Development of skills to utilize point-of-care ultrasonography in nephrology practice

Desenvolvimento de competências para o uso da ultrassonografia *point-of-care* em Nefrologia

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Abstract

Introduction: The use of ultrasonography (US) by non-radiologists has increased due to the need of physicians to integrate "new" clinical information into the diagnostic process. A defined and validated ultrasound training program has not been established in Nephrology. This study aimed to present the results of assessment of the development of skills to utilize point-of-care ultrasonography (POCUS) in Nephrology practice. **Methods:** Nine residents, four from Nephrology and five from internal medicine program, attended a 16-hour course that covered theoretical and practical aspects of ultrasonography. The course addressed topics related to urinary tract, lung, heart, and blood vessel ultrasonography and use of ultrasound to guide kidney biopsy and central venous catheter insertion. The resident evaluation consisted of cognitive tests (CT) with multiple-choice questions and image association tests, before and after the course, and assessment of skills in generating ultrasound images and performing procedures using the Objective Structured Clinical Examination (OSCE). **Results:** All residents completed the course. A significant improvement in knowledge was observed by comparing the residents' scores obtained on the CT ($p < 0.004$) and image association tests ($p < 0.02$) before and after the course. With the exception of the station regarding the lungs, they demonstrated very good performance on the assessment of the skills using the OSCE exams. **Conclusion:** A 16-hour nephrology POCUS training course that was not limited to topics involving the urinary tract enabled the development of skills to obtain images and perform Nephrology procedures. The program developed can be used as a model for learning POCUS in Nephrology.

Keywords: clinical competence; competency-based education; nephrology; ultrasonography.

Resumo

Introdução: O uso do ultrassonografia (US) por não radiologista tem aumentado e decorre da necessidade de o médico integrar "novas" informações clínicas ao processo diagnóstico. Na Nefrologia, ainda não foi estabelecido um currículo de treinamento em US definido e que tenha sido validado. O objetivo do estudo é apresentar os resultados do desenvolvimento de competências para o uso do ultrassom *point-of-care* (POCUS) em Nefrologia. **Métodos:** Nove residentes, quatro de Nefrologia e cinco de clínica médica, frequentaram um curso de ultrassom teórico-prático de 16 horas. Foram abordados temas de ultrassom relacionados ao trato urinário, pulmão, coração, vasos sanguíneos, biópsia renal e inserção de cateter venoso central. A avaliação constou de testes cognitivos (TC) de múltipla escolha e associação de imagens antes e após o curso e de avaliação prática de competências na geração de imagens ultrassonográficas e realização de procedimentos pelo Exame Estruturado de Habilidades Clínicas (OSCE). **Resultados:** Todos os residentes concluíram o curso. Observou-se melhora significativa dos conhecimentos quando se compararam as notas obtidas pelos residentes antes e após o TC de múltipla escolha ($p < 0{,}004$) e de associação de imagens ($p < 0{,}02$). A avaliação de competência dos residentes pelo OSCE, com exceção da estação sobre pulmão, foi considerada muito boa. **Conclusão:** Um curso de POCUS em Nefrologia de apenas 16 horas, não limitado aos temas do trato urinário, possibilita o desenvolvimento de competências na obtenção de imagens e a realização de procedimentos nefrológicos. O currículo desenvolvido pode servir de modelo para o aprendizado do POCUS em Nefrologia.

Palavras-chave: competência clínica; educação baseada em competências; nefrologia; ultrassonografia.

Introduction

Point-of-care ultrasonography (POCUS) is emerging as a powerful propedeutic in clinical diagnosis.[1] In general, clinicians have demonstrated skills in obtaining images that allow them to answer simple, typically binomial, questions. The integration of these images into the clinical history and physical examination results in improved patient management by the clinicians.[2]

Physicians are demonstrating an interest in POCUS, and some medical schools, especially in the USA, have already introduced ultrasonography into their undergraduate curriculum.[3,4] In Brazil, the Medical School of the Federal University of Juiz de Fora (Faculdade de Medicina da Universidade Federal de Juiz de Fora - FAMED/UFJF) is developing a pioneering initiative of a structured and horizontal incorporation of POCUS into a medical school curriculum. It is noteworthy that the incorporation of POCUS training into medical schools and residency programs has generated great satisfaction among students and residents.[3,5]

To date, the use of ultrasonography in nephrology in the majority of the residency training programs has been restricted to performing procedures such as renal biopsy and placement of central venous catheters in patients requiring hemodialysis.[6-9] However, POCUS in nephrology offers an unique opportunity to evaluate not only the diseases that affect the urinary tract but also the comorbidities that unfavorably impact the clinical course of nephropathies.

Thus, a comprehensive renal evaluation should involve both clinical context (history and physical examination) and ultrasound imaging of the upper and lower urinary tract, heart, lungs, and inferior vena cava (IVC). In addition, ultrasonography should be used to guide certain procedures, such as renal biopsies and placement of vascular access for renal replacement therapy (RRT). The availability of portable ultrasound machines and increasingly affordable prices combined with ultrasonography training programs focused on the immediate responses to simple questions provide the conditions to consolidate POCUS in the nephrology practice and, therefore, improve the clinical management of patients with renal diseases.

Accordingly, we hypothesized that medical residents with proper knowledge in ultrasonography could manipulate ultrasound machines and generate images that will enable them to respond to dichotomous questions regarding common diseases of the urinary tract, heart function, lung disorders, and inferior vena cava diameter, as well as to perform procedures often necessary for nephrology practice. This study aimed to analyze the development of skills obtained in a short-term *course* to utilize POCUS in nephrology practice.

Material and methods

Site and participants

Four residents from the nephrology residency program at the University Hospital of a Federal University and five residents from the internal medicine residency program at a State Regional Hospital in Barbacena city (MG) voluntarily attended the course on POCUS in nephrology. None of the residents had previously attended a comprehensive ultrasound training course. The study was approved by the Ethics Committee of the Ethical Committee of the University Hospital of Federal University of Juiz de Fora (number 638,325) where it was done. All residents signed a free and informed consent form before the study.

Ultrasonography training

The POCUS in nephrology training was administered in two periods of eight hours on two consecutive days and combined dialogued expository lectures, simulation activities using the SONOSIM™ software, hands-on activities developed in Phantoms (CAE Healthcare™), and volunteer models. The content was chosen to cover topics related to the main pathologies of the upper and lower urinary tract; blood volume assessment through cardiac performance, the diameter of the inferior vena cava, and pulmonary congestion; the principles of Doppler vessel mapping of the upper limbs; and the most common procedures used in nephrology including ultrasound-guided renal biopsy and ultrasound-guided central venous access.

The course curriculum of the POCUS in nephrology was taught by nephrologists without formal training in ultrasonography (faculties and invited lecturers) but with clinical experience in using focused US and involved with the POCUS training in the undergraduate curriculum of the Federal University. The images were generated using LOGIQe ultrasound machines (GE Healthcare, USA) equipped with curvilinear low frequency, phased array (cardiac), and linear high frequency probes.

The the course program is presented in Chart 1 and 2.

Chart 1 Curriculum developed in the first day of the course Point of care ultrasonography in nephrology

First day	Time of the activity	Description of the activity
8:00 AM	60 minutes	Physical principle of ultrasound, knobology, image acquisition and artifacts
9:00 AM	60 minutes	Hands-on session on management of the ultrasound machine
10:00 AM	60 minutes	Anatomic and diagnostic assessment of the kidneys and urinary tract
11:00 AM	60 minutes	Hands-on session on kidneys and urinary tract
12:00 Noon	60 minutes	Lunch break
13:00 PM	60 minutes	Ultrasound poin-of-care in renal transplantation
14:00 PM	60 minutes	Hands-on session on ultrasound in renal transplantation
15:00 PM	30 minutes	Renal biopsy guided by ultrasound
15:30 PM	90 minutes	Hands-on session on renal biopsy guided by ultrasound

Chart 2 Curriculum developed in the second day of the course point of care ultrasonography in nephrology

Second day	Time of the activity	Description of the activity
8:00 AM	50 minutes	Review of the main topics covered in the first day of the course
8:50 AM	45 minutes	Principles of Doppler ultrasound
9:35 AM	60 minutes	Vascular ultrasound: venous access and vascular mapping for arterio-venous fistula
10:35 AM	90 minutes	Hands-on session on venous access and venous mapping in phantoms and volunteers
12:00 noon	60 minutes	Lunch break
1:00 PM	30 minutes	Cardiac windows, systolic and diastolic function and pericardium effusion with phantoms, volunteers and the software SONOSIM
1:30 PM	60 minutes	Hands-on on cardiac echography with phantoms, actors, and software SONSOSIM
2:30 PM	30 minutes	Lung ultrasound (pneumothorax, lung congestion and pleural effusion
3:00 PM	60 minutes	Hands-on on lung ultrasound
4:00 PM	30 minutes	Ultrasound of inferior vena cava
4:30 PM	30 minutes	Hands-on session on inferior vena cava and volume assessment

Learning evaluation

The knowledge of POCUS in nephrology was evaluated in three steps. The first step was performed immediately before the course, in which one of the two sets of cognitive tests was randomly selected. The tests had the same number of questions with the same degree of difficulty. Each test consisted of 20 multiple-choice questions, and each question had four options. Additionally, one of the two other sets of image association tests, each question with four options were also applied to evaluate knowledge regarding the physical principles of ultrasound, image interpretation and contextualization of ultrasonographic findings in clinical nephrology cases, and procedures (renal biopsy and central venous access). To ensure the accuracy and technical quality of the questions, they were reviewed by one of the authors (OSE), who is a medical education specialist.

The second step was performed immediately after the course using the set of test questions (cognitive and image association tests) that was not used in the first step. Finally, the third step was performed ten days after completing the training of POCUS in nephrology to assess the skills for generating ultrasound images and procedures using a five-station objective structured clinical examination (*OSCE*)[10] that covered the topics studied (Chart 3). The residents who scored at least 70% on the cognitive and OSCE tests were considered qualified to use POCUS in the nephrology practice.

Statistical analysis

The cognitive assessments using multiple-choice questions and image association tests were evaluated by comparing the scores obtained in the pre- and post-tests. Non-parametric methods were used due to the small sample size and type of scores. The Wilcoxon

Chart 3 Ultrasound skill taught in the objective structured clinical after cholecalciferol supplementation examination (OSCE)

Station	Activities
1. Renal biopsy	Done in Phantom
2. Central venous access (IJV)*	Done in Phantom
3. Systolic and diastolic function	Done in human models
4. Diameter assessment of the IVC**	Done in human models
5. Lung ultrasound	Done in human models

IJV: internal jugular vein; IVC: inferior vena cava.

test was used for dependent samples to analyze intragroup differences (before and after). Values were expressed as medians and amplitudes (Max - Min), and the significance level used was $p < 0.05$.

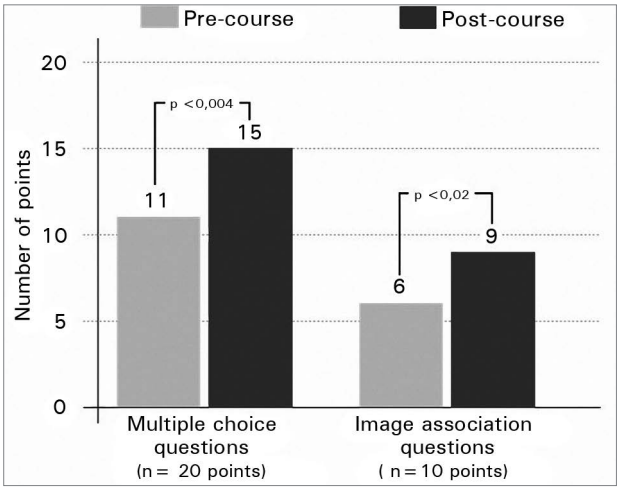
Results

Among the nine residents who attended the course of POCUS in nephrology, there were five males and four females. The mean age of the group was 30 years, and the garduation time ranged from 13 to 24 months (four residents), 25 to 48 months (four residents), and longer than 48 months (one resident). Although none of the residents had received structured training in ultrasonography before, three had an opportunity to perform kidney ultrasonography; three had performed bladder ultrasonography; two had performed heart ultrasonography; two had performed lung ultrasonography; two had performed inferior vena cava ultrasonography; and one resident had performed blood vessel ultrasonography. All residents completed the POCUS in nephrology training and participated in the evaluation processes.

Figure 1 shows the results of the cognitive evaluation before and after the POCUS in nephrology course. The training significantly improved the scores of the residents in both cognitive assessment based on multiple-choice questions ($p < 0.004$) and ultrasonography image association test ($p < 0.02$).

Figure 2 shows the individual representation of the scores obtained by the residents in the cognitive assessment with multiple choice questions (A) and ultrasound image association tests (B) before and after the training. Due to the superposition of scores, the nine lines that correspond the performance of each resident are not seen. The residents showed increased scores after the course and only one resident did not achieve a final score greater than or equal to seven, although there was an improvement in his/her score (45% in the pre-course *vs*. 60% after the course). In

Figure 1. Scoring of the cognitive assessment using multiple choice and image association tests pre- and post-course of point of care ultrasonography in nephrology.



the ultrasound image association tests, the residents' scores were above seven, and two residents had the same scores (eight and nine) before and after the course.

Figure 3 shows the assessment of the skills to generate ultrasound images using the objective structured clinical examination (OSCE) stations. With the exception of the station related to lung ultrasound, which was the first station evaluated, the residents showed very good performance on the stations.

Discussion

Diseases that affect the kidneys, particularly chronic diseases that progress with loss of kidney function, are often complicated by morphofunctional abnormalities that are not limited to the urinary tract,[11] being the cardiovascular complications the leading causes of death in such patients.[12] Therefore, structuring courses to develop skills for the use of POCUS in nephrology but covering topics not limited to the urinary tract seems to be quite relevant. To the

Figure 2. Graphic representation of individual score obtained by the residents in the multiple choice (A) and image association (B) tests pre- and post-course of point of care ultrasonography in nephrology.

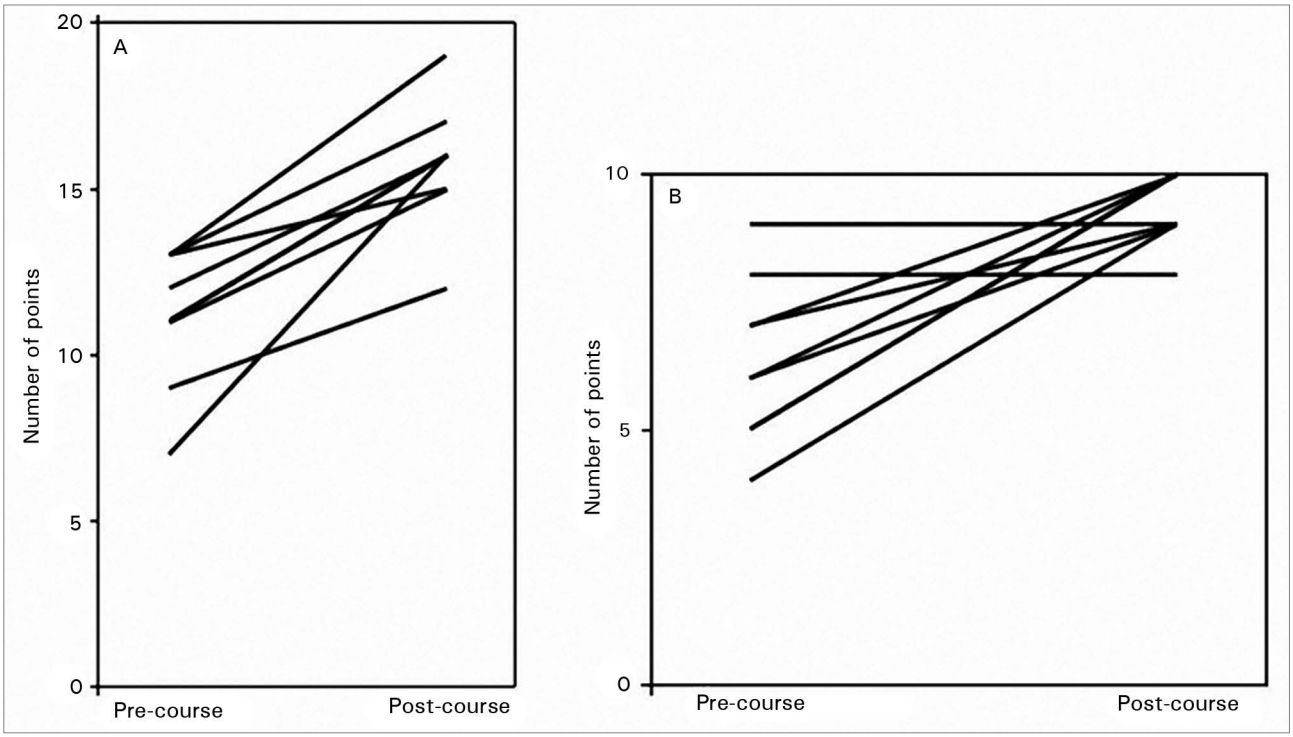
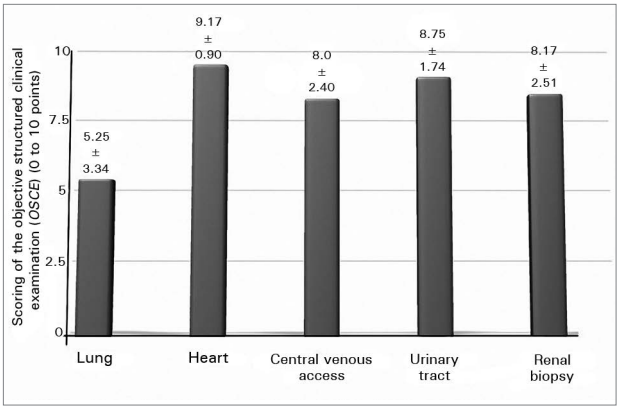


Figure 3. Assessment of skills for generating ultrasound images and realization of procedures using a five-station objective structured clinical examination (OSCE) ten days post-course of point of care ultrasonography in nephrology.



best of our knowledge, a course with such curriculum has not yet been addressed in the literature.

This course on POCUS in nephrology introduced the residents to the following topics associated with ultrasound: the upper and lower urinary tract, lungs (pulmonary edema, pneumothorax, and pleural effusion), heart (systolic and diastolic function of the left ventricle, right ventricular overload, and pericardial effusion), inferior vena cava (variation of the diameter with breathing) and blood vessels (vessel mapping of the upper limbs) in a focused context. In addition, information about the main uses of ultrasonography to guide procedures in nephrology such as renal biopsy and central venous access were also available in hands on activities to the residents.

The approach was targeted to answer simple, typically binomial (yes or no) questions such as the following: 1. Is the urinary tract obstructed? 2. Is pulmonary edema present? 3. Is the left ventricular systolic function normal? 4. Was pneumothorax observed after venous access of the internal jugular vein?

The hypothesis of this study was that residents with ultrasonography knowledge would be able to manipulate the ultrasound machine to generate images that will enable them to answer questions such as those mentioned above and perform ultrasound-guided procedures that are often required in nephrology practice. A significant improvement in the performance of the residents was observed after the course compared to the results of pre-course assessments.

This improvement was observed in the cognitive assessment scores obtained from both multiple-choice questions (11 to 15; $p < 0.004$) and image association tests (6 to 9; $p < 0.02$). Individually, only one resident did not score at least seven, which is the acceptable lower limit for the assessment of cognitive competence in multiple-choice tests. Two residents

whose pre-course scores were eight and nine in the image association tests did not improve their results in the post-course evaluation.

The ability of residents to adequately perform both ultrasound of organs and the procedures covered in the course was evident in the OSCE assessment. Except for the station on lung ultrasound, the performance of the residents in the other stations, such as the heart, central venous access, renal biopsy and the urinary tract, was above the 70% target predetermined for the study. The poor performance of six of the nine participants in the lung station, which was the first to be assessed, might be explained by the inexperience of the residents with the OSCE exam.

In other clinical areas, ultrasonography training guidelines have recommended a number of supervised tests after a course that are considered necessary for achieving competence.[13] This specific aspect of the training was not addressed in the present study, and future studies are needed to answer this question. The main goal of this study was to develop a program that would allow physicians without previous formal experience in ultrasound to develop skills for utilizing POCUS in nephrology practice, as well as in areas other than the urinary tract. The development of a program aimed at the use of POCUS in nephrology is extremely important to consolidate improvements in the technology and expand the physical examination.

Our results show that a short-term ultrasound course (16 hours) that addresses the minimum theoretical aspects and mainly based on practical training allows the development of skills to respond to simple questions. This information, in addition to the medical history and physical examination, will improve the ability to make a clinical diagnosis and make the nephrology practice better.

It is important to recognize the limitations of the present study: 1. Despite that the questions were technically analyzed by an expert in education, the cognitive assessment and imaging tests were not subjected to any formal validation; 2. The practical training and assessment using the OSCE (except for the renal biopsy and central venous access procedures that were performed using Phantoms) were performed on normal individuals, which can influence the results in terms of the test accuracy; 3. The study was conducted only with residents who had volunteered to attend the course, i.e., individuals who were highly motivated.

Conclusion

This study demonstrated that a 16-hour training course in renal ultrasonography that also covered topics associated with major complications of kidney disease in other organs significantly improved the performance of the participants on cognitive tests and the OSCE exam. The residents developed the skills to utilize POCUS in nephrology practice. We believe that the program developed in this study can be used as an appropriate educational tool for nephrologists and should be considered by those who wish to improve their clinical skills by integrating ultrasonography in their daily practice.

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