEF, but the RV dysfunction did not independently influence the impact of LVEF categories on in-hospital mortality. One limitation of this study is that a significant number of patients

¹Critical Care, The Ottawa Hospital, University of Ottawa, Ottawa, ON, Canada

²Critical Care, Donald and Barbara Zucker School of Medicine at Hofstra/Northwell, Hempstead, NY, USA

³Critical Care, Hospital Ambroise Paré, Boulogne, France

Corresponding Author:

Scott J. Millington, Intensive Care Unit, Ottawa Hospital, General Campus, Box 207, 501 Smyth Road, Ottawa, ON K1H 8L6, Canada.

Email: smillington@toh.ca

received inotropic agents (40% in patients with severely or moderately reduced LVEF, which might be expected), but also in 20% of patients with hyperdynamic LV function (which is more surprising). Furthermore, during the period of study, 6665 patients were admitted for sepsis or septic shock, meaning that 52.7% of them did not have an echocardiogram within 3 days of ICU admission.

Echocardiography Phenotypes of Right Ventricular Involvement in COVID-19 ARDS Patients and ICU Mortality: Post-Hoc (Exploratory) Analysis of Repeated Data from the ECHO-COVID Study

Interest in the assessment of the RV, particularly among intensivists, continues to grow.⁴ Experienced echocardiography providers will be familiar with the inherent subjectivity that goes into a diagnosis of RV dysfunction, as well as the numerous potential different ways the RV can fail. This article, based on a data set generated in a previous study of ICU patients with ARDS due to COVID-19 pneumonia, looked at three different definitions of RV involvement. Acute cor pulmonale (ACP) was defined as RV dilatation plus paradoxical septal motion, RV failure was defined as RV dilatation plus systemic venous congestion (based on an elevated central venous pressure or distended inferior vena cava, controversially), and RV dysfunction was defined as a reduction in tricuspid annular plane systolic excursion (TAPSE).

A majority of patients (67%) in the cohort had RV involvement, with the RV failure definition most common. Of the three definitions, patients with ACP fared the worst (hazard ratio for mortality 3.25) and patients with RV dysfunction the best, compared to patients without RV involvement. The categories were not mutually exclusive, and patients who met multiple criteria did even worse, as one might expect. It is unusual and very helpful to see longitudinal data such as this drawing a link between states of RV dysfunction and their impact on patient prognosis. Beyond the raw results, this article is also important inasmuch as it opens our minds to the various states of RV dysfunction and how each might be caused by a different pathological mechanism, and potentially treated by a different strategy going forward.

Early Reversal of Right Ventricular Dysfunction after Venovenous Extracorporeal Membrane Oxygenation in Patients with COVID-19 Pneumonia

Although the use of extra-corporeal membrane oxygenation (ECMO) for COVID-19 pneumonia has significantly decreased compared to 2020 and 2021, the lessons learned are still applicable to patients with ARDS in general. RV dysfunction is a common complication of acute ARDS, given that RV function

is highly afterload dependent.⁵ In this article VV-ECMO was shown to reverse RV dysfunction rapidly, a finding that has not been clearly demonstrated before. This important element should, going forward, be considered when discussing ECMO indications in patients with severe ARDS, circulatory failure, and RV dysfunction.

This observational retrospective single-center study looked at 15 patients with COVID-19-related ARDS who met EOLIA criteria and were placed on VV-ECMO. The patients underwent a comprehensive echocardiographic examination pre-ECMO cannulation and at serial intervals post-cannulation. The main finding was a rapid improvement of RV function within 24 h of VV-ECMO initiation, reversal of acute cor pulmonale, and a decreased vasoactive inotropic score. All of these findings indicate a reversal of circulatory failure induced by acute cor pulmonale when patients are placed on VV-ECMO for ARDS. The likely mechanisms of action are the effects of VV-ECMO on pulmonary artery vasoconstriction by correction of hypoxia and hypercapnia, and the improvement of positive intrathoracic pressure by ultra-lung protective mechanical ventilation when on ECMO, which may improve RV afterload. Often the decision to choose VV-ECMO versus VA-ECMO in this patient population is difficult, and this study gives us evidence that the RV failure we are concerned about is quickly reversible with VV-ECMO.

Volume Responsiveness Revisited: An Observational Multicenter Study of Continuous Versus Binary Outcomes Combining Echocardiography and Venous Return Physiology

Predicting volume responsiveness (VR), the expected increase in cardiac output after administration of an intravenous fluid bolus, has garnered more attention as recognition of the risks associated with excessive fluid resuscitation has also increased.⁶ In this large (n = 540) trial, LV outflow tract velocity time integral (VTI) was used to quantify VR before and after a passive leg raise (PLR) maneuver. The authors review the physiology surrounding venous return in detail and seek to explore the relationship between concepts such as mean systemic pressure (MSP), driving pressure for venous return (DPVR), increased intra-abdominal pressure (IAP), and RV dysfunction on our ability to predict VR.

Most straightforwardly, this article reinforces the fact that elevated IAP and the presence of RV dysfunction do significantly confound efforts to predict VR. Additionally, the physiological variables of MSP and DPVR, which can be calculated based on relatively straightforward data gathered at the bedside and via POCUS, do indeed enhance the ability to predict VR. Most importantly, however, was the reminder (and evidence) provided by the authors that a state of VR is best viewed as a physiological continuum rather than the artificial binary definition which is traditionally imposed by most research efforts on this topic.

Extended Lung Ultrasound to Differentiate Between Pneumonia and Atelectasis in Critically Ill Patients: A Diagnostic Accuracy Study

Lung consolidation is a common finding in critically ill patients on ventilatory support, often raising the question as to whether the consolidation is pneumonia or rather atelectatic lung.⁷ This paper presents evidence that an extended lung ultrasonography (LUS) examination is helpful in making this differentiation. The study group comprised 120 ICU patients who had consolidation identified with chest radiography, and thereafter classified by LUS as having within it either static or mobile air bronchograms. In addition, the presence or absence of pulsatile flow in blood vessels within the consolidation was determined using color Doppler. Two clinicians who were blinded to the results of the LUS determined whether the patient had pneumonia, and any disagreement was refereed by a third clinician.

The results indicate that if the consolidated zone had mobile air bronchograms (defined as linear hyperechoic artifacts within the consolidated tissue, with motion visible in line with the respiratory cycle), there was a high probability that it was pneumonia. The presence of static air bronchograms without pulsatile blood flow indicated a high probability of atelectasis. The combination of static air bronchograms with positive blood flow was an indeterminate result that required further clinical correlation. The authors provide a useful algorithm that summarizes the application of the extended LUS examination, providing a useful method of differentiating pneumonia from atelectasis.

The Impact of Thoracic Ultrasound on Clinical Management of Critically Ill Patients (UltraMan): An International Prospective Observational Study

In this multicenter observational study, the impact of thoracic ultrasonography (TUS; defined to include cardiac, lung, diaphragm, and inferior vena cava examination) on the clinical management of critically ill patients was examined.⁸ Physicians first evaluated the patients without benefit of ultrasonography to establish an initial diagnosis. TUS examination was then performed, with one outcome of interest centering on whether the ultrasound results altered the initial diagnosis. Thereafter there was a determination made as to whether a change in therapeutic plan had occurred based on the ultrasonography findings. In total there were 725 studies performed by 111 operators with various levels of experience. TUS resulted in a change in initial clinical diagnosis in 48% of cases and caused a management change in 39%, ranging from non-invasive to lifesaving; 89% of these changes were executed within 8 h. Interestingly, most changes derived from findings of lung ultrasonography.

This study demonstrates the utility of TUS for management of critically ill patients. The report emphasizes the importance of the changes in diagnosis and treatment plans that resulted, as well as the utility in confirming both provisional diagnoses

and treatment plans. While the authors comment that they did not demonstrate improvement in patient outcomes, it is reasonable to presume that an accurate diagnosis should result in an improvement in outcome, with further study required.

Lung Ultrasound Prediction Model for Acute Respiratory Distress Syndrome: A Multicenter Prospective Observational Study

This prospective multicenter observational study aimed to develop and validate a data-driven LUS score for the diagnosis of ARDS.⁹ The hypothesis was that LUS (along with arterial blood gas results and patient history) performs better in terms of diagnostic accuracy compared to chest X-ray. Additionally, to evaluate how LUS could resolve diagnosis uncertainty, a subgroup of patients with CT-scan results available (and considered as the imaging gold standard) was analyzed. Four hundred and fifty-three patients invasively ventilated for an expected duration >24 h were included within 48 h, and divided into a derivation cohort (n=324) and a validation cohort (n=129). LUS aeration score and blood gases analysis were done on days 1 and 2. The reference test for ARDS diagnosis was a three-expert panel classification using Berlin criteria with chest X-ray. The LUS-ARDS score was developed using a logistic regression analysis in patients with certain ARDS (16%) and certain no-ARDS (54%), and included left LUS aeration score, right LUS aeration score, and the number of anterolateral lung regions with an abnormal pleural line.

The authors found that the diagnostic accuracy of the LUS-ARDS score was good, with an AUROC curve of 0.83 (95% CI 0.77-0.88), not different from the subgroup of 229 patients who had a CT scan. In cases of uncertain diagnosis, a low LUS-ARDS score resulted in an ARDS diagnosis (by expert consensus) in only 24% of cases, but alternatively in 90% of cases when the LUS-ARDS score was high, suggesting that the tool could indeed be helpful where diagnostic uncertainty exists. The main limitations of the study include the fact that LUS was not feasible in 11.4% of cases, and that the external validity could be questioned as LUS was here done by well-trained operator.

Artificial Intelligence (AI) Versus POCUS Expert: A Validation Study of Three Automatic AI-Based, Real-Time, Hemodynamic Echocardiographic Assessment Tools

There is already great interest in marrying POCUS techniques to artificial intelligence (AI) technology.¹⁰ If the ultrasound skill set as a whole can be divided into image generation, image interpretation, and clinical integration domains, then the lowest hanging fruit seems to be helping providers interpret their POCUS images. This article, a single-center effort, sought to compare AI-derived measurements of inferior vena cava (IVC) variability, LVEF, and LV outflow tract VTI with results obtained by human experts.

The authors found good levels of correlation for all three parameters (especially VTI), provided image quality was good. While results from a single cohort based on one company's technology should be taken with a grain of salt, what is much more exciting than the specific findings is the growing potential of AI to impact how ultrasound is delivered to patients. It appears clear that AI models can help us with image interpretation today, and it is unlikely to be long before they can help us with image generation and clinical interpretation.

Lung Ultrasound Signs to Diagnose and Discriminate Interstitial Syndromes in ICU Patients: A Diagnostic Accuracy Study in Two Cohorts

A wide variety of lung diseases that result in respiratory failure present with a pattern on LUS that is frequently labeled as an "interstitial syndrome"; here cardiogenic pulmonary edema (CPE) needs to be distinguished from non-cardiogenic interstitial syndromes (NCIS).¹¹ In this multicenter observational diagnostic accuracy study with a derivation and validation cohort, the authors present convincing evidence that LUS can be used to identify an interstitial syndrome, and furthermore is useful in distinguishing noncardiogenic from CPE. The investigators scanned four anterior lung zones and scored them for the number of B-lines (or their absence, with an A-line pattern) and characterized pleural line morphology for the presence of fragmentation, thickening, or irregularity. Two investigators who were blinded to the results determined, based upon comprehensive clinical data, the cause of the interstitial syndrome. Any disagreement was refereed by a third investigator.

The derivation cohort consisted of 110 patients, with a subsequent validation cohort of 122. The presence of a B-line pattern was the most accurate ultrasound sign to diagnose interstitial syndromes, and bilateral pleural line abnormalities were the most accurate to discriminate NCIS from CPE. In the validation cohort, bilateral pleural abnormalities (fragmentation, thickening, or irregularity) had a specificity of 100% for the differentiation of NCIS from CPE but limited sensitivity; interrater agreement for these ultrasound signs was excellent. The authors present a useful algorithm that can diagnose and discriminate interstitial syndromes in critically ill patients with high accuracy, also incorporating assessment of the posterolateral thorax for lung and pleural abnormalities. They propose a standard semiology for pleural abnormalities which heretofore has not been well defined, and present a comprehensive image set of examples of interstitial and pleural line abnormalities that is useful for applying their results at the bedside.

Point of Care Gastric Ultrasound to Predict Aspiration in Patients Undergoing Urgent Endotracheal Intubation in the Emergency Medicine Department

Emergent endotracheal intubation is considered a high-risk procedure, and gastric aspiration in this population is a significant

cause of morbidity and mortality.¹² New medications such as glucagon-like-peptide-1 receptor agonists (GLP-1 agonists), which have become very popular, delay gastric emptying and increase the risk of aspiration for such patients. Time from the last meal does not correlate well with an empty stomach in critically ill patients or patients on GLP-1 agonists. Point-of-care evaluation of the stomach can provide information about antral diameter, which correlates well with stomach content volumes; this information can thereafter be used to predict aspiration risk.

This prospective observational study was performed on 100 patients who came to the emergency room and required urgent endotracheal intubation; indications for intubation were primarily respiratory failure and hypercapnia. The anteroposterior diameter (AP) and craniocaudal diameter (CC) diameters were measured, and cross-sectional area (CSA) and gastric volume (GV) were calculated using the Perlas formula using a curved array low-frequency ultrasound probe; the antrum was located and evaluated as well. No intervention was done based on the ultrasound findings, and standard practice was continued as the ultrasound was performed. Visible aspiration was recorded, and it was shown that ultrasound-derived gastric volume, CC, AP diameters, CSA, and GV can be used to predict aspiration risk. For example, an estimated GV of >111 mL performed well (sensitivity 100%, specificity 92%, diagnostic accuracy 93%). This information can certainly aid, going forward, in decisions regarding intubation techniques and the specific algorithm to be used.

Conclusion

The 10 articles selected by our expert group represent important articles published over the past 12 months, each one of which has influenced our daily clinical practice.

Declaration of Conflicting Interests

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ORCID iD

Scott J. Millington  <https://orcid.org/0000-0002-2962-5771>

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