



Brief Observation

Nephrologist-Led Simulation-Based Focused Cardiac Ultrasound Workshop for Medical Students: Insights and Implications

Abhilash Koratala^{a,*}, Hari R. Paudel^b, Kevin R. Regner^a^a Division of Nephrology, Medical College of Wisconsin, Milwaukee, Wisconsin, USA^b Division of General Internal Medicine, Medical College of Wisconsin, Milwaukee, Wisconsin, USA

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ABSTRACT

Background: Point-of-care ultrasonography (POCUS) is being increasingly recognized as an adjunct to physical examination. However, limited availability of trained faculty in specialties other than emergency medicine and lack of universal training standards remain key barriers to its widespread integration into undergraduate and graduate medical curricula. In this study, we sought to explore the effectiveness of a short simulation-based workshop for medical students teaching basic cardiac ultrasound led by a nephrologist.

Methods: Workshops were conducted for 2 different groups of 4th-year medical students with a total of 25 attendees. The workshop consisted of a 1-hour lecture followed by 15 minutes of cardiac anatomy simulation and a 2- to 2.5-hour hands-on session in the simulation laboratory. An anonymous precourse questionnaire comprising 10 questions assessing the interpretation of common grayscale ultrasound findings encountered in patients with undifferentiated hypotension was performed. After the workshop, a postcourse exam and survey were conducted, retesting the same concepts and seeking the students' feedback on the course.

Results: In total, 23 and 20 students answered the pre- and postcourse surveys, respectively. The mean total score on the pretest was $63.8\% \pm 13.6\%$, which significantly increased to $91.5\% \pm 10.5\%$ on the posttest ($P < .001$). About 90% of the respondents strongly agreed that the cardiac anatomy simulation improved their understanding of the cardiac sonographic anatomy; 75% strongly agreed that the hands-on simulation enhanced their confidence in image acquisition and interpretation; and 70% said they would choose nephrology elective if POCUS training was integrated with it.

Conclusions: A nephrologist-led diagnostic POCUS workshop using simulation techniques is effective in improving the learners' knowledge, understanding of the sonographic cardiac anatomy, and confidence in image acquisition. Integration of POCUS training may increase medical student interest in nephrology elective rotations.

Background

Point-of-care ultrasonography (POCUS) is a focused ultrasound examination performed by the clinician to answer pertinent clinical questions at the bedside and guide management. POCUS has evolved as an enhancement to physical examination over the past several decades, particularly in specialties such as emergency medicine, where it is a mandatory component of residency training.¹ Now there is a growing interest in incorporating this skill in undergraduate medical education (UME). In fact, according to a 2020 survey, 57% of the responding medical schools (69 out of 122) in the United States have integrated POCUS instruction into their UME curricula.² However, lack of trained faculty and adequate time have been identified as key barriers to the development of structured longitudinal training programs.

To avoid overburdening of the emergency medicine physicians who typically lead such curricula, it is imperative that other specialties share the responsibility. This also provides an opportunity for the students to learn how to interpret similar POCUS findings in different clinical contexts. Once confined to procedural guidance such as dialysis catheter placement,³ the scope of POCUS in nephrology is expanding to include diagnostic applications like kidney ultrasound and fluid status assessment using lung and focused cardiac ultrasound. In our fellowship program, we have successfully incorporated advanced ultrasound applications such as Doppler-assisted hemodynamic assessment.⁴ This not only enhanced the attractiveness of our program but also was well received by the consulting teams. As a result, we were entrusted with the responsibility to teach the fundamentals of sonographic evaluation of the hemodynamic status to 4th-year medical students during their general medicine acting internship rotation. We organized half-day POCUS

* Corresponding author: 8701 W Watertown Plank Rd, Division of Nephrology, Room A 7633, Wauwatosa, Wis, 53226.
E-mail address: akoratala@mcw.edu (A. Koratala).

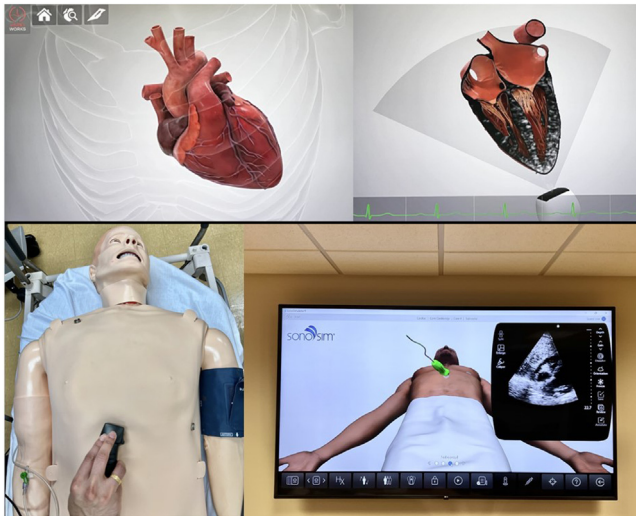


Figure 1. Images obtained during the workshop using Heartworks augmented reality portable simulator demonstrating cardiac anatomy (*upper panel*) and SonoSim ultrasound simulator with manikin demonstrating the probe position and corresponding ultrasound image. Pericardial effusion is seen in this photograph (*lower panel*).

workshops for small groups of students focusing on basic cardiac and lung ultrasound and pursued this study to gauge the effectiveness of this initiative.

Methods

Workshops were conducted for 2 different groups of 4th-year medical students in September 2022 and October 2022, attended by 14 and 11 students, respectively (total of 25). The format of the workshop was multimodal and consisted of a 1-hour lecture followed by 15 minutes of cardiac anatomy simulation and a 2- to 2.5-hour hands-on session in the simulation laboratory. The lecture included basics of image orientation, normal and abnormal lung ultrasound findings, cardiac sonographic anatomy and key abnormalities, and case scenarios demonstrating the utility of cardiopulmonary ultrasound in patients with undifferentiated hypotension and/or fluid overload. Heartworks augmented reality portable simulator connected to an external monitor was used to demonstrate the cardiac imaging planes and echocardiographic windows (*Figure 1, upper panel*). This device enables the user to move around a fully interactive and accurate 3-dimensional heart via touch screen, label structures, and slice in any plane. For the hands-on component, SonoSim ultrasound simulator was used, consisting of a laptop-based software with an online library of patient cases and a hand motion-sensing probe. The laptop was connected to an external display and a SimMan medical manikin was used to teach probe positioning for optimal image acquisition (*Figure 1, lower panel*). Each student was assigned a case from the focused cardiac ultrasound module where they were required to place the probe in the appropriate cardiac window, acquire optimal image, interpret the findings, and integrate with the given clinical scenario. They were guided at each step by the instructor with discussion of relevant imaging pearls and pitfalls. Prior to the workshop, a precourse questionnaire was emailed to the participants consisting of 10 questions assessing the interpretation of common grayscale sonographic findings encountered in patients with undifferentiated hypotension. A postcourse questionnaire was emailed after the workshop, retesting the same concepts using same images and additionally seeking learner feedback. An online secure survey management tool (Qualtrics.com) was used to collect the responses anonymously and store for data analysis.

Results

In total, 23 students answered the precourse and 20 answered the postcourse surveys (response rate 92% and 80%, respectively). The mean total score on the pretest was $63.8\% \pm 13.6\%$, which significantly increased to $91.5\% \pm 10.5\%$ on the posttest ($P < .001$). The learning objectives for questions 1-10 are listed in *Figure 2*. The post-course survey results are shown in *Figure 3*. About 90% of the respondents strongly agreed that the postlecture cardiac anatomy simulation improved their understanding of the cardiac sonographic anatomy; 10% somewhat agreed; and none of them disagreed with this statement. With respect to hands-on simulation, 75% of the respondents strongly agreed that it enhanced their confidence in cardiac image acquisition and interpretation, whereas 25% agreed somewhat. About 95% of the respondents said that they would be interested in attending another simulation-based POCUS course. Of these, 67% said they would prefer a dedicated POCUS rotation with both simulated scenarios and supervised scanning of real patients. Interestingly, 70% of the students said they would choose nephrology elective if POCUS training was integrated with it; 5% opined nephrology is totally unattractive and 25% said their attitude toward nephrology is neutral regardless of POCUS and would prefer another specialty elective instead. Of note, 70% of the respondents did not have prior POCUS training and 30% had some exposure during clinical rotations such as emergency medicine.

Discussion

POCUS has been shown to improve diagnostic accuracy of bedside clinical examination in various clinical settings.^{5,6} In addition, it reduces the time to diagnosis, fragmentation of care and number of follow-up imaging studies and enhances patient satisfaction.⁷⁻⁹ However, with the widespread availability of the low-cost handheld ultrasound equipment, use of POCUS by physicians with limited or no training is on the rise, which could potentially result in patient harm. In fact, Emergency Care Research Institute has listed the increased adoption of POCUS outpacing institutional safeguards as one of the top health technology hazards.¹⁰ Therefore, it is imperative that proper training is offered at all levels of medical education as well as for practicing physicians. Competency in sonography relies on visuospatial perception and thorough knowledge of the anatomy, particularly with respect to cardiac applications. It is difficult to derive a 3-dimensional mental construct utilizing 2-dimensional images. Therefore, we used the cardiac anatomy simulator in our workshop, which substantially improved the self-reported comprehension of the students. Similarly, simulation-based ultrasound education allows the learners to acquire images in a controlled environment with reproducible clinical scenarios and learn clinical integration with no patient risk.¹¹ Remarkably, all the students reported improvement in their confidence level in acquiring cardiac images after the hands-on session. Of note, the simulators we used are relatively less expensive compared to the ones used in prior similar studies.^{12,13}

Another interesting aspect of our study is relevance of cardiopulmonary ultrasound to nephrology. Nephrologists are frequently consulted to manage patients with complex fluid and electrolyte disorders such as cardiorenal syndrome, cirrhosis-related kidney dysfunction, end-stage kidney disease, and hyponatremia. Hence it is conceivable that the POCUS applications that facilitate objective assessment of fluid status are of interest in day-to-day nephrology practice.^{14,15} We picked sonographic evaluation of undifferentiated hypotension as the central theme as the typical findings in this setting are also seen in patients with renal disorders requiring fluid administration or removal, albeit with varying degrees of severity. For example, a hyperdynamic left ventricle coupled with low right atrial pressure in a patient with acute kidney injury is suggestive of hypovolemic etiology, whereas reduced cardiac contractile function, elevated right atrial pressure, and increased extravascular lung water favor congestive nephropathy. Similarly, pericardial effusion, pleural effusions, and dilated right ventricle are commonly seen

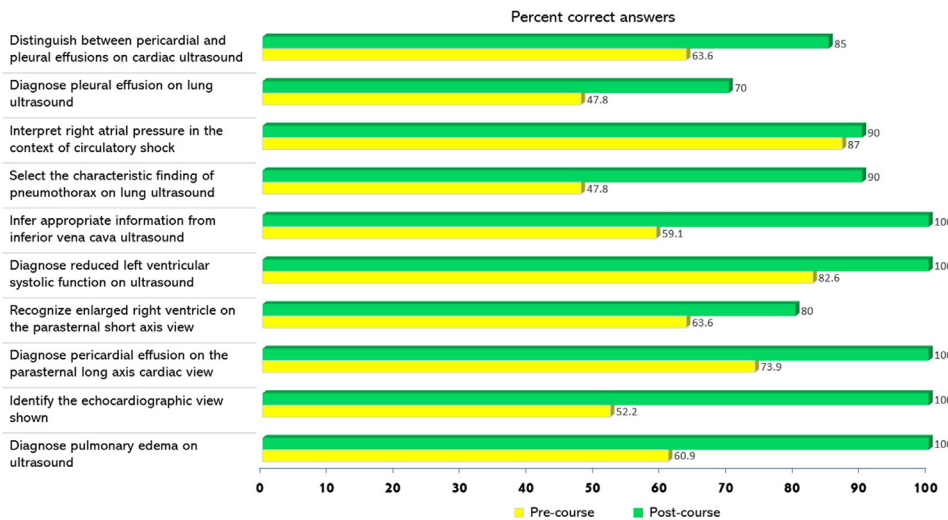


Figure 2. Pre- and postcourse survey results showing the percentage of correct answers and corresponding learning objectives for questions 1-10 testing POCUS-related medical knowledge.

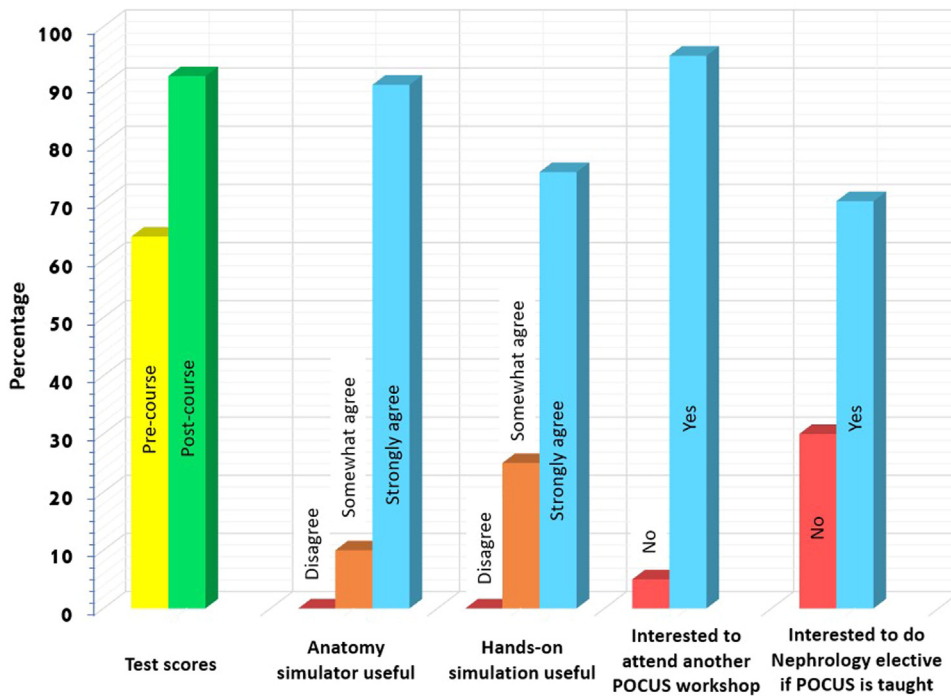


Figure 3. Representation of the overall pre- and postcourse test scores and feedback from the learners.

countered in patients with chronic kidney disease and generalized volume overload. Further, acute right ventricular strain may be seen in a nephrotic syndrome patient who develops venous thrombosis and consequent pulmonary embolism, and a dilated left atrium is often a clue to diastolic dysfunction that limits fluid tolerance. The workshop instructor (author AK) is a nephrologist who completed the special competency in critical care echocardiography examination administered by the National Board of Echocardiography and possesses institutional privileges to perform multiorgan ultrasound.

With dwindling interest in nephrology as a career choice among trainees over the past decade, efforts to increase the exposure of medical students to full breadth of nephrology topics are ongoing.^{16,17} POCUS, which is one of the novel developments in nephrology education and clinical practice, can potentially address this issue. Our study supports this notion as 70% of students felt POCUS enhances the attractiveness of nephrology elective. While one could argue that this observation reflects interest in POCUS and not necessarily nephrology, it possibly will

serve as a motivating factor for nephrology fellowship programs to make POCUS an integral component of routine patient care, thereby enhancing the competitiveness of the specialty.

In summary, through this study, we have established that nephrologist-led POCUS workshop can lead to improved knowledge of the learners. Additionally, incorporation of simulation leads to improvement in learner-reported understanding of the sonographic anatomy and confidence in image acquisition. Based on these results and feedback, we intend to expand the course with longitudinal training opportunities and scanning sessions on standardized patients. Also, encouraged by the positive impressions that students had on the 3-dimensional cardiac anatomy simulation, we have carried out these demonstrations at the POCUS courses organized by the American Society of Nephrology and National Kidney Foundation (2022-2023) and received similar feedback. With respect to limitations, the small sample size may limit the generalizability of the findings to other institutions. Moreover, the availability of nephrology instructors trained in multiorgan ultrasound

is sparse. Lack of objective testing of image acquisition skills is another limitation of this study as it remains elusive whether self-reported confidence translates into competence. It is also noteworthy that short workshops such as these serve as starting points for continued practice, without which skills decay over time.¹⁸

Conclusions

Implementation of a short simulation-based POCUS workshop focusing on 3-dimensional cardiac anatomy, image acquisition, and interpretation is effective in improving learners' knowledge and confidence. POCUS can potentially boost the interest in pursuing nephrology elective, which in turn would increase their exposure to the specialty. As such, it is time for nephrology professional societies to devise formal guidelines to establish uniform standards in POCUS training. Future task is to objectively test the image acquisition skills using standardized simulated clinical scenarios and long-term knowledge retention.

Study Approval Statement

Institutional Review Board approval and informed consent were waived due to the nature of the study (quality improvement) and anonymized data collection. Data was reviewed by the vice chair for quality, Department of Medicine at the Medical College of Wisconsin.

Author Contributions

AK designed the surveys and led the POCUS workshop. HP and KRR reviewed and revised the manuscript for critical intellectual content.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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