Point-of-care-ultrasound for the assessment of post-renal transplant recipients

Michael Uy[1], Cameron Lam[1], Yanbo Guo[1,2], Rahul Bansal[1,2], Richard Hae[2,3], Azim Gangji[2,3], Christine Ribic[2,3], Shahid Lambe[1,2]
[1]Division of Urology, Department of Surgery, McMaster University, Hamilton, ON, Canada; [2]Department of Urology, St. Joseph's Healthcare Hamilton, ON, Canada; [3]Division of Nephrology, Department of Medicine, McMaster University, Hamilton, ON, Canada

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Corresponding author: Dr. Michael Uy, Division of Urology, Department of Surgery, McMaster University, Hamilton, ON, Canada; Michael.uy@medportal.ca

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ABSTRACT

Introduction: Postoperative imaging for deceased donor renal transplants is often delayed, as these surgeries occur after-hours These delays can be critical in identifying immediate complications. To our knowledge, there are no formal training programs for point-of-care ultrasound (POCUS) in this setting; therefore, we aimed to develop and evaluate a feasible and practical POCUS curriculum for the assessment of a renal transplant graft.

Methods: Urology and nephrology transplant physicians completed a three-hour online course, followed by a five-hour hands-on seminar for sonographic scanning. Simulated patients with transplanted kidneys were used. Course material was developed with licensed ultrasound technologists based on Sonography Canada national competency profiles. Pre- and post-course

KEY MESSAGES

- This study introduces a novel and feasible POCUS curriculum designed for the assessment of renal transplant grafts, addressing the critical need for immediate postoperative imaging in deceased donor renal transplants.
- The curriculum significantly enhances theoretical knowledge and skill confidence of transplant physicians,
- Future efforts should emphasize ongoing assessment of competency through supervised scanning and regular training to ensure safe and effective POCUS use in clinical practice

surveys focused on user confidence, while pre- and post-course multiple-choice questionnaires assessed theoretical knowledge.
Results: Twelve participants were included, six of whom were urologists. Theoretical knowledge in POCUS improved significantly ($p<0.001$). Confidence in manipulation of ultrasound controls, Doppler imaging, and POCUS of the transplant kidney also improved (all $p<0.001$, $d>2.0$). Participants indicated an increased likelihood of POCUS use in clinical practice and that training should be integrated into a transplant fellowship.
Conclusions: We introduced a novel and guideline-based POCUS curriculum that leveraged local ultrasound educators and found improved theoretical knowledge and skill confidence in our cohort of transplant physicians. This course will serve as the first step toward a validated competency-based training system for POCUS use in the immediate post-renal transplant setting, and likely will be incorporated into the training of the modern transplant physician.

INTRODUCTION

Diagnostic ultrasound is paramount in the assessment of post-operative complications in renal transplantation.[1] Immediate post-operative ultrasound is routine practice in most academic transplant centers for living related renal transplants. Compared to living transplants, deceased donor renal transplants generally have delays in ultrasounds as these surgeries may occur after hours and imaging may not be readily available. Point-of-care ultrasound (POCUS) is a clinical diagnostic exam performed by non-radiology healthcare professionals and has the capacity to fulfill this diagnostic need.[2] However, the user-dependency of POCUS necessitates appropriate use and competence. The International Federation of Emergency Medicine state that the use of POCUS in untrained users has the potential for negative outcomes, and adequate training is mandatory.[3] Fortunately, medical practitioners are able to learn and gain confidence in the use of POCUS with proper education.[4]

Curricula exist in the realm of nephrology as it pertains to kidney biopsy, venous access, and dialysis catheter placement;[5] however, to our knowledge, there are no formal training programs for POCUS specifically for the immediate post-renal transplant assessment. Therefore, the objective of this study is to develop and evaluate a low-cost, feasible, and practical POCUS curriculum for the improvement of foundational technical skills and theoretical knowledge in ultrasound assessment of a renal transplant graft.

METHODS

Study design and participants

This prospective study was conducted in December 2022 and followed a pre- and post-course intervention design. Participants were recruited from McMaster University's transplant urology and nephrology fellowship programs. All fellows and staff physicians were invited to participate.

We excluded any participants who have had formal education in POCUS as it relates to the assessment of renal transplantation. The study received approval from the Hamilton Integrated Research Ethics board (2022-14633-GRA).

Course design and content rationale

Development of this course was made in collaboration with licensed sonographers and educators from St. Joseph's Hospital Healthcare Hamilton (Hamilton, ON, Canada) who regularly perform post renal transplant diagnostic ultrasounds. Course material was based on national competences outlined by Sonography Canada National Competency Profiles,[6] and formed after group consensus of learning objectives between the nephrology and urology services. Material falls within the limits set by the IFEM position statement on POCUS. [3]

The course comprised of two components: 1) A pre-course, three-hour, online module with associated assessments, and 2) A five-hour, hands on session with simulated patients.

The pre-course online content consisted of pre-recorded lectures with associated slides and assessment forms. Learning objectives based on national competency profiles were chosen based on the input from sonography and transplant stakeholders. The course was divided into 4 modules: Introduction to POCUS and Image formation, Ultrasound Controls and Image Optimization, Ultrasound of the Native Kidney and Bladder, and Ultrasound of the Graft Kidney and Doppler Imaging. Detailed learning objectives are outlined in Appendix A. Content was hosted on an established online learning platform (AvenueToLearn, Desire2Learn, Kitchener, ON, Canada).[7] Participants were given two weeks prior to the hands-on portion to complete the pre-course content.

The hands-on session was facilitated by our local licensed sonographers. Participants were divided into groups of 2-3 and had their own ultrasound machine. Simulated patients with previously transplanted kidneys were recruited for this day, and groups had a chance to scan different patient profiles and body habitus. Under the guidance of the sonographers, participants completed ultrasound image optimization and interrogations of the native kidney, bladder, and graft kidney. Emphasis was placed on doppler imaging optimization and interrogation.

Analysis of confidence and theoretical knowledge

All participants completed a pre- and post-course survey and multiple-choice questionnaire (MCQ) assessment. The survey will use a five-point Likert scale to determine self-rated user confidence and interest in POCUS prior to, and after, the course. This scale was adapted from a previous ultrasound study.[8] To evaluate knowledge, the MCQ assessments will use questions from a bank produced by ultrasound experts from the Sonography Canada National Competency Profiles and topics focused on relevant transplant clinical applications.[6] To control for practice bias, an additional 10 unique questions from the same question bank will be added to the post-course MCQ assessment. These additional questions will be created to assess participant learning objective completion without the potential bias of recall from writing the previous pre-course MCQ assessment. We will further randomize the question order to control for order bias. The

Wilcoxon signed rank test will used to compare means of pre- and post-course MCQ assessments and Likert scale responses. For the initial comparative assessment, to ensure true pre- and post-course analysis, we will compare questions that were present in both the pre- and post-course test. The additional 10 unique questions on the post-course test will be marked independently and reported separately as another indicator of knowledge acquisition. Effect size (Cohen's d) will be used to calculate the magnitude of improvement, which can range from 0.2 (small) to 0.8 (large), while 1.2 is very large and >2.0 is considered a huge effect size. Due to a potential small sample size, it was determined a priori that only effect sizes of > 2.0 were determined clinically meaningful. Feedback will be elicited via open-ended questions to assist in guiding any future changes to the curriculum. The α-level will be set at 0.05 for statistical significance for all tests. Convenience sampling was conducted due to the pilot nature of this study. Statistical analysis was performed using IBM SPSS Statistics version 26.0 (Armonk, NY, U.S.).

RESULTS

A total of 12 participants were eligible and participated in the course. The cohort consisted of 7 nephrologists (3 fellows, 4 attendings) and 5 urologists (3 fellows, 2 attendings). All participants completed the pre- and post-course survey, as well as the MCQ assessment.

Theoretical knowledge

Improvements were noted among the participants' knowledge (Table 1). Post course exam marks were improved from baseline (respectively, 76.0 ± 8.2 vs. 52.0 ± 11.0, $p = 0.001$, $d = 2.5$). Additional question scores were similar to that of the post course exam marks (respectively, 72.2 ± 6.7 vs 76.0 ± 8.2, $p = 0.12$), which accounted for practice bias. Confidence in theoretical knowledge of POCUS significantly improved (all $p = 0.001$), with clinically meaningful effect sizes ($d = 2.5 - 3.8$).

Skill confidence

Post course mean confidence scores improved significantly for all skills ($p = 0.001$), with meaningful effect sizes (all $d > 0.8$). The smallest effect size change was observed in utilization of general doppler imaging and doppler imaging of the transplant kidney (respectively, $d = 2.8$ and 2.9) (Table 2).

Course evaluation

Before and after the curriculum, participants noted that they were highly interested in POCUS, believed it is a helpful adjunct to their physical examination skillset, will improve their clinical practice, and that POCUS training should be integrated into a transplant fellowships programs (all responses were above 4.0 on the five-point Likert scale). The course itself improved confidence and participants highly agreed that they were more likely to utilize POCUS in clinical practice (mean of 4.8 ± 0.4 on the five-point Likert scale). Post course commentary from the group suggested that success came from hands on training with sonographers on real transplant patients, and one participant commented that "[the course] should be a regular feature for all staff and trainees in this fellowship program."

DISCUSSION

Point-of-care ultrasound as a clinical adjunct has gained rapid popularity over the last decade, and with that, comes the increased responsibility of users to be adequately trained and competent. This paper describes an innovative curriculum in POCUS use in the immediate post renal transplant setting. We found that utilizing a mixed online and hands-on curriculum, structured around national training recommendations for ultrasound, improved theoretical knowledge and self-confidence in our cohort of transplant urologists and nephrologists. This foundational course is inexpensive, feasible, reproducible, and may serve as a pre-cursor to a competency-based model for POCUS in a renal transplant setting.

Participants in our cohort had significant increases in theoretical knowledge (Table 1). Focusing on clinically relevant physics and knobology, the course allowed users to develop a deeper understanding of image optimization ($d > 2.0$ on theoretical knowledge assessments). By understanding the principles of image formation, users are not bound to strict imaging protocols, but rather, are able to problem-solve a multitude of imaging scenarios. These concepts are reinforced by specific MCQ assessments tailored to identify improper image settings and poorly optimized images. Moreover, theoretical content also highlighted the importance of appropriate use of POCUS. That is, utilizing the technology as an adjunct test to supplement the clinical examination, rather than replacing it. This principle underscores the core tenant highlighted in many POCUS guidelines. As defined by the Society of Radiologists in Ultrasound and the American College of Radiology Ultrasound Commission, POCUS should be limited in its scope of use for specific clinical questions.[9] In the context of renal transplantation, appropriate clinical questions include binary assessment (yes or no) of the presence of doppler flow, hydronephrosis, or a peri-graft collection. Thus, by highlighting these limitations set forth by the modality, users may avoid scenarios where POCUS may lead to misdiagnosis or further confusion.

Our users also reported an increase in overall skill confidence in POCUS of the native kidney, native bladder, and transplant kidney (all $p < 0.001$, $d \geq 2.0$). Although confidence is not equivalent to competency, it can be an early marker for skill development and has been used in other POCUS curricula studies.[10,11] Increased confidence also increases the likelihood of utilizing the tool in clinical practice. Our participants indicated that they were more likely to use POCUS after the course (mean of 4.8 ± 0.4 on the five-point Likert scale), thus will ultimately obtain more experience from skill repetition. As the user becomes more comfortable with the modality, we hope to observe an uptake in the use of this adjunct test at our transplant center.

Although there were significant increases in skill confidence ($d \geq 2.0$), doppler imaging had one of the lowest increases in skill confidence compared to other measures (pre-course 1.7 ± 0.8 and post course 3.8 ± 0.6, $d = 2.9$). This is likely due to the advanced nature of the skill, and the potential of both false negative and false positive findings in the transplant setting. The quality of doppler imaging is dependent on an adequate grey scale imaging, the optimization of doppler scale and gain settings, and the knowledge of doppler interpretation as it relates to the clinical case.[12] In other words, using doppler imaging correctly requires a baseline competency in grey scale imaging and optimization. Overall, this highlights the need for future curriculums to place an emphasis on doppler imaging. POCUS users in this space may create machine pre-sets with their ultrasound vendors to minimize the need for doppler setting manipulation; however, it is our opinion that a strong foundation in doppler theory is more robust than relying on machine pre-sets.

The strengths of our course come from utilization of local sonographer educators experienced in transplant imaging. Leveraging resources available in the majority of transplant healthcare centers, such as diagnostic sonographers or radiologists, can assist in the local development of POCUS protocols and courses. Additionally, by modelling the same guidelines used to train licensed sonographers in Canada, we were able to highlight important topics already set forth by our local licensing body.[6] Finally, the course itself is low cost, reproducible, and feasible at any transplant center. As the online curriculum has already been built, future iterations of the course can be offered with low upfront investment. The investment in a POCUS curriculum in a transplant center has the potential to ultimately prevent graft loss. From a patient perspective, the morbidity of graft loss after enduring such an invasive procedure cannot be understated. Repeat transplantation after a failed primary graft not only assumes the same surgical risks, but also depletes the already short supply of renal grafts. From a health systems perspective, the burden of cost alone from one failed transplant can be up to $100,000.[13] Saving even one graft through a POCUS training curriculum will repay course investment multiple times over.

Though the findings of this study are unique and promising, there are limitations to universal implementation. First, confidence and knowledge acquisition are not equivalent to competency attainment. As useful as POCUS may be, its misuse in untrained hands has the capacity for misdiagnosis.[2,3,9] Thus, it is imperative that further work be built upon an introductory course, such as this curriculum, to investigate competency. In other specialties such as emergency medicine, this may mean meeting a minimum number of supervised scanning every year, with accompanying peer-to-peer image quality review.[14] Secondly, improvements in user confidence likely is transient and does not reflect how users will feel in true clinical practice. The need for regular training and assessment, perhaps annually, is likely part of a true competency training system. Finally, this course was limited to one Canadian tertiary hospital with a small cohort based on convenience sampling and may not be generalizable to other transplant programs.

CONCLUSIONS

The utilization of POCUS in renal transplantation is inevitable and there is a responsibility of modality users to be adequately trained and competent in this skill. We introduced a novel and unique POCUS curriculum that was inexpensive, feasible, and guideline-based that leveraged local ultrasound educators, and found significantly improved theoretical knowledge and skill confidence in our transplant urology and nephrology cohort. This introductory course will serve as the first step towards a validated competency-based training system for POCUS use in the immediate post renal transplant setting and likely will be incorporated into the training of the modern transplant physician.

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FIGURES AND TABLES

Table 1. Theoretical Knowledge of POCUS				
	Pre-course	**Post-course**	**p**	**d**
Quantitative assessments				
MCQ Assessment (%)	52.0 (11.0)	76.0 (8.2)	0.001	2.5
Additional questions (%)	–	72.2 (6.7)	–	–
Theoretical knowledge†				
Indications	2.3 (0.8)	4.5 (0.5)	0.001	3.3
Terminology	2.3 (0.8)	4.3 (0.5)	0.001	3.0
Image formation	2.3 (0.7)	4.3 (0.5)	0.001	3.3
Probe selection	2.2 (0.7)	4.4 (0.4)	0.001	3.8

Standard deviation in brackets. †Confidence assessed via 5-point Likert data: 1=very unskilled (little to no experience), 2 unskilled (beginner proficiency), 3=intermediate performer (proficient), 4=skilled user (comfortable with use), 5=very skilled (expert).

Table 2. POCUS skill confidence				
	Pre-course	**Post-course**	**p**	**d**
POCUS controls†				
Depth	2.2 (1.0)	4.6 (0.5)	0.001	3.0
Gain	2.1 (0.9)	4.6 (0.4)	0.001	3.6
Focus	2.1 (0.9)	4.4 (0.5)	0.001	3.1
Time gain compensation	1.8 (0.8)	4.3 (0.4)	0.001	3.9
Doppler	1.8 (0.7)	3.8 (0.7)	0.001	2.8
POCUS native kidney†				
Overall assessment	2.2 (0.8)	4.4 (0.5)	0.001	3.3
Identify normal	2.4 (0.8)	4.4 (0.5)	0.001	3.0
Hydronephrosis	2.8 (0.9)	4.8 (0.4)	0.001	2.9
Stones	1.9 (0.9)	4.5 (0.5)	0.001	3.6
POCUS bladder†				
Overall assessment	1.9 (0.8)	4.5 (0.5)	0.001	3.9
Identify normal	1.8 (0.8)	4.8 (0.6)	0.001	4.2
POCUS transplant kidney†				

Overall assessment	2.4 (0.8)	4.6 (0.5)	0.001	3.3
Identify normal	2.4 (0.5)	4.4 (0.5)	0.001	4.0
Hydronephrosis	2.4 (0.8)	4.1 (0.6)	0.001	3.4
Collections	2.1 (0.5)	4.5 (0.5)	0.001	4.8
Doppler	1.7 (0.8)	3.8 (0.6)	0.001	2.9

Standard deviation in brackets. †Confidence assessed via 5-point Likert data: 1=very unskilled (little to no experience), 2=unskilled (beginner proficiency), 3=intermediate performer (proficient), 4=skilled user (comfortable with use), 5=very skilled (expert).