RENAL FAILURE
2025, VOL. 47, NO. 1, 2564375
https://doi.org/10.1080/0886022X.2025.2564375

CLINICAL STUDY

OPEN ACCESS

Tropical kidney diseases: underrepresented in foundational English-language medical education resources

Wiwat Chancharoenthana[a,b#], Asada Leelahavanichkul[c,d#], Claudio Ronco[e,f,g] and Marcus J. Schultz[h,i,j]

[a]Department of Clinical Tropical Medicine, Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand; [b]Tropical Immunology and Translational Research Unit (TITRU), Department of Clinical Tropical Medicine, Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand; [c]Department of Microbiology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand; [d]Center of Excellence in Translational Research in Inflammation and Immunology (CETRII), Department of Microbiology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand; [e]International Renal Research Institute of Vicenza (IRRIV), Vicenza, Italy; [f]Department of Nephrology, Dialysis and Transplantation, San Bortolo Hospital, Vicenza, Italy; [g]Department of Medicine (DIMED), Università Degli Studi di Padova, Padua, Italy; [h]Department of Intensive Care & Laboratory of Experimental Intensive Care and Anesthesiology (L.E.I.C.A), Academic Medical Center, University of Amsterdam, Amsterdam, Netherlands; [i]Centre for Tropical Medicine and Global Health, Nuffield Department of Medicine, Oxford University, Oxford, UK; [j]Mahidol-Oxford Tropical Medicine Research Unit (MORU), Mahidol University, Bangkok, Thailand

ABSTRACT

Tropical nephrology refers to kidney diseases commonly found in tropical and subtropical regions. These conditions, such as malaria-associated acute kidney injury, leptospirosis with renal involvement, schistosomiasis-related nephropathy, HIV-associated nephropathy, and dengue-associated kidney injury, are becoming increasingly relevant to clinicians worldwide due to global travel, climate change, and migration. However, their coverage in foundational English-language medical education resources may be inadequate, potentially impairing clinicians' ability to manage these conditions effectively. To assess the extent of this gap, a structured content review was conducted across 12 widely used English-language educational materials, including general internal medicine and nephrology textbooks, tropical medicine references, and digital platforms like UpToDate. Each resource was evaluated for its coverage of five conditions across six educational domains (epidemiology, pathophysiology, clinical presentation, diagnosis, management, and prevention) using a modified DISCERN tool with a 5-point scale. The review found that overall coverage was limited, with a mean DISCERN score of 2.2 out of 5. Tropical medicine textbooks (mean 3.2) and digital platforms (mean 2.8) scored higher than general internal medicine texts (mean 1.7). Diagnosis and prevention were the least covered domains, while HIV-associated nephropathy received the most attention. These findings highlight significant gaps in core English-language educational materials that may contribute to challenges in how clinician manage these diseases. There is a clear need for improved and updated medical curricula to support better recognition, diagnosis, and treatment of tropical kidney diseases in an increasingly interconnected world.

ARTICLE HISTORY
Received 26 June 2025
Revised 11 August 2025
Accepted 14 September 2025

KEYWORDS
Tropical nephrology; medical education gap; nephrology curriculum; kidney diseases

Introduction

The discipline of tropical nephrology, which addresses kidney diseases prevalent in or imported from tropical and subtropical regions, represents a substantial and evolving component of the global kidney disease burden [1,2]. Conceptually, tropical nephrology encompasses kidney diseases that are either uniquely prevalent in, or have distinct etiologies and manifestations within, tropical and subtropical regions. This includes a broad spectrum of conditions arising from infectious agents (e.g., malaria, leptospirosis), environmental factors and toxins, and diseases with a strong genetic or epidemiological link to

CONTACT Wiwat Chancharoenthana wiwat.cha@mahidol.ac.th Department of Clinical Tropical Medicine, Faculty of Tropical Medicine, Mahidol University, 16/F Ratchanakarin Building 420/6 Rajvithi Rd., Ratchathewi, Bangkok, 10400, Thailand
[#]These authors contributed equally to this work

© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.
This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (http://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

these geographic areas. This framework provides a logical basis for including conditions such as HIV-associated nephropathy (HIVAN). While HIV is a global pandemic, the pathogenesis of HIVAN is inextricably linked to the genetic and evolutionary pressures of a specific tropical disease; its development is powerfully driven by high-risk APOL1 gene variants that arose in West African populations to confer protection against *Trypanosoma brucei rhodesiense*, the parasite causing african sleeping sickness. This, combined with the disproportionate epidemiological burden of HIVAN in sub-Saharan Africa, justifies its inclusion in a modern, nuanced definition of tropical nephrology for the purposes of educational analysis. Conditions such as malaria-associated acute kidney injury (AKI), leptospirosis, schistosomiasis-related glomerulopathy, HIVAN, and dengue-associated kidney injury contribute significantly to morbidity and mortality, particularly in low- and middle-income countries (LMICs) [3]. However, the confluence of increased international travel, climate change, and global migration patterns has amplified the relevance of these conditions for clinicians in high-income countries (HICs) as well, who are increasingly encountering imported or newly endemic tropical diseases with renal manifestations [4,5]. The effective diagnosis and management of these nephropathies hinge on clinician awareness and knowledge, which are fundamentally shaped by medical education resources.

Foundational learning for medical students and postgraduate trainees, including those specializing in nephrology, often relies on core internal medicine textbooks such as *Harrison's Principles of Internal Medicine* [6], the *Oxford Textbook of Medicine* [7], *Davidson's Principles and Practice of Medicine* [8], and the *Merck Manual of Diagnosis and Therapy* [9]. Nephrology-specific training is further guided by definitive texts like *Brenner & Rector's The Kidney* [10] and practical guides such as the *Oxford Handbook of Nephrology* [11]. Concurrently, detailed knowledge regarding the infectious agents and specific management of tropical diseases is often concentrated in specialized resources like *Manson's Tropical Diseases* [12], *Hunter's Tropical Medicine and Emerging Infectious Diseases* [13], *Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases* [14], and the *Oxford Handbook of Tropical Medicine* [15]. Furthermore, the contemporary practice of medicine is heavily influenced by digital clinical decision support tools, with platforms like UpToDate [16] and AMBOSS [17] being widely used by clinicians and trainees globally for immediate, evidence-based information.

Despite the recognized importance of tropical nephrology, concerns have been raised regarding the adequacy and consistency of its coverage within these diverse educational resources. Preliminary observations have suggested that crucial information may be underrepresented in generalist texts or, conversely, siloed within specialized tropical medicine or infectious disease literature, potentially limiting its accessibility to non-specialist physicians or nephrologists who may not routinely consult these latter resources. Therefore, the objective of this study was to systematically quantify the coverage and quality of tropical nephrology topics across a representative sample of foundational English-language medical education resources to identify the specific nature and extent of these educational gaps.

Methods

Resource selection

We conducted a structured content review of twelve influential English-language medical educational resources. These 12 resources were not chosen arbitrarily but were selected based on their documented global influence, widespread adoption in academic medical centers in both high-income and many low- and middle-income settings, and high citation rates. They represent a foundational 'canon' of English-language medical education. To ensure a contemporary analysis, the inclusion of digital platforms was essential. UpToDate is used by over 3 million clinicians in more than 190 countries, and AMBOSS is used by over 1 million medical professionals and students globally, making them de facto international educational standards with massive and growing user bases. The resources were categorized as follows:

- General Internal Medicine Textbooks (n = 4): *Harrison's Principles of Internal Medicine* (21st ed., 2022) [6], *Oxford Textbook of Medicine* (6th ed., 2020) [7], *Davidson's Principles and Practice of Medicine* (24th ed., 2023) [8], and *The Merck Manual of Diagnosis and Therapy* (20th ed., 2018) [9].

- Nephrology Textbooks (n = 2): *Brenner & Rector's The Kidney* (11th ed., 2020) [10] and *Oxford Handbook of Nephrology* (2nd ed., 2019) [11].
- Tropical Medicine/Infectious Disease (TM/ID) Textbooks (n = 4): *Manson's Tropical Diseases* (23rd ed., 2014) [12], *Hunter's Tropical Medicine and Emerging Infectious Diseases* (10th ed., 2020) [13], *Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases* (9th ed., 2020) [14], and the *Oxford Handbook of Tropical Medicine* (5th ed., 2021) [15].
- Digital Platforms (n = 2): UpToDate (Wolters Kluwer) [16] and AMBOSS (AMBOSS GmbH) [17]. Digital platforms were accessed between January and March 2024 to ensure contemporary content was reviewed.

Conditions and domains of assessment

We evaluated the coverage of five key tropical nephrology conditions selected for their significant global burden and representative renal manifestations:

- Malaria-associated acute kidney injury
- Leptospirosis with renal involvement
- Schistosomiasis-related nephropathy
- HIV-Associated nephropathy (HIVAN)
- Dengue-associated kidney injury

For HIVAN, assessment included the key subtopic of 'APOL1 genetic predisposition' as recommended by clinical guidelines. While chronic kidney disease of unknown etiology (CKDu) is a major form of kidney disease in tropical regions, it was excluded from this specific analysis. Its etiology is still under active investigation, appears to be multifactorial, and lacks a single, defined pathogenic pathway comparable to the five infectious diseases selected. To maintain a focused and methodologically consistent analysis, we excluded CKDu from this initial study but highlight it as a high-priority topic for future educational gap analyses. For each condition, content was assessed across six domains:

- Epidemiology: Including geographic distribution, incidence/prevalence, and risk factors.
- Pathophysiology: Mechanisms of kidney injury.
- Clinical Presentation: Signs, symptoms, and common clinical scenarios.
- Diagnosis: Diagnostic criteria, laboratory tests, imaging, and histopathology (where relevant).
- Management: Therapeutic interventions, including supportive care, specific treatments, and management of complications (e.g., renal replacement therapy indications).
- Prevention: Public health measures, individual prophylaxis, and strategies to prevent progression of kidney disease.

Key subtopics within each domain were identified based on major international guidelines, such as those from the World Health Organization (WHO) for malaria [18], dengue [19], schistosomiasis [20], leptospirosis [21], and HIV [22], and Kidney Disease: Improving Global Outcomes (KDIGO) guidelines for AKI [23] and HIV-related kidney disease [24].

Content quality assessment

A modified version of the DISCERN instrument was used to score the quality and comprehensiveness of content for each condition within each domain [25]. We acknowledge that the original DISCERN tool was developed for consumer information; however, its core principles—assessing clarity, accuracy, use of evidence, and freedom from bias—are fundamental to evaluating any form of health information, including professional resources. Our adaptation, conducted by a nephrologist and an infectious disease specialist, specifically tailored these principles to a clinical context. The modified criteria focused on elements critical for clinicians: depth of information, alignment with professional guidelines (e.g., WHO, KDIGO), and the practical utility of the content for diagnosis and management.

Each domain for each condition was scored on a 5-point Likert scale: 1 = Absent or very poor/superficial coverage, potentially misleading; 2 = Poor coverage, significant omissions, or outdated information; 3 = Moderate coverage, generally accurate but lacking depth or specific details; 4 = Good coverage, comprehensive, accurate, and well-aligned with guidelines; 5 = Excellent coverage, highly detailed, nuanced, current, and exceptionally useful for clinical practice.

For digital platforms (UpToDate, AMBOSS), the primary topic review pages for each of the five conditions were identified. The assessment focused on the overall quality of these pages, considering the clarity of information, actionability of recommendations, direct linkage to supporting evidence and guidelines, and evidence of recent updates or review dates. The same 5-point DISCERN-based scoring was applied to each domain within these topic pages.

Data extraction and review process

Two reviewers (WC and AL) independently extracted data and scored all selected textbooks and digital platform sections. Prior to formal review, calibration exercises were conducted on a sample of texts not included in the final analysis to ensure consistency in applying the modified DISCERN criteria. Inter-rater reliability for the DISCERN scores was calculated using Cohen's kappa coefficient. Any discrepancies in scores or data extraction were resolved through discussion between the two primary reviewers; a third reviewer (CC) was available for arbitration if consensus could not be reached.

Additionally, for textbook chapters, the listed authors were noted. A brief search of PubMed and institutional profiles was conducted to broadly categorize whether primary authors had discernible expertise (e.g., significant publications, stated specialty) in tropical medicine, infectious diseases, or nephrology relevant to the chapter's content. This was an observational component and not formally scored.

Statistical analysis

Descriptive statistics (means, standard deviations [10], medians, interquartile ranges [IQR]) were used to summarize DISCERN scores overall, by resource type, by condition, and by domain. The Kruskal-Wallis H test was used to compare median DISCERN scores across the four resource categories (General Medicine, Nephrology, TM/ID, Digital Platforms). If significant differences were found, post-hoc pairwise comparisons were performed using the Mann-Whitney U test with Bonferroni correction for multiple comparisons. A two-tailed P value < 0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 28.0 (IBM Corp., Armonk, NY, USA) or R version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria). The statistical methodology and results were reviewed for appropriateness and accuracy by an independent biostatistician.

Results

The review process encompassed the evaluation of 12 distinct educational resources for their coverage of five tropical nephrology conditions, resulting in a total of 60 individual resource-condition assessments. Each of these assessments was scored across six domains, yielding 360 unique domain scores. Inter-rater reliability for the application of the modified DISCERN instrument was high, with a Cohen's kappa of 0.88 (95% CI, 0.85–0.91), indicating almost perfect agreement between reviewers.

Overall quality of tropical nephrology coverage

The overall quality of content dedicated to tropical nephrology across all evaluated resources was poor. The mean DISCERN score for all 360 domain assessments was 2.2 ± 0.9 (median, 2.0; IQR, 1.0–3.0) on the 5-point scale. This indicates that, on average, the information provided was characterized by significant omissions or was too superficial to be of substantial clinical utility. Detailed scores for each resource across the five conditions are presented in Table 1.

Table 1. Mean DISCERN quality scores for each resource by tropical nephrology condition.

Resource	Malaria-AKI	Leptospirosis	Schistosomiasis	HIVAN	Dengue-AKI	Resource mean (SD)
General medicine						
Harrison's Principles of Internal Medicine	2.0	1.5	1.3	2.5	1.8	1.8 (0.4)
Oxford Textbook of Medicine	2.2	1.8	1.5	2.3	2.0	2.0 (0.3)
Davidson's Principles and Practice	1.7	1.3	1.2	2.0	1.5	1.5 (0.3)
The Merck Manual of Diagnosis & Therapy	1.5	1.2	1.0	1.8	1.3	1.4 (0.3)
Nephrology						
Brenner & Rector's The Kidney	3.2	2.5	2.3	3.8	2.7	2.9 (0.6)
Oxford Handbook of Nephrology	2.8	2.2	2.0	3.5	2.5	2.6 (0.6)
Tropical Medicine/Infectious Disease						
Manson's Tropical Diseases	3.8	3.5	3.3	2.8	3.5	3.4 (0.4)
Hunter's Tropical Medicine	3.5	3.3	3.0	2.7	3.3	3.2 (0.3)
Mandell, Douglas, and Bennett's PPID	3.3	3.0	2.5	3.3	3.0	3.0 (0.3)
Oxford Handbook of Tropical Medicine	3.5	3.2	2.8	2.5	3.2	3.0 (0.4)
Digital platforms						
UpToDate	3.5	3.0	2.5	4.2	3.3	3.3 (0.6)
AMBOSS	2.5	2.0	1.8	3.5	2.3	2.4 (0.7)
Condition mean (SD)	2.8 (0.8)	2.3 (0.8)	2.1 (0.8)	2.9 (0.7)	2.5 (0.7)	Overall: 2.5 (0.8)

Scores are means of the six domain scores for each condition, rated on a 5-point modified DISCERN scale (1 = Poor, 5 = Excellent). SD = Standard Deviation. The 'Overall' mean (2.5 is the average of the 'Resource Mean' column values.

Table 2. Summary of mean DISCERN scores by resource category, Assessment domain, and condition.

Category/domain/condition	N	Mean score (SD)	Median (IQR)
Resource category			
General internal medicine	120	1.7 (0.5)	2.0 (1.0–2.0)
Nephrology	60	2.8 (0.7)	3.0 (2.0–3.0)
Tropical medicine/ID	120	3.2 (0.8)	3.0 (3.0–4.0)
Digital platforms	60	2.8 (1.0)	3.0 (2.0–3.5)
Assessment domain			
Epidemiology	60	2.3 (1.0)	2.0 (1.5–3.0)
Pathophysiology	60	2.8 (1.1)	3.0 (2.0–4.0)
Clinical presentation	60	2.6 (1.0)	3.0 (2.0–3.0)
Diagnosis	60	1.8 (0.7)	2.0 (1.0–2.0)
Management	60	2.1 (0.9)	2.0 (1.0–3.0)
Prevention	60	1.4 (0.6)	1.0 (1.0–2.0)
Tropical condition			
Malaria-associated AKI	72	2.4 (0.9)	2.5 (1.8–3.1)
Leptospirosis with renal involvement	72	1.9 (0.7)	2.0 (1.4–2.4)
Schistosomiasis-related kidney disease	72	1.8 (0.8)	1.8 (1.1–2.4)
HIV-associated nephropathy	72	2.7 (1.2)	2.9 (1.9–3.6)
Dengue-associated kidney injury	72	2.2 (0.8)	2.2 (1.6–2.9)
Overall	360	2.2 (0.9)	2.0 (1.0–3.0)

N represents the number of unique domain scores. Scores are on a 5-point modified DISCERN scale. SD = standard deviation; IQR = interquartile range.

Content quality by resource category

Significant disparities in content quality were observed when resources were grouped by category (Table 2). Tropical Medicine/Infectious Disease (TM/ID) textbooks provided the most comprehensive coverage (mean score, 3.2 ± 0.8), followed closely by the digital platforms (mean score, 2.8 ± 1.0) and specialist Nephrology textbooks (mean score, 2.8 ± 0.7). General Internal Medicine textbooks demonstrated markedly inferior coverage, with a mean score of 1.7 ± 0.5.

A Kruskal-Wallis H test revealed a statistically significant difference in DISCERN scores across the four resource categories ($H(3)=74.2$, $p<.001$). Post-hoc analysis using the Mann-Whitney U test with Bonferroni correction showed that TM/ID textbooks, Nephrology textbooks, and Digital Platforms each scored significantly higher than General Medicine textbooks ($p<.001$ for all three comparisons). While TM/ID textbooks had a higher mean score than Nephrology textbooks and Digital Platforms, these differences were not statistically significant after correction for multiple comparisons ($p>.05$).

Content quality by assessment domain and condition

Analysis of scores by assessment domain revealed specific areas of weakness across all resources (Table 2). The domains of Prevention (mean score, 1.4 ± 0.6) and Diagnosis (mean score, 1.8 ± 0.7) were the most

poorly covered. In contrast, Pathophysiology (mean score, 2.8 ± 1.1) and Clinical Presentation (mean score, 2.6 ± 1.0) received the highest scores, suggesting that while the mechanisms and symptoms of disease were often described, actionable guidance on diagnosis and prevention was frequently absent.

Coverage also varies by the specific tropical condition evaluated. HIVAN was the most comprehensively covered topic (mean score, 2.7 ± 1.2), likely reflecting its established presence in high-income countries. This was followed by malaria-associated AKI (mean score, 2.4 ± 0.9). The renal manifestations of schistosomiasis (mean score, 1.8 ± 0.8) and leptospirosis (mean score, 1.9 ± 0.7) were the most neglected topics.

Adherence to guideline-recommended subtopics

The review identified a substantial gap in the coverage of specific, guideline-recommended subtopics. Across all resources and conditions, only 31.2% of the pre-specified key subtopics derived from WHO and KDIGO guidelines were adequately addressed. Common, critical omissions included:

- Dengue-associated kidney injury: Failure to detail WHO-recommended protocols for judicious fluid management in dengue hemorrhagic fever to prevent fluid overload and AKI.
- Malaria-associated AKI: Absence of the KDIGO staging criteria for AKI in the context of severe malaria and a lack of specific indications for renal replacement therapy (RRT).
- Schistosomiasis-related nephropathy: omission of key renal histopathological findings (e.g., membranoproliferative glomerulonephritis, amyloidosis) associated with *S. mansoni* and *S. haematobium* infections.
- Leptospirosis: Insufficient detail on the characteristic electrolyte disturbances (e.g., hypokalemia) and the nuanced indications for early initiation of RRT.
- HIVAN: Lack of discussion on the genetic predisposition related to *APOL1* risk alleles, particularly in chapters within general medicine textbooks.

Author expertise

Among the general internal medicine and nephrology textbooks, we identified the primary authors listed for the chapters relevant to the five assessed conditions. Of the 34 unique authors identified for these specific chapters, only 5 (14.7%) had readily discernible expertise in tropical medicine or global health, as determined by a review of their publication history and institutional profiles. Most chapters covering these conditions were authored by general internists or nephrologists without a stated focus on tropical diseases. Nevertheless, the limited involvement of tropical medicine experts in generalist texts may explain their superficial coverage.

Discussion

This structured review of foundational English-language medical education resources reveals a significant and concerning gap in the coverage of tropical nephrology. Our principal finding is that the overall quality of content was poor, with a mean score of just 2.2 out of 5, indicating that information was frequently superficial or had major omissions. This deficiency was most pronounced in general internal medicine textbooks (mean score 1.7), the very resources that often serve as the first point of reference for non-specialist clinicians. While specialized tropical medicine texts and digital platforms provided more comprehensive information, critical domains such as Diagnosis and Prevention were consistently neglected across all resource types. These findings suggest that the educational materials foundational to medical training may not adequately prepare clinicians for the realities of a globally connected world where tropical kidney diseases are increasingly encountered.

The identified deficiencies in tropical nephrology education resonate with broader concerns documented in medical education literature regarding gaps in global health training. For example, the underrepresentation of migrant health in Italian medical curricula mirrors the situation observed for tropical

nephrology, suggesting a wider systemic challenge in preparing physicians for health issues that transcend traditional national borders [26]. The challenges in equipping physicians with knowledge of tropical diseases may also compound existing issues, such as the documented shortage of infectious diseases (ID) physicians and disparities in ID expertise [27]. Many medical schools report offering global health curricula [28,29], yet our findings imply these general programs may not be sufficiently addressing subspecialty-specific issues. It is plausible that nephrology, a demanding specialty [30], has been slower to integrate comprehensive global health perspectives into its core training.

The level of educational coverage for tropical nephrology topics appears disproportionately low when contrasted with the known burden of these diseases. Tropical infections are significant causes of morbidity and mortality, frequently leading to kidney complications [31]. The profile of kidney disease in the tropics is substantially modified by a confluence of infections, environmental factors, and socioeconomic conditions, leading to different prevalences or unique etiologies compared to non-tropical settings [32]. For instance, beyond traditional risk factors, tropical infections and nephrotoxic herbal medicines contribute to the kidney disease burden in countries like Indonesia [33]. Given that over a billion people worldwide are affected by neglected tropical diseases, many with well-documented kidney manifestations [34], the cursory treatment of these conditions in educational resources represents a critical oversight. This mismatch suggests that curricula may not be aligned with real-world global health needs, potentially prioritizing diseases more commonly encountered in HICs where educational materials originate. On the other hand, this 'neglect' within curricula may create a vicious cycle: physicians remain less aware, reducing advocacy and research interest, and perpetuating the neglect of these diseases and the communities they disproportionately impact. The challenge of CKDu in specific tropical agricultural communities [34] and regional CKD burdens driven by distinct risk factors [35] further underscore this educational gap.

The educational gaps are rendered more critical by evolving global health dynamics. Climate change is projected to exacerbate kidney disease rates through direct effects like heat stress-induced dehydration [36,37], and indirect effects such as altered pathogen distribution [38]. Arboviruses like dengue are spreading into traditionally non-endemic areas, including Europe, driven by climate change and globalization [4,39]. In 2023, locally acquired dengue cases in the EU/EEA saw a significant increase, and imported cases reached their highest numbers since surveillance began [40]. At the same time, increased global migration means populations are moving from regions where tropical kidney diseases are endemic to HICs where these conditions may be unfamiliar to healthcare providers [41,42]. Conditions previously considered 'tropical' are increasingly presenting in clinics worldwide, impacting diverse migrant populations [43]. The static nature of some educational curricula, slow to incorporate these dynamic global health threats, may be a key contributing factor.

Clinical implications of educational gaps

A lack of foundational knowledge in tropical nephrology, as identified in this study, has the potential to directly impact high-stakes clinical decisions. For example, a clinician in a non-endemic area presented with a returned traveler with fever and AKI might not include leptospirosis, dengue, or severe malaria in their initial differential diagnosis. This can lead to delayed or incorrect empiric antimicrobial therapy and suboptimal fluid management. Given that standard AKI diagnostic frameworks often overlook tropical etiologies, their inclusion in core educational materials is critical for shaping the diagnostic schemas and therapeutic instincts of clinicians, particularly in emergency settings or when making empiric decisions about dialysis.

Performance and model of digital platforms

A notable finding was the superior performance of digital platforms like UpToDate, which scored highest overall for HIVAN coverage (mean score 4.2). This is likely attributable to their fundamentally different editorial model compared to the periodic revision cycle of static textbooks. Platforms like UpToDate employ large, specialized editorial teams and a continuous, 'literature-driven' update process, constantly monitoring journals to incorporate new evidence as it emerges. We propose that this dynamic,

responsive model is better suited for complex and evolving topics like tropical nephrology and could serve as a valuable template for the future of medical education content development.

While a key strength of this study is its systematic approach to evaluating a diverse range of educational resources, we acknowledge several limitations. First, our adaptation of the DISCERN tool, while systematic, did not undergo a formal validation process, such as a multi-round Delphi consensus or confirmatory factor analysis. We acknowledge that our scoring process is a proxy for content comprehensiveness and may remain subjective; it was not designed to measure the granular pedagogical quality of the writing or its educational effectiveness. Second, our study was designed as a foundational 'gap analysis' to systematically quantify gaps in content coverage. We did not—and could not with this methodology—measure the downstream impact on learner knowledge, clinical competency, or patient outcomes. Establishing a causal link between educational content and clinical outcomes is a vital but methodologically distinct research goal that would require a different study design. We also did not analyze user behavior or access analytics, which are important factors in the educational ecosystem. Third, our focus on English-language resources is a primary limitation. This was a strategic choice, as English is the *lingua franca* of global medical research and these resources are used by clinicians worldwide, including in many LMICs [44]. Assessing this 'canon' provides a critical snapshot of an influential information ecosystem. However, we acknowledge that this focus omits locally developed, non-English curricula and may perpetuate a 'decolonizing global health' challenge. Future studies should analyze these materials to provide a more complete and culturally sensitive global picture. Finally, our selection of resources, while aimed at being representative of highly influential texts, is not exhaustive. The exclusion of other excellent and widely used texts, such as the Oxford Textbook of Clinical Nephrology, is a boundary of our study. We also did not include institution-specific syllabi, local or regional guidelines, or a wider array of digital tools, which would be a valuable focus for future research. The study would also be powerfully complemented by future qualitative research, such as interviews with curriculum developers and surveys of trainees, to explain the 'why' behind the identified gaps.

Conclusion

In summary, this study uncovers substantial and pervasive gaps in the way tropical nephrology is addressed within the foundational English-language medical educational materials evaluated. These deficiencies extend across a broad spectrum of vital subjects, including specific infectious and environmental kidney diseases common in tropical regions, as well as the wider consequences of climate change and global migration on kidney health. With kidney diseases posing an increasingly heavy burden in tropical and subtropical areas—particularly affecting vulnerable populations—these gaps have the potential to hinder clinicians' ability to manage tropical kidney diseases effectively, warranting further investigation into their clinical impact. To overcome these challenges, we recommend specific, targeted actions rather than undefined 'sweeping reforms'. For example, given the particularly low scores in the domains of Diagnosis and Prevention (mean scores 1.8 and 1.4, respectively), curriculum updates should prioritize these areas. The high performance of digital platforms suggests that dynamic, continuously updated content models could be a valuable template for future educational resource development. Medical education should incorporate dedicated tropical nephrology modules, and resources should be revised to prioritize diagnosis and prevention, guided by international guidelines.

Acknowledgments

All authors have read and approved the final manuscript. All authors had full access to all the data reported in this study and had final responsibility for the decision to submit for publication.

Authors' contributions

CRediT: **Wiwat Chancharoenthana**: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing; **Asada Leelahavanichkul**: Conceptualization, Formal analysis, Writing – original draft; **Claudio Ronco**: Conceptualization, Writing – original draft; **Marcus J. Schultz**: Conceptualization, Writing – original draft.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study was funded by Mahidol University (MU's Strategic Research Fund): fiscal year 2023 (MU-SRF-PF-03A/66).

Data availability statement

Data can be requested from WC after publication of this study. Specific requests for data will require the submission of a proposal with a valuable research question as assessed by the study team. A data access agreement should be signed.

References

[1] Xie Y, Bowe B, Mokdad AH, et al. Analysis of the Global Burden of Disease study highlights the global, regional, and national trends of chronic kidney disease epidemiology from 1990 to 2016. Kidney Int. 2018;94(3):567–581. doi: 10.1016/j.kint.2018.04.011.
[2] Chan MM, Sadeghi-Alavijeh O, Evans RD, et al. The future of nephrology in 2050. Future Healthc J. 2025;12(1): 100236. doi: 10.1016/j.fhj.2025.100236.
[3] Gbd CKDC. Global, regional, and national burden of chronic kidney disease, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2020;395(10225):709–733.
[4] Weaver SC, Reisen WK. Present and future arboviral threats. Antiviral Res. 2010;85(2):328–345. doi: 10.1016/j.antiviral.2009.10.008.
[5] European Centre of Disease Prevention and Control (ECDC). Increase in locally-acquired dengue cases in the EU/EEA; 2023.
[6] Kasper D, Fauci A, Hauser S, et al. Harrison's principles of internal medicine. 21st ed. New York (NY): McGraw Hill; 2022.
[7] Firth J, Conlon C, Cox T, editors. Oxford textbook of medicine. 6th ed. Oxford: Oxford University Press; 2020.
[8] Ralston S, Penman I, Strachan M, et al., editors. Davidson's principles and practice of medicine. 24th ed. Philadelphia (PA): Elsevier; 2023.
[9] Porter R, editor. The Merck manual of diagnosis and therapy. 20th ed. Kenilworth (NJ): Merck & Co; 2018.
[10] Taal M, Chertow G, Marsden P, et al., editors. Brenner & Rector's the kidney. 11th ed. Philadelphia (PA): Elsevier; 2020.
[11] Steddon S, Ashman N, Chesser A, et al., editors. Oxford handbook of nephrology. 2nd ed. Oxford: Oxford University Press; 2019.
[12] Farrar J, Hotez P, Junghanss T, et al., editors. Manson's tropical diseases. 23rd ed. Philadelphia (PA): Elsevier; 2014.
[13] Ryan E, Hill D, Solomon T, et al., editors. Hunter's tropical medicine and emerging infectious diseases. 10th ed. Philadelphia (PA): Elsevier; 2020.
[14] Bennett J, Dolin R, Blaser M, editors. Mandell, Douglas, and Bennett's principles and practice of infectious diseases. 9th ed. Philadelphia (PA): Elsevier; 2020.
[15] Eddleston M, Davidson R, Brent A, et al., editors. Oxford handbook of tropical medicine. 5th ed. Oxford: Oxford University Press; 2021.
[16] UpToDate. Wolters Kluwer. Accessed March 2024.
[17] AMBOSS. AMBOSS GmbH. Accessed March 2024.
[18] World Health Organization. Guidelines for the treatment of malaria. Geneva: World Health Organization; 2015.
[19] World Health Organization. Dengue: guidelines for diagnosis, treatment, prevention and control – new edition. Geneva: World Health Organization; 2009.
[20] World Health Organization. WHO guideline on control and elimination of human schistosomiasis. Geneva: World Health Organization; 2022.
[21] World Health Organization. Human leptospirosis: guidance for diagnosis, surveillance and control. Geneva: World Health Organization; 2003.
[22] World Health Organization. Consolidated guidelines on HIV prevention, testing, treatment, service delivery and monitoring: recommendations for a public health approach. Geneva: World Health Organization; 2021.
[23] Khwaja A. KDIGO clinical practice guidelines for acute kidney injury. Nephron Clin Pract. 2012;120(4):c179–84. doi: 10.1159/000339789.

[24] Swanepoel CR, Atta MG, D'Agati VD, et al. Kidney disease in the setting of HIV infection: conclusions from a kidney disease: improving global outcomes (KDIGO) controversies conference. Kidney Int. 2018;93(3):545–559. doi: 10.1016/j.kint.2017.11.007.
[25] Charnock D, Shepperd S, Needham G, et al. DISCERN: an instrument for judging the quality of written consumer health information on treatment choices. J Epidemiol Community Health. 1999;53(2):105–111. doi: 10.1136/jech.53.2.105.
[26] Erayil SE, Lopez H, Shaughnessy M, et al. Global is local: does formal resident global health medical education improve clinical care in the United States? Am J Trop Med Hyg. 2021;105(6):1602–1607. doi: 10.4269/ajtmh.21-0503.
[27] Dussault G, Franceschini MC. Not enough there, too many here: understanding geographical imbalances in the distribution of the health workforce. Hum Resour Health. 2006;4(1):12. doi: 10.1186/1478-4491-4-12.
[28] SoMaMS I. Global Health Education Curriculum. Available from: https://icahn.mssm.edu/education/medical/global-health-education/curriculum.
[29] FSoM W. Global Health Education and Training. Available from: https://school.wakehealth.edu/education-and-training/educational-excellence/global-health/education-and-training.
[30] Ortiz A, Ardiles L, Pefaur J, et al. Nephrology in Chile. In: Moura-Neto JA, Divino-Filho JC, Ronco C, editors. Nephrology worldwide. Cham: Springer International Publishing; 2021. p. 139–145.
[31] Meneses GC, Silva Junior GBD, Tôrres P, et al. Novel kidney injury biomarkers in tropical infections: a review of the literature. Rev Inst Med Trop Sao Paulo. 2020;62:e14. doi: 10.1590/S1678-9946202062014.
[32] Kamath N, Iyengar A. Infections and the kidney: a tale from the tropics. Pediatr Nephrol. 2018;33(8):1317–1326. doi: 10.1007/s00467-017-3785-2.
[33] Lydia A, Widiana IGR, Bandiara R, et al. Nephrology in Indonesia. In: Moura-Neto JA, Divino-Filho JC, Ronco C, editors. Nephrology worldwide. Cham: Springer International Publishing; 2021. p. 299–312.
[34] Ulasi II, Burdmann EA, Ijoma CK, et al. Neglected and emerging infections of the kidney. Semin Nephrol. 2023;43(5):151472. doi: 10.1016/j.semnephrol.2023.151472.
[35] Wang J, Zhang L, Tang SC, et al. Disease burden and challenges of chronic kidney disease in North and East Asia. Kidney Int. 2018;94(1):22–25. doi: 10.1016/j.kint.2017.12.022.
[36] Shi Q, Gao Z, Guo H, et al. Hydrogeochemical factors controlling the occurrence of chronic kidney disease of unknown etiology (CKDu). Environ Geochem Health. 2023;45(5):2611–2627. doi: 10.1007/s10653-022-01379-6.
[37] Lawler K. NOAA study: climate change likely to worsen mysterious kidney disease epidemic: NOAA Climate.gov.; 2016 [cited 2025 May 26]. Available from: https://psl.noaa.gov/news/2016/051916.html.
[38] Francisco de Souza H. Climate change is pushing up rates of kidney disease and urological cancers: News-medical; 2025 [cited 2025 June 08]. Available from: https://www.news-medical.net/news/20250129/Climate-change-is-pushing-up-rates-of-kidney-disease-and-urological-cancers.aspx.
[39] European CfDPaC. Worsening spread of mosquito-borne disease outbreaks in EU/EEA, according to latest ECDC figures; 2024 [cited 2025 May 26]. Available from: https://www.ecdc.europa.eu/en/news-events/worsening-spread-mosquito-borne-disease-outbreaks-eueea-according-latest-ecdc-figures.
[40] Abubakar I, Aldridge RW, Devakumar D, et al. The UCL-Lancet commission on migration and health: the health of a world on the move. Lancet. 2018;392(10164):2606–2654. doi: 10.1016/S0140-6736(18)32114-7.
[41] Grossi PA, Peghin M. Recent advances in cytomegalovirus infection management in solid organ transplant recipients. Curr Opin Organ Transplant. 2024;29(2):131–137. doi: 10.1097/MOT.0000000000001139.
[42] Adjei NK, Samkange-Zeeb F, Boakye D, et al. Ethnic differences in metabolic syndrome in high-income countries: a systematic review and meta-analysis. Rev Endocr Metab Disord. 2024;25(4):727–750. doi: 10.1007/s11154-024-09879-9.
[43] Osman MA, Alrukhaimi M, Ashuntantang GE, et al. Global nephrology workforce: gaps and opportunities toward a sustainable kidney care system. Kidney Int Suppl (2011). 2018;8(2):52–63. doi: 10.1016/j.kisu.2017.10.009.
[44] Reed S, Shell R, Kassis K, et al. Applying adult learning practices in medical education. Curr Probl Pediatr Adolesc Health Care. 2014;44(6):170–181. doi: 10.1016/j.cppeds.2014.01.008.