Point-of-Care Ultrasound and Modernization of the Bedside Assessment

Anna M. Maw, MD, MS
Amy G. Huebschmann, MD, MSc
Nee-Kofi Mould-Millman, MD
Amanda F. Dempsey, MD, PhD, MPH
Nilam J. Soni, MD, MS

We live in an era of rapid technological advancement, and as newer diagnostic modalities have emerged, the traditional physical examination has become less central to the clinical assessment of patients. Point-of-care ultrasound (POCUS), ultrasound imaging acquired and interpreted by a treating clinician at the bedside, has emerged as a tool that can augment the diagnostic accuracy of the traditional bedside assessment.[1–3] Emerging evidence shows that the accuracy of certain POCUS applications rivals and sometimes surpasses that of conventional imaging tests.[4–6] Growing literature supports the notion that POCUS can expedite diagnosis as well as reduce the number of imaging tests, patient exposure to ionizing radiation, and overall costs.[7–10] Recently, several low-cost handheld ultrasound devices that generate high-resolution images have entered the market and are being purchased directly by clinicians. Given the increasing availability of POCUS, we discuss its utility from the patient, clinician, and societal perspectives as well as the key barriers to its successful incorporation into graduate medical education.

Increased Diagnostic Accuracy at the Bedside

Available evidence has suggested that POCUS can improve the detection of many common diagnoses compared to traditional physical examination maneuvers.[3,11–13] Although an exhaustive discussion of all POCUS applications is beyond the scope of this article, we highlight applications that are relevant across multiple specialties, including emergency, family, and internal medicine (TABLE). For patients presenting with dyspnea, POCUS examinations of the heart and lungs have been shown to be more accurate than traditional physical examination techniques in detecting the most common etiologies of this concern.[2,3] Further, multiple prospective cohort studies have found lung ultrasound to be more accurate than chest x-ray, currently the first-line imaging modality for work up of dyspnea and detection of pleural effusion,[14] pulmonary edema,[15] pneumonia,[4] and pneumothorax[5]—some of the most common causes of dyspnea.

Reduced Time to Diagnosis and Improved Patient Outcomes

While many of the studies evaluating POCUS have been prospective cohort studies designed to evaluate its accuracy relative to a reference standard,[6,16] more rigorously designed studies intended to evaluate the effect of POCUS on patient outcomes are now emerging. A recent randomized control trial demonstrated that lung ultrasound can diagnose acute decompensated heart failure in patients presenting with dyspnea quicker and more accurately than the standard workup with brain natriuretic peptide and chest x-ray.[17] Two additional randomized control trials have shown that lung ultrasound-guided diuresis in ambulatory patients with heart failure reduces urgent visits.[18,19] In order to further inform best practices in training and use, pragmatic trials are needed to assess patient outcomes and cost associated with POCUS implementation in real world settings.

Fewer Tests, Less Radiation, Lower Cost

Critics have expressed concerns that POCUS may result in additional testing to evaluate incidental findings. However, evidence is mounting that POCUS has the potential to decrease the use of additional imaging tests and has been associated with lower radiation exposure and fewer follow-up tests with no difference in adverse events in multiple studies.[8–10,20] If these results are broadly reproducible, cost savings and higher value care may be seen as POCUS is implemented across health care systems.

DOI: http://dx.doi.org/10.4300/JGME-D-20-00216.1

TABLE

Test Characteristics of Traditional Physical Examination Findings Versus Point-of-Care (POC) Ultrasound Findings for Common Pathologies

Pathology	Physical Exam Finding	Sensitivity	Specificity	LR+	LR-	POC Ultrasound Finding	Sensitivity	Specificity	LR+	LR-
Pleural effusion	Dullness to percussion	89%	81%	4.8	0.1	Pleural fluid visualization	93%	96%	23	0.07
	Decreased breath sounds	88%	83%	5.2	0.1					
Pulmonary edema	Crackles	19%–64%	82%–94%	3.4	NS	B lines (bilateral)	94%	92%	10.4	0.06
Pneumonia	Bronchial breath sounds	14%	96%	3.3	NS	Consolidation pattern	94%–95%	90%–96%	13.5	0.06
	Egophony	4%–16%	96%–99%	4.1	NS					
	Crackles	19%–67%	36%–94%	1.8	0.8					
Elevated LV pressure	Fourth heart sound	37%–71%	50%–70%	NS	NS	PCWP 17 if IVC > 2.0	75%	83%	4.4	0.3
Elevated CVP > 8 cm H_2O	Neck vein inspection	47%–92%	93%–96%	9.7	0.3	For CVP > 10 mm Hg: IVC size > 2 cm	73%	85%	4.9	0.32
Reduced ejection fraction < 50%	Third heart sound	11%–51%	85%–98%	3.4	0.7	LV systolic dysfunction	84%–91%	85%–88%	6.5	0.14
Congestive heart failure	Crackles	12%–23%	88%–96%	NS	NS	B lines, bilateral	97%	95%	19.4	0.03
	Elevated JVP	10%–58%	96%–97%	3.9	NS	For CVP > 10 mm Hg: IVC size > 2 cm	73%	85%	4.9	0.32
	Abdominojugular test	55%–84%	83%–98%	8.0	0.3					
	Edema	10%	93%–96%	NS	NS					
Ascites	Bulging flanks	73%–93%	44%–70%	1.9	0.4	Ascites visualization	96%	82%	32	0.04
	Flank dullness	80%–94%	29%–69%	NS	0.3					
	Shifting dullness	60%–87%	56%–90%	2.3	0.4					
	Fluid wave	50%–80%	82%–92%	5.0	0.5					
Lower extremity DVT	Calf swelling > 2 cm	61%–67%	69%–71%	2.1	0.5	Compression venous ultrasonography	96%	97%	32	0.04
	Homan's sign	10%–54%	39%–89%	NS	NS					
	Wells score (high probability)	38%–87%	71%–99%	6.3	NA					

Note: Table adapted from Reference 13 (Bhagra et al 2016).

Abbreviations: NS, not significant; LV, left ventricle; PCWP, pulmonary capillary wedge pressure; IVC, inferior vena cava; CVP, central venous pressure; JVP, jugular venous pressure; DVT, deep vein thrombosis.

Improved Patient and Clinician Experience

From the patient perspective, POCUS offers advantages that include avoidance of ionizing radiation, immediate availability of results, and most important, greater time with their clinician at the bedside. The available evidence supports the notion that the patient experience is enhanced by the use of POCUS.[21,22] From a clinician's perspective, some of the highest yield POCUS applications include basic cardiac, pulmonary, and vascular ultrasound examinations that are relatively easy to learn and quick to perform.[11,16,23,24]

For these reasons, POCUS stands poised to offer the bedside assessment a renaissance. Many have lamented the waning physical examination skills of clinicians. However, POCUS uniquely brings clinicians back to the bedside, allowing for a more thorough assessment that combines both POCUS and traditional physical examination maneuvers.

Barriers to Implementation: Past and Present

Given the complexity of POCUS integration into diverse and multi-level health systems, the extent of adoption will likely vary based on a wide range of contextual factors, including the availability of other tests, patient population, and workflow. Below we discuss some of the most prominent barriers within the literature to date.

Access to Equipment

Until recently, one of the most significant barriers to the adoption of POCUS was access to an ultrasound machine related to cost and portability.[25] Less than 10 years ago, a portable cart-based ultrasound machine with adequate image quality cost between $40,000 to $50,000 and had to be wheeled from room to room by a clinician. The surge of affordable handheld ultrasound devices, including some that connect with smartphones or tablets, has greatly mitigated access to an ultrasound machine as a barrier. Currently, handheld ultrasound devices can be purchased for approximately $2,000 to $5,000, allowing many clinicians to purchase their own personal devices, greatly increasing access.

Training

To date, POCUS training has been more widely implemented in undergraduate medical education than in graduate medical education (GME),[26,27] and there is not yet clear consensus regarding what a POCUS curriculum should contain for many specialties. However, following the lead of emergency medicine, national professional societies that represent specialties like family and internal medicine have now officially endorsed the implementation of POCUS.[28–30] Given this formal support by professional societies and a desire for POCUS training among trainees and residency leadership,[25] many expect that at least some POCUS applications will become required competencies for many specialties. Lack of faculty experts has been recurrently cited as one of the most important barriers to adoption of POCUS by clinicians and residency leadership.[25,31,32] To address the current gap between their society recommendations and actual practice, many specialties have launched training courses meant to provide a pathway to competency.

Although novice POCUS operators can attain basic competency in image acquisition and image interpretation with relatively brief training,[11,33] expert use of any test requires a more complex skill set to integrate test results into clinical decision-making. This higher order skill includes the ability to combine an accurate pretest probability with knowledge of the test characteristics and limitations of the POCUS examination performed to arrive at an accurate posttest probability and appropriate management plan. Because of the complexity of clinical decision-making, POCUS competency, like other clinical skills, will be most consistently achieved with longitudinal mentoring in real world clinical settings. For this reason, faculty expertise is critical for effective integration of POCUS into GME.[25,34,35] Residency leadership interested in developing competency-based POCUS curricula must consider investing in the development of POCUS expertise in their clinical educators as a foundational strategy.

Conclusions

Given growing evidence of its utility, endorsement by professional societies, and increasing availability, POCUS is poised to modernize the bedside assessment across specialties. Residencies will play a pivotal role in the widespread adoption of POCUS. Development of POCUS expertise among clinical educators is an important first step in creating training curricula that allow for the attainment of competency during residency.

References

1. Spencer KT, Flachskampf FA. Focused cardiac ultrasonography. *JACC Cardiovasc Imaging*. 2019;12(7 pt 1):1243–1253. doi:10.1016/j.jcmg.2018.12.036.
2. Thomas F, Flint N, Setareh-Shenas S, Rader F, Kobal SL, Siegel RJ. Accuracy and efficacy of hand-held

echocardiography in diagnosing valve disease: a systematic review. *Am J Med*. 2018;131(10):1155–1160. doi:10.1016/j.amjmed.2018.04.043.

3. Miglioranza MH, Gargani L, Sant'Anna RT, Rover MM, Martins VM, Mantovani A, et al. Lung ultrasound for the evaluation of pulmonary congestion in outpatients: a comparison with clinical assessment, natriuretic peptides, and echocardiography. *JACC Cardiovasc Imaging*. 2013;6(11):1141–1151. doi:10.1016/j.jcmg.2013.08.004.
4. Ye X, Xiao H, Chen B, Zhang S. Accuracy of lung ultrasonography versus chest radiography for the diagnosis of adult community-acquired pneumonia: review of the literature and meta-analysis. *PLoS One*. 2015;10(6):e0130066. doi:10.1371/journal.pone.0130066.
5. Chan KK, Joo DA, McRae AD, Takwoingi Y, Premji ZA, Lang E, et al. Chest ultrasonography versus supine chest radiography for diagnosis of pneumothorax in trauma patients in the emergency department. *Cochrane Database Syst Rev.* 2020;7:CD013031. doi:10.1002/14651858.CD013031.pub2.
6. Pomero F, Dentali F, Borretta V, Bonzini M, Melchio R, Douketis JD, et al. Accuracy of emergency physician-performed ultrasonography in the diagnosis of deep-vein thrombosis: a systematic review and meta-analysis. *Thromb Haemost*. 2013;109(1):137–145. doi:10.1160/TH12-07-0473.
7. Van Schaik GWW, Van Schaik KD, Murphy MC. Point-of-care ultrasonography (POCUS) in a community emergency department: an analysis of decision making and cost savings associated with POCUS. *J Ultrasound Med*. 2019;38(8):2133–2140. doi:10.1002/jum.14910.
8. Zieleskiewicz L, Cornesse A, Hammad E, Haddam M, Brun C, Vigne C, et al. Implementation of lung ultrasound in polyvalent intensive care unit: impact on irradiation and medical cost. *Anaesth Crit Care Pain Med*. 2015;34(1):41–44. doi:10.1016/j.accpm.2015.01.002.
9. Peris A, Tutino L, Zagli G, Batacchi S, Cianchi G, Spina R, et al. The use of point-of-care bedside lung ultrasound significantly reduces the number of radiographs and computed tomography scans in critically ill patients. *Anesth Analg*. 2010;111(3):687–692. doi:10.1213/ANE.0b013e3181e7cc42.
10. Smith-Bindman R, Aubin C, Bailitz J, Bengiamin RN, Camargo CA Jr, Corbo J, et al. Ultrasonography versus computed tomography for suspected nephrolithiasis. *N Engl J Med*. 2014;371(12):1100–1110. doi:10.1056/NEJMoa1404446.
11. Mjolstad OC, Andersen GN, Dalen H, Graven T, Skjetne K, Kleinau JO, et al. Feasibility and reliability of point-of-care pocket-size echocardiography performed by medical residents. *Eur Heart J Cardiovasc Imaging*. 2013;14(12):1195–1202. doi:10.1093/ehjci/jet062.
12. Kobal SL, Liel-Cohen N, Shimony S, Neuman Y, Konstantino Y, Dray EM, et al. Impact of point-of-care ultrasound examination on triage of patients with suspected cardiac disease. *Am J Cardiol*. 2016;118(10):1583–1587. doi:10.1016/j.amjcard.2016.08.028.
13. Bhagra A, Tierney DM, Sekiguchi H, Soni NJ. Point-of-care ultrasonography for primary care physicians and general internists. *Mayo Clin Proc*. 2016;91(12):1811–1827. doi:10.1016/j.mayocp.2016.08.023.
14. Soni NJ, Franco R, Velez MI, Schnobrich D, Dancel R, Restrepo MI, et al. Ultrasound in the diagnosis and management of pleural effusions. *J Hosp Med*. 2015;10(12):811–816. doi:10.1002/jhm.2434.
15. Maw AM, Hassanin A, Ho PM, McInnes MD, Moss A, Juarez-Colunga E, et al. Diagnostic accuracy of point-of-care lung ultrasonography and chest radiography in adults with symptoms suggestive of acute decompensated heart failure: a systematic review and meta-analysis. *JAMA Netw Open*. 2019;2(3):e190703. doi:10.1001/jamanetworkopen.2019.0703.
16. Al Deeb M, Barbic S, Featherstone R, Dankoff J, Barbic D. Point-of-care ultrasonography for the diagnosis of acute cardiogenic pulmonary edema in patients presenting with acute dyspnea: a systematic review and meta-analysis. *Acad Emerg Med*. 2014;21(8):843–852. doi:10.1111/acem.12435.
17. Pivetta E, Goffi A, Nazerian P, Castagno D, Tozzetti C, Tizzani P, et al. Lung ultrasound integrated with clinical assessment for the diagnosis of acute decompensated heart failure in the emergency department: a randomized controlled trial. *Eur J Heart Fail*. 2019;21(6):754–766. doi:10.1002/ejhf.1379.
18. Rivas-Lasarte M, Alvarez-Garcia J, Fernandez-Martinez J, Maestro A, López-López L, Solé-González E, et al. Lung ultrasound-guided treatment in ambulatory patients with heart failure: a randomized controlled clinical trial (LUS-HF study). *Eur J Heart Fail*. 2019;21(12):1605–1613. doi:10.1002/ejhf.1604.
19. Araiza-Garaygordobil D, Gopar-Nieto R, Martinez-Amezcua P, Cabello-López A, Alanis-Estrada G, Luna-Herbert A, et al. A randomized controlled trial of lung ultrasound-guided therapy in heart failure (CLUSTER-HF study). *Am Heart J*. 2020;227:31–39. doi:10.1016/j.ahj.2020.06.003.
20. Brogi E, Bignami E, Sidoti A, Shawar M, Gargani L, Vetrugno L, et al. Could the use of bedside lung ultrasound reduce the number of chest x-rays in the intensive care unit? *Cardiovasc Ultrasound*. 2017;15(1):23. doi:10.1186/s12947-017-0113-8.
21. Howard ZD, Noble VE, Marill KA, Sajed D, Rodrigues M, Bertuzzi B, et al. Bedside ultrasound maximizes

patient satisfaction. *J Emerg Med*. 2014;46(1):46–53. doi:10.1016/j.jemermed.2013.05.044.
22. Claret PG, Bobbia X, Le Roux S, Bodin Y, Roger C, Perrin-Bayard R, et al. Point-of-care ultrasonography at the ED maximizes patient confidence in emergency physicians. *Am J Emerg Med*. 2016;34(3):657–659. doi:10.1016/j.ajem.2015.12.042.
23. Botker MT, Jacobsen L, Rudolph SS, Knudsen L. The role of point of care ultrasound in prehospital critical care: a systematic review. *Scand J Trauma Resusc Emerg Med*. 2018;26(1):51. doi:10.1186/s13049-018-0518-x.
24. Zuker-Herman R, Ayalon Dangur I, Berant R, Sitt EC, Baskin L, Shaya Y, et al. Comparison between two-point and three-point compression ultrasound for the diagnosis of deep vein thrombosis. *J Thromb Thrombolysis*. 2018;45(1):99–105. doi:10.1007/s11239-017-1595-9.
25. Schnobrich DJ, Gladding S, Olson AP, Duran-Nelson A. Point-of-care ultrasound in internal medicine: a national survey of educational leadership. *J Grad Med Educ*. 2013;5(3):498–502. doi:10.4300/JGME-D-12-00215.1.
26. LoPresti CM, Jensen TP, Dversdal RK, Astiz DJ. Point-of-care ultrasound for internal medicine residency training: a position statement from the Alliance of Academic Internal Medicine. *Am J Med*. 2019;132(11):1356–1360. doi:10.1016/j.amjmed.2019.07.019.
27. Bahner DP, Goldman E, Way D, Royall NA, Liu YT. The state of ultrasound education in U.S. medical schools: results of a national survey. *Acad Med*. 2014;89(12):1681–1686. doi:10.1097/ACM.0000000000000414.
28. American College of Physicians. ACP Statement in Support of Point-of-Care Ultrasound in Internal Medicine. https://www.acponline.org/meetings-courses/focused-topics/point-of-care-ultrasound-pocus-for-internal-medicine/acp-statement-in-support-of-point-of-care-ultrasound-in-internal-medicine. Accessed October 8, 2020.
29. Soni NJ, Schnobrich D, Mathews BK, Tierney DM, Jensen JP, Dancel R, et al. Point-of-care ultrasound for hospitalists: a position statement of the Society of Hospital Medicine. *J Hosp Med*. 2019;14:e1–e6. doi:10.12788/jhm.3079.
30. American Academy of Family Physicians. Recommended Curriculum Guidelines for Family Medicine Residents. https://www.aafp.org/dam/AAFP/documents/medical_education_residency/program_directors/Reprint290D_POCUS.pdf. Accessed October 8, 2020.
31. LoPresti CM, Schnobrich DJ, Dversdal RK, Schembri F. A road map for point-of-care ultrasound training in internal medicine residency. *Ultrasound J*. 2019;11(1):10. doi:10.1186/s13089-019-0124-9.
32. LoPresti CM, Boyd JS, Schott C, Core M, Lucas BP, Colon-Molero A, et al. A national needs assessment of point-of-care ultrasound training for hospitalists. *Mayo Clin Proc*. 2019;94(9):1910–1912. doi:10.1016/j.mayocp.2019.07.016.
33. Swamy V, Brainin P, Biering-Sorensen T, Platz E. Ability of non-physicians to perform and interpret lung ultrasound: a systematic review. *Eur J Cardiovasc Nurs*. 2019;18(6):474–483. doi:10.1177/1474515119845972.
34. Ailon J, Mourad O, Nadjafi M, Cavalcanti R. Point-of-care ultrasound as a competency for general internists: a survey of internal medicine training programs in Canada. *Can Med Educ J*. 2016;7(2):e51–e69.
35. Wong J, Montague S, Wallace P, Negishi K, Liteplo A, Ringrose J, et al. Barriers to learning and using point-of-care ultrasound: a survey of practicing internists in six North American institutions. *Ultrasound J*. 2020;12(1):19. doi:10.1186/s13089-020-00167-6.

Anna M. Maw, MD, MS, is Assistant Professor, Division of Hospital Medicine, University of Colorado School of Medicine, and Director, Point of Care Ultrasound, Hospital Medicine, University of Colorado Hospital; **Amy G. Huebschmann, MD, MSc,** is Associate Professor, Division of General Internal Medicine, University of Colorado School of Medicine; **Nee-Kofi Mould-Millman, MD,** is Associate Professor, Department of Emergency Medicine, University of Colorado School of Medicine; **Amanda F. Dempsey, MD, PhD, MPH,** is Professor, Department of Pediatrics, University of Colorado Anschutz Medical Campus; and **Nilam J. Soni, MD, MS,** is Professor, Division of Pulmonary and Critical Care Medicine and Division of General and Hospital Medicine, University of Texas Health San Antonio, Section of Hospital Medicine, South Texas Veterans Health Care System, and Director, Society of Hospital Medicine Point of Care Ultrasound Certificate of Completion Program.

Funding: Dr Maw reports receiving support through grant K12 HL137862 funded by National Heart, Lung, and Blood Institute. Dr Soni reports receiving grant HX002263-01A1 from the US Department of Veterans Affairs Quality Enhancement Research Initiative Partnered Evaluation Initiative.

Corresponding author: Anna M. Maw, MD, MS, University of Colorado Hospital, 12605 E 16th Avenue, Aurora, CO 80045, 720.848.4289, anna.maw@cuanschutz.edu