Nephrology education for medical students: a narrative review

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A review of the published literature on nephrology education for medical students was conducted on two major online search engines (PubMed and ERIC). In addition, references of the manuscripts discovered in these searches were reviewed. The empirical studies were categorized by subject within nephrology and research design.

We found 26 original studies in which a method of teaching nephrology to medical students was described. The studies dated from 1977 to 2015. The focus of these nephrology teaching experiences was as follows: anatomy (6.5%), physiology (22.6%), pathophysiology (29.0%), pathology (6.5%), treatment (25.8%), and general nephrology (9.7%). The studies were also categorized into various types of research design. 6.9% had either no assessment of the educational experience or had a description too vague to categorize it; 3.4% involved a survey about the existing educational approach before a curriculum change was implemented; 55.2% used surveys or tests after an educational course was carried out; 10.3% sought feedback from students before and after the educational experience; 13.8% were case studies; and 10.3% included a randomized controlled trial. The randomized controlled trials involved teaching techniques focused on the pathophysiology of renal disease.

Conclusions: Rigor was lacking in most empirical studies on medical student education in nephrology. Well-designed randomized controlled studies are needed to accurately assess the effectiveness of the educational techniques introduced into medical school curricula.

Introduction

Over the last decade, there have been several publications documenting a decline in the number of United States medical graduates pursuing nephrology fellowships.1–6 This concerning finding is magnified by the reality that an aging population and rising incidence of such chronic diseases as diabetes mellitus and hypertension continue to increase the demand for specialists, including nephrologists.

Recent studies suggest that experiences in medical school – both positive and negative – can influence a medical trainee’s decision to pursue nephrology. Limited medical student exposure to clinical nephrology,7 confusing methods of teaching complex material,7 a dearth of nephrology courses taught by nephrologists,2 and the widespread view of nephrology as a highly specialized field focused on rare and severe diseases6 may contribute to apathy toward a career in nephrology. Conversely, effective teaching and role models may explain the finding of a study6 that over 20% of nephrology fellows first became interested in the field during medical school.

These studies suggest that medical school is an important time for medical trainees to become interested or disinterested in nephrology, and therefore that it would be an appropriate target of intervention.7 Yet little is known about existing approaches to teaching nephrology to medical students. In this article, we review the strategies being employed to teach different topics of nephrology to medical students and the extent to which those methods have been successful.

Methods

We conducted a review of the English published literature on nephrology education of medical students using two major online academic search engines, PubMed and Education Resources Information Center (ERIC). This study was deemed exempt by the Institutional Review Board.
Board at Northwell Health. After our search, we were assisted by a librarian who conducted an additional review. Together, we used the following keywords in our searches: “medical students,” “nephrology,” “education,” “kidney,” and “teaching.” We also reviewed references of the papers discovered in these searches. Exclusion criteria were abstracts, articles that focused on nephrology education of trainees other than medical students (e.g. internal medicine residents, nephrology fellows, or college physiology students), and articles providing commentary on medical school education of nephrology without an accompanying empirical study. We did not limit the review by the year of publication or geography.

We categorized the empirical studies by subject within nephrology based on the primary focus of the teaching method: anatomy, physiology, pathophysiology, pathology, treatment, and general nephrology. We then recorded the research design of each study using a list (see Table 1) adapted from Beckman and Cook.9 Questionnaires, evaluations, and feedback are grouped under the umbrella term “surveys.” Finally, for studies that included an assessment of the teaching method, we noted factors that appeared to contribute to the success of the educational experience.

| Type of study design | Description |
|----------------------|-------------|
| Pre-course design    | Survey or test distributed to students in advance of the institution of a new teaching method. These pre-course assessments collect students’ demographic information or learning style preferences and evaluate their knowledge prior to any intervention. |
| Post-course design   | Survey or test distributed to students after a new teaching method has been used. These post-course assessments evaluate student knowledge after the intervention, gauge student satisfaction, and/or elicit feedback from students. |
| Before and after      | Survey or test distributed to students both before and after the educational experience. The types of assessments are the same as listed above in pre-course design and post-course design. |
| Ethnography           | Observation of students in a real clinical environment, such as in the hospital or an outpatient facility. |
| Case study            | Qualitative analysis of student knowledge and behavior based on their performance in a clinically-related task. |
| Randomized controlled trial | Assessment of students who were randomly allocated to an intervention group compared to a control group. |

Results

We identified 26 publications in which an original method of teaching nephrology to medical students was described (see Table 2). The publications dated from 1977 to 2015. Three studies utilized two different educational research designs. Five studies covered two different subject materials.

There were many (more than 25) publications that were discovered in the original search but were excluded in our study because they focused on the education of learners other than medical students, lacked an empirical trial, were published as abstracts, or were not written in English.

Figure 1 depicts the breakdown of studies by subject material. Figure 2 portrays the breakdown of studies by research design.

Medical student assessment

Each of the studies categorized above aimed to assess the success of an innovational approach to teaching nephrology to medical students. There were four major threads that ran through the publications.

First, several studies support the notion that interactive teaching of nephrology is crucial to the engagement and therefore learning of medical students. For example, Brands and Schumacher10 found that students appreciated small group problem-solving sessions and worksheet exercises. Dietz and Stevenson11 engaged students with clicker questions designed to facilitate active learning. These authors also used group exercises and faculty-led class-wide discussions, and they reduced time spent in traditional lectures. Elzubeir12 championed problem-based learning as an effective method to allow students to develop new skills while building on prior knowledge. Shafi et al.13 claimed that “integrated learning is the need of the hour” and used “large-group interactive sessions, small group learning, problem-based learning, practical, and self-directed learning” to maximize efforts to fulfill that need.

Second, many authors considered the value of technology in educating their students. In 1993, Rabushka et al.14 advocated for the use of an interactive computer program to teach medical students to evaluate and manage renal masses. Leong et al.15 offered computer cases to fill gaps in students’ clinical experiences during their clerkships. Brands and Schumacher16 used patient simulations to teach renal physiology, and Kalinski et al.16 presented 3D visualizations of renal pathological specimens to improve education in renal pathology. Telemedicine was advanced by Bramstedt et al.,17 in which medical students who conducted interviews via Skype with dialysis patients had improved
| Authors (publication date) | Year of medical school (country if other than US) | Subject material | Research design |
|---------------------------|--------------------------------------------------|------------------|-----------------|
| Schwartz and Rauch (1977) | Unknown                                          | Pathophysiology and Treatment | No structured assessment |
| Bernstein et al. (1980)   | First year                                       | Treatment        | Post-course design (survey) |
| Schwab and Knox (1991)    | Unknown                                          | Physiology and Treatment | Post-course design (survey) |
| Preiss et al. (1992)      | Second year (Canada)                             | Pathophysiology Randomized controlled trial and post-course design |
| Rabushka et al. (1993)    | Unknown                                          | Pathophysiology and Treatment | Post-course design |
| Lio et al. (2001)         | Second year                                      | Pathophysiology | Post-course design (survey) |
| McLaughlin and Mandin (2002) | First year (Canada)                              | Physiology Case study | Pre-course design |
| Piccoli et al. (2002)     | Third and fourth year (Italy)                    | Treatment        | Post-course design (survey) |
| Leong et al. (2003)       | Second and third year (Canada)                   | Pathophysiology | Post-course design (survey) and randomized controlled trial |
| Arger et al. (2005)       | Third and fourth year (Canada)                   | Anatomy          | Post-course design |
| McLaughlin et al. (2005)  | First year (of five) (Pakistan)                  | Pathophysiology | Case study |
| Brands and Schumacher (2009) | First year (of five) (Pakistan)                  | Physiology | Case study |
| Harrison-Brandt (2009)    | First year (of five) (Pakistan)                  | Pathology        | No structured assessment |
| Klinski et al. (2009)     | First year (of five) (Pakistan)                  | Physiology       | No structured assessment |
| Shaff et al. (2010)       | First year (of five) (Pakistan)                  | Physiology       | No structured assessment |
| Ali and Sawhney (2011)    | First year (of five) (Pakistan)                  | Physiology       | No structured assessment |
| Dietz and Stevenson (2011) | First year (of five) (Pakistan)                  | Physiology       | No structured assessment |
Table 2. Continued

| Authors (publication date) | Title                                                                 | Year of medical school (country if other than US) | Subject material                      | Research design                        |
|----------------------------|----------------------------------------------------------------------|--------------------------------------------------|---------------------------------------|----------------------------------------|
| Elzubeir (2012)            | Teaching of the renal system in an integrated, problem-based curriculum | First year (Saudi Arabia)                        | Anatomy and Physiology                | Post-course design (survey)             |
| Kiesewetter et al. (2013)  | Cognitive problem solving patterns of medical students correlate with success in diagnostic case solutions | Fourth and fifth year (of six) (Germany)          | General Nephrology                    | Case study                              |
| Bramstedt et al. (2014)    | Telemicine as an ethics teaching tool for medical students within the nephrology curriculum | Second year                                      | Treatment                             | Post-course design (survey)             |
| Ho et al. (2014)           | Online testable concept maps: benefits for learning about the pathogenesis of disease | First and second year (of six) (Australia)        | Pathophysiology                       | Post-course design (survey) and randomized controlled trial |
| Nambudiri et al. (2014)    | Creation of a novel, interdisciplinary, multisite clerkship: “understanding lupus” | Fourth year                                      | Pathophysiology and Treatment         | Before and after (surveys)              |
| Bijol et al. (2015)        | Medical student web-based formative assessment tool for renal pathology | Second year                                      | Pathology                             | Post-course design (tests and surveys)  |

Figure 1. Subject material: anatomy (6.5%), physiology (22.8%), pathology (6.5%), treatment (25.8%), and general nephrology (9.7%).

Figure 2. Research design: 6.9% had either no assessment of the educational experience or had a description too vague to categorize; 3.4% involved a survey about the existing educational approach before a curriculum change was implemented; 55.2% used surveys or tests after a practice was carried out; 10.3% sought feedback from students before and after the educational experience; 13.8% were case studies; and 10.3% included a randomized controlled trial. There were no ethnographic studies.
acquired knowledge. Students in a study by Ho et al. performed better on their quizzes after using pathogenesis maps, and they reported enjoying the exercises because they felt encouraged to do more self-directed learning. McLaughlin and Mandin connected students’ use of ‘schemes’ – internal representations of knowledge – and success on a concept sorting task to improved scores on questions relating to metabolic alkalosis. Novak et al. was a follow-up study that raised the idea that diagnostic schemes help to build long-term knowledge.

**Educational study design**

Two studies had no structured assessment of the educational approach that was introduced to students. Schwartz and Rauch developed a 38-page course study guide that covered the major topics in pediatric nephrology and organized a weekly seminar with staff to emphasize major points and allow students to ask questions. The authors merely reported that “…their [the students’] comments have been complimentary,” so the extent to which the study met its goals of providing organization to the students’ study time and ensuring standardization of the students’ learning cannot be adequately gauged. Similarly, Harrison-Bernard described a method of teaching the renal renin-angiotensin system to first year medical students without an assessment of that method.

Several studies used surveys with qualitative and quantitative components in order to examine student preference of teaching technique or assess the extent to which those techniques contributed to improved knowledge. In some of these studies, surveys were distributed before the new technique was presented (“pre-course designs”); others circulated surveys after the new technique was presented (“post-course designs”); and still others disseminated surveys both before and after the technique was introduced (“before and after studies”). In the quantitative sections, respondents were typically asked to rate certain features of the teaching method on a scale, and their ratings were then averaged. In the qualitative parts, respondents provided feedback about the teaching experience and answered questions about changes in their perceived understanding of a topic in nephrology after the teaching experience. Most publications incorporated both quantitative and qualitative assessment. For example, in order to determine the effectiveness of its problem-based learning curriculum during the renal system block in first year of medical school, Elzubier used Likert-type rating scales to measure the extent to which students found the problems relevant, stimulating, and educational. There was also an opportunity for students to comment on aspects of the problem-based learning that they appreciated or would like to see changed. However, without a control group, even surveys that compared students’ impressions before and after an educational experience are unable to reliably assess the impact of the intervention.

Furthermore, many of these publications are missing details regarding the surveys used to assess the outcomes of their teaching method. Schwab and Knox, for instance, described a laboratory experiment in which students administered diuretics to anesthetized dogs in an effort to improve their understanding of the physiology of diuretics. The authors concluded that the experience was effective but provided only the following evidence: “Of the students responding to our questionnaire, 72% felt this laboratory was a good to excellent learning experience.” Similarly, after describing the use of an interactive computer program to teach the evaluation and management of renal masses, Rabushka et al. simply stated that the “comments and suggestions” they received from residents, staff, and medical students indicated that they “enjoy the interactive nature of the program and the hypermedia environment.” Without specific information about the nature of the surveys, it is difficult both to assess the extent to which the educational methods made a difference in students’ learning and to apply the approach to other trainee groups.

In some studies, the authors administered tests to assess student knowledge of subjects related to the kidney and to evaluate the effectiveness of the educational approach introduced to the students. For example, Arger et al. described a pilot sonography course aiming to teach students anatomy of the aorta and right kidney through experience with ultrasound technology. The authors gave students an identical test in the first and final weeks of the course with questions that focused on the “clinical diagnostic sonography of the aorta and kidney” and concluded based on these tests that exposure to sonography improved student comprehension of the relevant anatomy. Lack of control group again limits the internal validity of these studies.

There were four case studies in which the knowledge of students was assessed through observing the skills they demonstrated during a clinically-related task. Wimmers et al. showed that if the patient’s history and physical findings were not provided in a case (i.e. only lab data was present), intermediate recall (at the level of advanced medical students) was equivalent to expert recall (at the level of nephrology attendings). However, when asked to think aloud and elaborate on how the presented lab data related to the patient’s
problem, experts outperformed intermediates. McLaughlin and Mandin\textsuperscript{22} and McLaughlin et al.\textsuperscript{28} evaluated the teaching of different clinical presentations (metabolic alkalosis in the former study; hyponatremia, hyperkalemia, metabolic acidosis, and metabolic alkalosis in the latter study) to first year medical students. The authors found the use of concept schemes to be an effective way of learning about patients with such presentations. Specifically, McLaughlin et al.\textsuperscript{28} reported an “independent association between expert-type concepts in knowledge structure and diagnostic success” as well as “between the use of diagnostic schemes by preceptors and the number of expert-type concepts in knowledge structure in students.” Lastly, Kiesewetter et al.\textsuperscript{29} instructed students to think aloud about three cases related to renal disease (hematuria due to glomerulonephritis, symptoms of acute renal failure and depression, and hypertensive crisis due to renal artery stenosis) and found that in 56% of cases, students employed cognitive actions that used “higher level reasoning,” which the authors believed may have improved the students’ diagnostic capabilities. Although lessons can be learned from the observations made in these studies, there were limited numbers of participants, and many relied on cognitive reasoning that was expressed verbally with no ability to account for any connections made that were not explicitly shared with the data collectors.

There were only three randomized controlled trials in the 26 publications. They all involved teaching techniques focused on the pathophysiology of renal disease. In Preiss et al.,\textsuperscript{20} second year medical students who had volunteered to be part of the study were randomly divided into two groups. Each group was provided with a text that summarized 13 pathological conditions in nephrology. The experimental group was also given color photocopies of graphic summaries of those 13 pathological conditions and an accompanying glossary. Both groups were given 30 min to study. Then both groups were given a short quiz with four “memorization questions” (which tested the memorization of a single fact associated with one pathology) and five “correlation questions” (which tested the ability to correlate “two or more causally related facts of a characteristic of a given pathology”). Grades were significantly higher in the experimental group for the correlation questions, but no difference was observed for the memorization questions. The grader of the quizzes was not involved in the study and was blinded to the group identity of the students. The authors concluded that concept graphics aid students’ understanding of complex subjects, possibly through the representation of patterns unique to distinct pathologies.

In the second randomized controlled trial, Leong et al.\textsuperscript{15} had medical students read two articles, and complete either a paper case or a computer case on low back pain associated with kidney stones. Though randomly assigned to each of these interventions, the medical students were again a self-selected group of students who had volunteered to test the computer cases. The authors found no statistical significance among the groups in learning preferences, but the students rated the computer case highest on a 10-point scale in response to the question, “Do you think the case study was helpful?” (8.0 for the computer case vs. 7.4 for the paper case and 6.5 for the articles). There was also no significant difference on the post-test administered to the students in this study. The authors commented that “students reported enjoying the computer format” and that “this educational method proved at least as effective as the others tested.”

Finally, Ho et al.\textsuperscript{21} is a crossover study in which medical students were randomized to receive either access to online pathogenesis concept maps related to acute kidney injury and chronic kidney disease or links to sections of the existing pathology textbook (Robbins Basic Pathology) that covered the same concepts. In the subsequent block on hepatic disease, the groups crossed over in their access to concept maps on alcoholic liver disease and complications of cirrhosis; both groups then received access to concept maps in the final block on pancreatic disease. An online assessment that was given to both groups at the end of each block showed a significantly higher quiz score in the group that received access to the concept maps on questions related to the pathogenesis of renal disease. This difference between the two groups was seen also on the assessments on hepatic disease, and there was no difference between the groups on any of the questions in the assessment on pancreatic disease. The authors argued that their results demonstrate the effectiveness of concept maps in teaching students about disease processes.

**Discussion**

To our knowledge, this study marks the first analysis of published empirical studies designed to teach nephrology to medical students. Our research reveals that rigor is lacking in research on medical student education in nephrology.

Overall, only three published studies in the literature used a study design with randomization and a control group. These studies point toward the usefulness of concept maps and computer cases in helping medical students learn about the pathophysiology of renal disease. Still, the success of these approaches was gauged
mainly by student report and tests taken immediately after a course, so the long-term impact of these educational approaches remains unknown. Most importantly, the results of these studies cannot attest to improved patient outcomes as a result of the employed educational methods.

Our findings support the conclusion of a recent review, in which the authors noted a paucity of high quality medical education research in nephrology as compared to other areas of medicine. We encourage the use of carefully designed randomized controlled trials (see) as have been conducted in other areas of medical education. In cardiology, for instance, there are several randomized controlled studies that assess medical students’ learning of cardiac auscultation, electrocardiogram interpretation, and cardiac ultrasound exams. Similarly, in pulmonary medicine and critical care, randomized controlled trials exist to evaluate the value of ultrasound on learning the clinical exam, the effectiveness of counseling techniques on smoking cessation, and the impact of simulation-based training on managing dyspnea and septic shock. Other studies randomized medical students to different educational modalities to determine how students most effectively learn to use proper pressurized metered dose inhalers and to recognize agonal breathing as a sign of cardiac arrest. As a final example, randomized controlled studies in gastroenterology have assisted in ascertaining the effects of various educational experiences, including: 3D visualizations on learning of liver anatomy, role-playing and simulations in the learning of digital rectal exam, and abdominal ultrasound training in learning the physical examination of the abdomen. Further studies assess the value of computer-aided learning on student understanding of the anatomy and physiology of the liver and biliary tree, as well as the influence of peer teaching on students’ knowledge acquisition and retention in a gastroenterology/hematology course.

More rigorous studies are needed in the field of nephrology to reliably assess the effectiveness of the educational techniques used for teaching the subject to medical students. Though a complete training of nephrologists to conduct such studies is beyond the scope of this article, we offer the following recommendations on improving the rigor of nephrology education studies based on our experience in undergraduate medical education:

1. Clinicians should be trained via certificate courses and degree programs to conduct education research. Examples include the medical education research training at the Association of American Medical Colleges and Harvard Macy Institute.

2. A general three-step method, as recently outlined in an article on this subject, is to (a) refine and clearly articulate the study question; (b) identify the design and methods for the qualitative or quantitative study; and (c) select outcomes and outcome methods.

3. Trials should measure changes in patient-centered outcomes in addition to changes in student knowledge. The results of such studies will provide a more significant contribution to the field of nephrology. They are also more likely to garner funding from sources that focus on patient care.

In conclusion, rigor is lacking in the design of studies on medical student education of nephrology. Well-designed randomized controlled studies are needed to accurately assess the effectiveness of the educational techniques introduced into medical school curricula.

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