Bibliometric Analysis of Uremia Research: 2021–2025

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Introduction. This study aimed to perform a bibliometric analysis of academic research on uremia, identifying research hotspots, development trends, and international collaboration networks in this field.
Methods. Relevant publications related to uremia were retrieved from Web of Science database. Bibliometric analysis was conducted using R software. Co-occurrence analysis of keywords, co-citation network analysis, and author/country collaboration analysis were performed to explore research focuses and academic influence.
Results. From 2021 to 2022, research on uremia mainly concentrated on traditional areas such as chronic kidney disease, hemodialysis, and patient management. Since 2023, the focus has gradually shifted toward emerging topics including plasma biomarkers, inflammation mechanisms, and precision patient care. Co-citation network analysis revealed that studies related to chronic kidney disease and hemodialysis had the strongest academic influence, while research on inflammation and uremia also occupied central positions in the network. International collaboration was most active in China, the United States, and Europe, reflecting a trend toward cross-border and interdisciplinary research. Meanwhile, keywords such as gut microbiota, metabolomics, and precision medicine are increasingly frequent, highlighting new research frontiers.
Conclusion. This study demonstrates that uremia research is shifting from traditional areas such as chronic kidney disease and hemodialysis toward emerging themes including inflammation, biomarkers, and patient management. These findings provide objective evidence of research hotspots and trends in uremia and underscore the importance of enhancing international and interdisciplinary collaboration.

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Review

INTRODUCTION

Uremia is a clinical syndrome resulting from advanced chronic kidney disease, characterized by the systemic accumulation of uremic toxins and the development of multisystem symptoms due to impaired renal function. With the global increase in the prevalence of diabetes mellitus and hypertension, the prevalence of CKD and the incidence of uremia are rising steadily, leading to substantial disease and economic burdens.[1-4] Patients with uremia often require lifelong dialysis or kidney transplantation, which are costly and associated with poor prognosis and reduced quality of life.[5] Moreover, uremia is accompanied by a high risk of cardiovascular events, infections, and systemic inflammation, further worsening its clinical and public health significance.[6,7] Although numerous studies have investigated the epidemiology, risk factors, molecular mechanisms, and therapeutic strategies of uremia,[8-11] these findings are

fragmented and heterogeneous. Most reviews have focused on specific clinical or mechanistic aspects, and there is currently no comprehensive overview that quantitatively synthesizes the global research landscape in this field.

Bibliometric analysis provides a systematic and objective approach to evaluating scientific output, finding research hotspots, and mapping collaborative networks.[12] In recent years, bibliometric studies have been increasingly applied in nephrology-related subfields.[13] For example, researchers have analyzed publication trends and hotspots in uremic cardiomyopathy,[14] cardiorenal syndrome type 4,[15] the association between CKD and depression,[16] and CKD-associated pruritus.[17] These studies have provided valuable insights into specific complications and related mechanisms. However, despite the clinical significance of uremia itself, no bibliometric study has systematically characterized the overall research hotspots, developmental trends, and international collaboration patterns in this field. Therefore, this study aimed to perform a comprehensive bibliometric analysis of uremia-related publications from 2021 to 2025, with the goal of identifying major research themes, developmental trends, and international collaboration networks. By systematically mapping the research landscape, this study seeks to provide useful insights for guiding future scientific investigations and clinical practice in the field of uremia.

MATERIALS AND METHODS

Literature Retrieval and Selection

This study was based on the Web of Science Core Collection database (https://www.webofscience.com/wos/woscc/basic-search) to retrieve literature published from 2021 to 2025. The search terms used were "Uremia (Topic) OR Uremias (Topic)". A PRISMA-style flow diagram was created to illustrate the selection process, including the number of records identified, screened, excluded (with reasons), and included in the final analysis (Figure 1).

Inclusion and Exclusion Criteria

Inclusion criteria: Full-text publications thatfocus on original research articles related to uremia. Exclusion criteria included review articles, consensus statements, and guidelines. Although such publications are often influential, they primarily summarize existing knowledge rather than contribute new original data. To avoid duplication of citations and to ensure that the bibliometric analysis reflects original research output, only

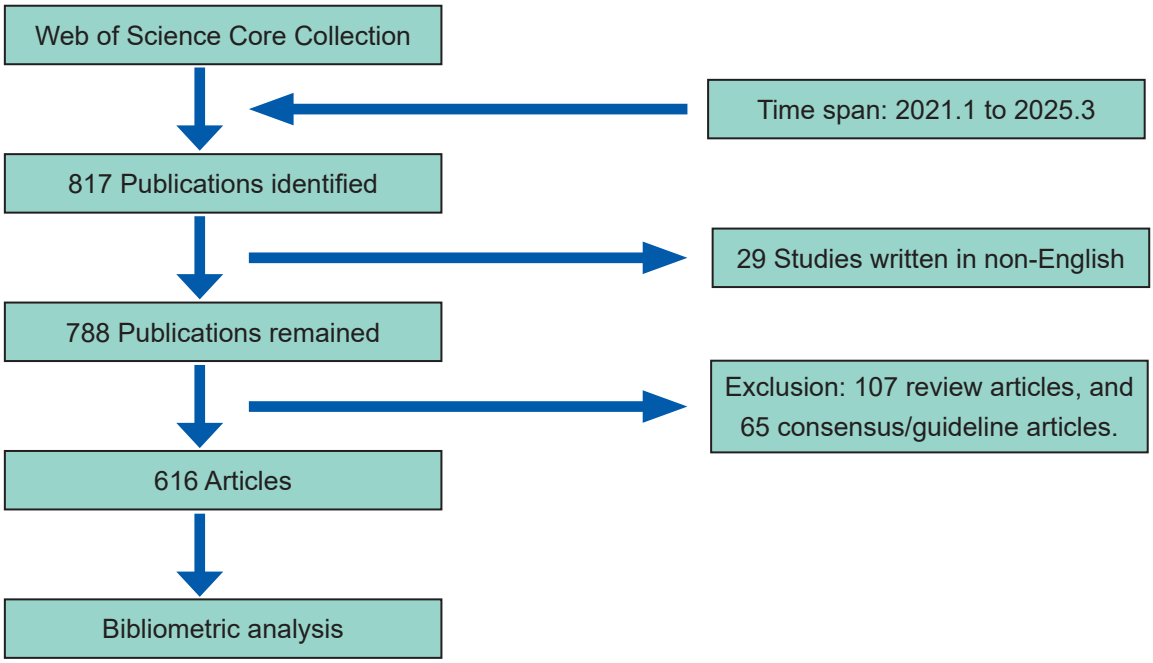

Figure 1. PRISMA flow diagram of the study selection process. (After excluding 29 non-English studies, 107 review articles, and 65 consensus/guideline articles, 616 original research articles were retained for bibliometric analysis. Boxes indicate the number of records, and arrows show the screening process.)

full-length original articles were included.

The selection process was conducted independently by two researchers, with disagreements resolved by a third independent reviewer.

Data Extraction

Data were retrieved from the Web of Science Core Collection (Science Citation Index Expanded, SCI-EXPANDED, 1900–present) and exported in BibTeX format. The exported records included the article title, authors, institutional affiliations, country of origin, citation count, publication year, journal name, and journal impact factor. All extracted data were subsequently organized and stored in an Excel spreadsheet (Microsoft, Redmond, WA, USA).

Data Visualization

Bibliometric analyses were conducted using R software (Version 4.3.2, R Foundation for Statistical Computing, Vienna, Austria) with the Bibliometrix package (Version 4.2.2). The package was used for data cleaning, descriptive performance analysis (publications, authors, citations, keywords), construction of collaboration and co-occurrence networks, thematic mapping, and trend analysis.[18] To comprehensively characterize the research landscape, we performed multiple bibliometric analyses, including descriptive analysis (publications, authors, citations, keywords), co-authorship analysis (authors, institutions, countries), source analysis (journals), keyword co-occurrence analysis, thematic clustering, thematic evolution (trend analysis), and countries' collaboration mapping.

For keyword co-occurrence analysis, only keywords with a minimum occurrence of five times were included. For co-citation analysis, references cited at least 20 times were considered. Network normalization was performed using the association strength method, and clusters were identified using the Louvain clustering algorithm.

RESULTS

Bibliometric overview of uremia research

A total of 616 original articles on uremia research were retrieved for the period 2021–2025, published across 338 journals and authored by 4,153 researchers. Only 17 papers were written by a single author, reflecting a clear trend toward multi-author collaboration, with an average of 7.54 authors per article. International collaborations accounted for 17.53% of publications, underscoring the importance of cross-border research networks. In total, 1,800 unique keywords were identified. The retrieved articles received 26,703 citations, with an average of 6.40 citations per article, suggesting a notable academic impact. The mean age of the literature was 2.56 years. However, the annual publication growth rate was –66.4%, indicating a declining trend in output during the study period (Figure 2).

Institutional, author, and country collaboration network

The Sankey plot (Figure 3) illustrated extensive international collaboration in uremia research. The leading contributing countries were China, Italy, the United States, Germany, France, and Thailand, with China occupying a dominant position,

Figure 2. Annual Publication Trends in Uremia Research from 2021 to 2025. (Overview of publications in uremia research from 2021 to 2025, showing the annual number of published articles and overall publication trends during the study period.)

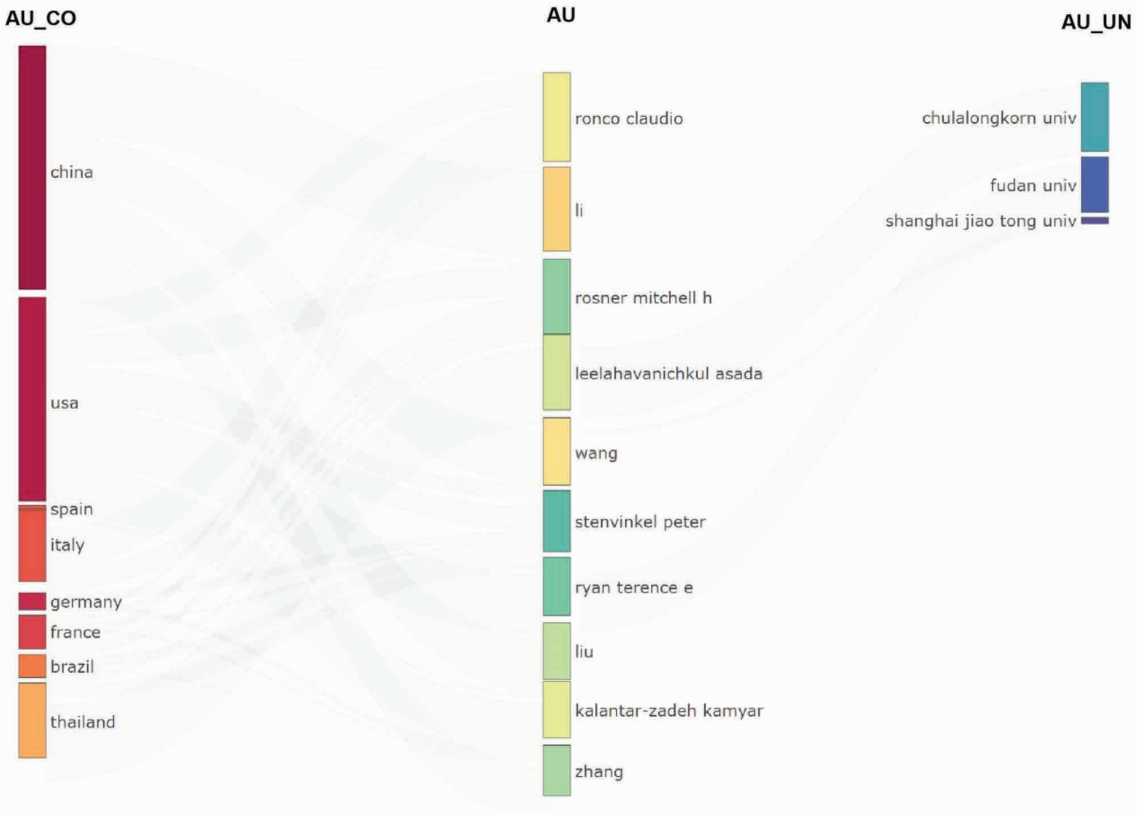

Figure 3. Three-fields plot of institutions, authors, and countries.
Note: The Sankey diagram illustrates the connections among authors (AU), author affiliations (AU_UN), and author countries (AU_CO), with link width indicating the strength of collaboration and node size representing publication output.

particularly through institutions such as Fudan University and Shanghai Jiao Tong University. Prominent scholars, including Claudio Ronco, Kamyar Kalantar-Zadeh, and Peter Stenvinkel, were identified as influential contributors, many with substantial international collaborative backgrounds. Key research institutions included Chulalongkorn University, Fudan University, and Shanghai Jiao Tong University, underscoring the prominent role of Asian universities in advancing uremia research.

Bibliometric patterns of institutions, authors, and journals

The analysis of institutional productivity (Figure 4A) and the most relevant affiliations (Figure 4B) illustrated differences in research output and institutional contributions within the field of uremia. Leading institutions included Chulalongkorn University (55 publications) and the University of Florida (51 publications). Analyses of corresponding authors' countries (Figure 4C) and countries' production over time (Figure 4D) further revealed the dominant roles of China (227 publications) and the United States (101 publications) in global uremia research. The assessment of authors' production over time (Figure 4E) highlighted the research output and academic influence of key scholars such as Li Y and Wang XT, thereby identifying core contributors to the field. In addition, the analysis of the most relevant sources (Figure 4F) showed that high-output journals, such as the International Journal of Molecular Sciences and Toxins, represented the primary publication outlets for uremia research, providing guidance for future literature searches.

Analysis of keyword co-occurrence

Keywords with the highest frequency in uremia-related literature included CKD (81 occurrences), uremia (69 occurrences), inflammation (55 occurrences), mortality (55 occurrences), and disease (47 occurrences) (Figure 5A). The word cloud was presented in Figure 5B.

Thematic clustering of research topics

The thematic map (Figure 6), constructed on

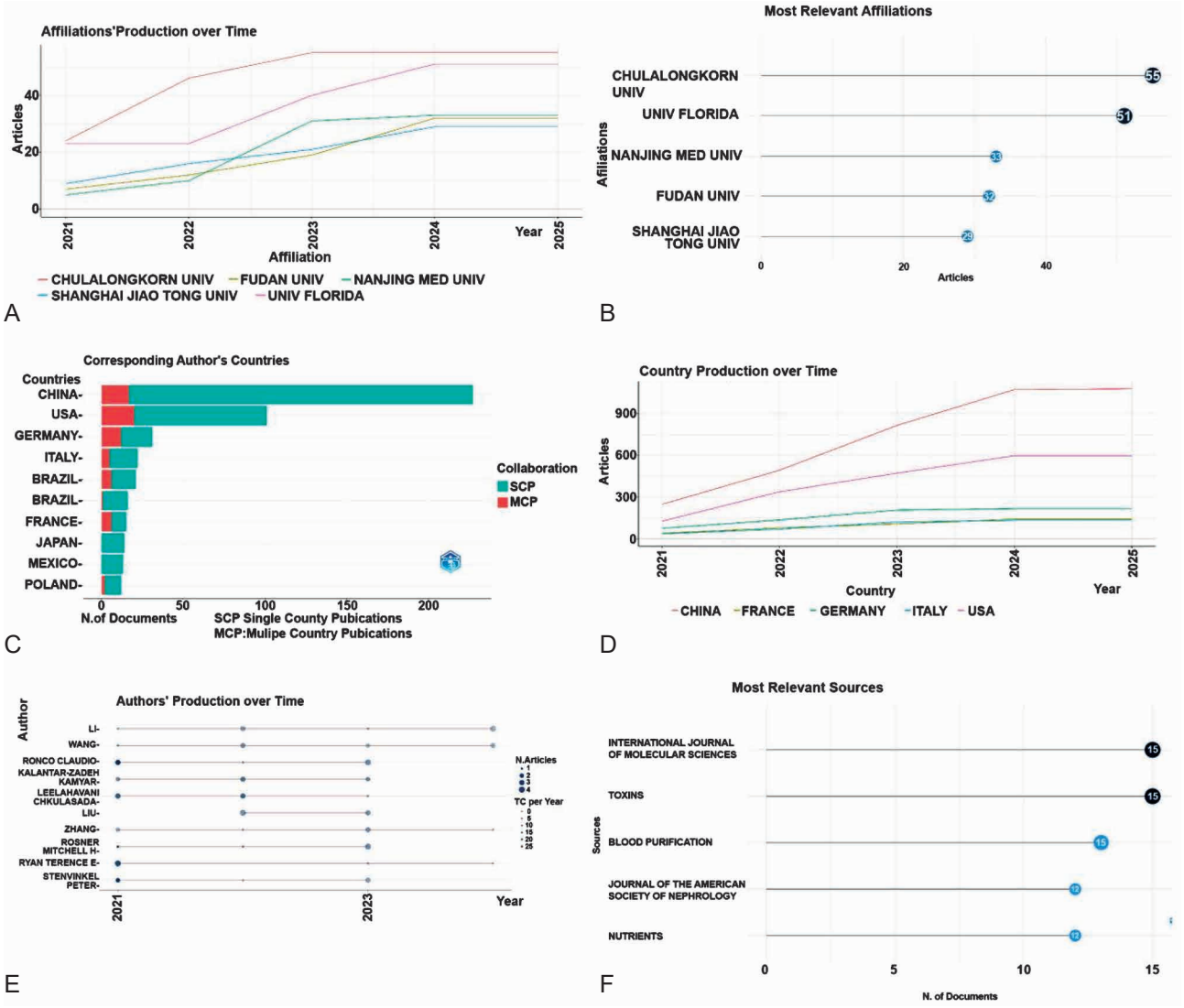

Figure 4. Co-authorship and source analysis of institutions, authors, and countries (A. Affiliations production over time, showing the annual research output of major institutions involved in uremia studies; B. Most relevant affiliations, listing institutions with the highest cumulative publication counts; C. Corresponding author's countries, presenting the geographical distribution of leading contributors; D. Countries' production over time, illustrating changes in national research productivity; E. Authors' production over time, depicting the publication trends and academic influence of core scholars; F. Most relevant sources (journals), identifying the journals with the largest number of publications in uremia research. Node size represents the number of publications, and colors indicate cluster membership.)

the indicators of impact and centrality, illustrated the distribution and significance of research topics within the uremia field. The upper-right quadrant contained themes with both high impact and high centrality—such as acute kidney injury, microbiota, and inflammation—highlighting their status as research hotspots with strong potential for interdisciplinary collaboration. The lower-right quadrant included topics such as CKD and protein carbamylation, which exhibited high centrality but relatively lower impact, suggesting their foundational importance in basic research. In contrast, the upper-left quadrant comprised themes like hemodialysis patients and vascular calcification, characterized by high impact but lower centrality, indicating their relevance to clinical practice despite weaker network connectivity. Finally, the lower-left quadrant contained themes with both low impact and low centrality, including uremia and risk, which may have represented underexplored areas or emerging fields of investigation.

Temporal evolution of research themes

Between 2021 and 2025, research themes in the

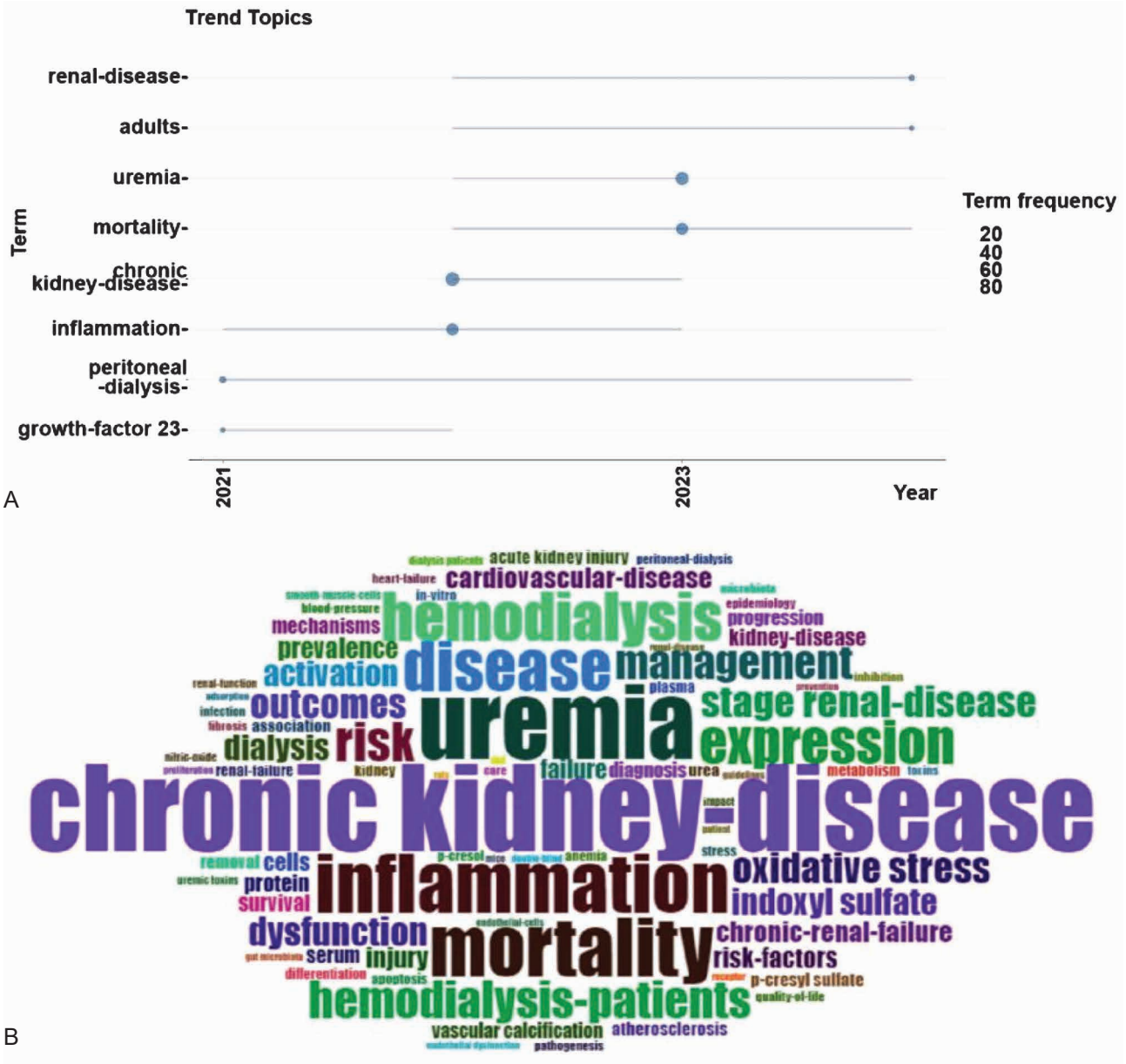

Figure 5. Analysis of keywords in published articles on uremia. (A. High-frequency keywords with their occurrence counts; B. Word cloud map showing the relative frequency of keywords, where larger font size corresponds to higher frequency.)

field of uremia demonstrated a clear evolutionary trend. During 2021–2022, the main hotspots centered on CKD, hemodialysis, and dialysis patients, reflecting the traditional focus of uremia studies. From 2023 to 2025, while CKD remained a central theme, increasing attention shifted toward emerging areas such as biomarker discovery, inflammatory mechanisms, and precision patient care. This shift underscores the dynamic nature of CKD-related research and its movement toward more innovative and translational directions (Figure 7).

Countries'research collaboration network

The world map of international collaboration (Figure 8) depicted the global research network in uremia. China and the United States emerged as leading contributors (Table 1) and played pivotal roles in fostering international cooperation. Collaboration between Italy and the United States was particularly strong, resulting in numerous high-quality publications on dialysis technologies and nephritis mechanisms. Overall, uremia research during this period was characterized by cross-border and inter-institutional partnerships, which

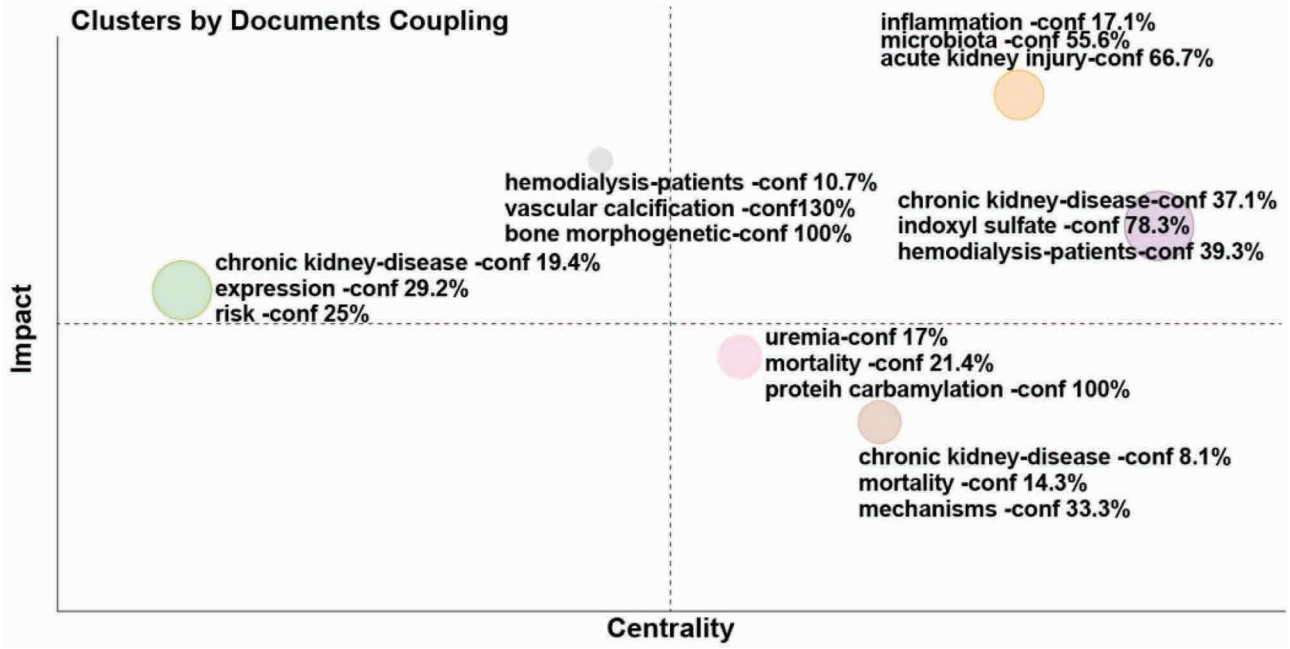

Figure 6. Thematic clustering of research themes. (Upper right: motor themes; lower right: basic themes; upper left: highly developed but isolated themes; lower left: emerging or declining themes.)

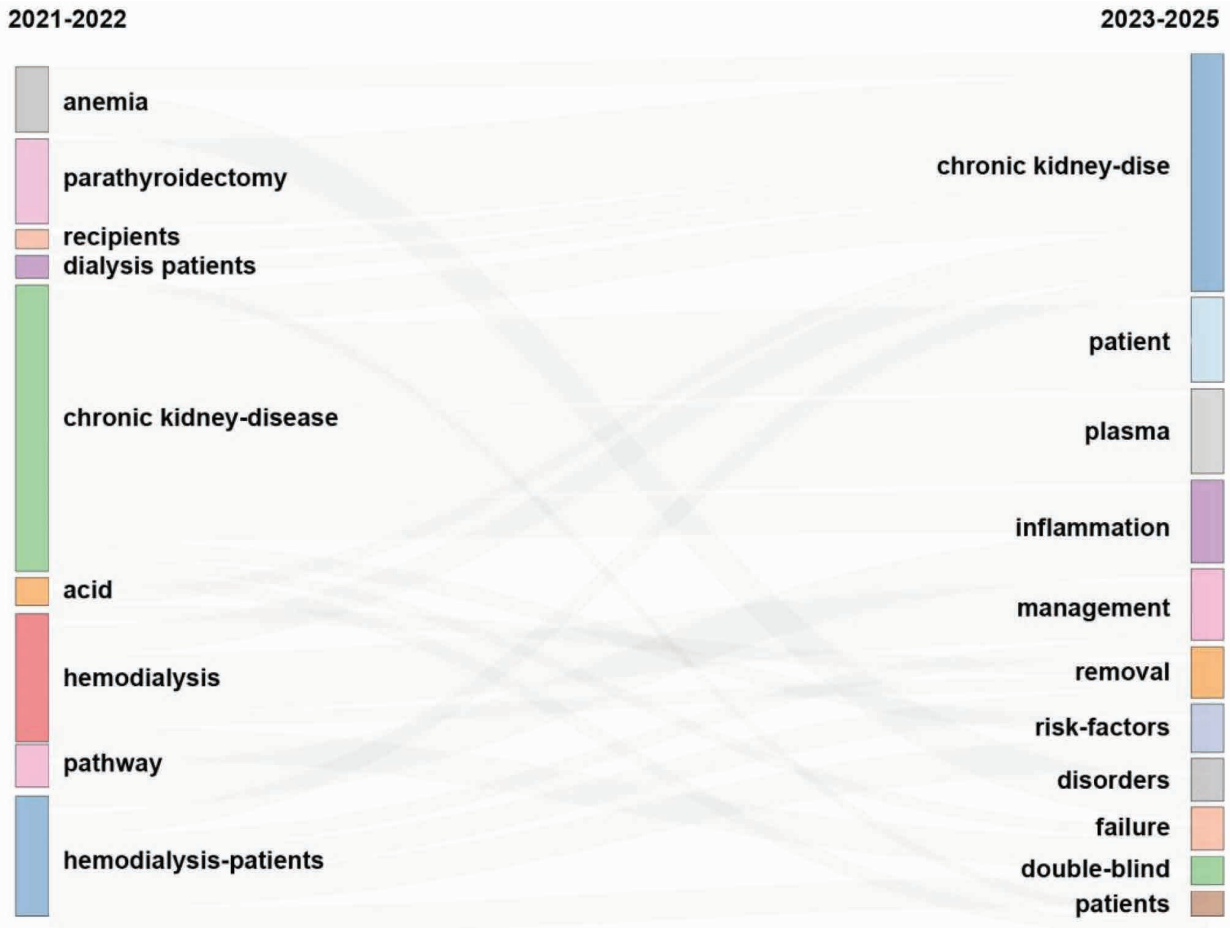

Figure 7. Evolution of the theme over the period 2021-2025. (2021–2022: Research was mainly focused on CKD, hemodialysis, and dialysis patients. 2023–2025: The focus shifted toward biomarkers, inflammation, and precision patient care.)

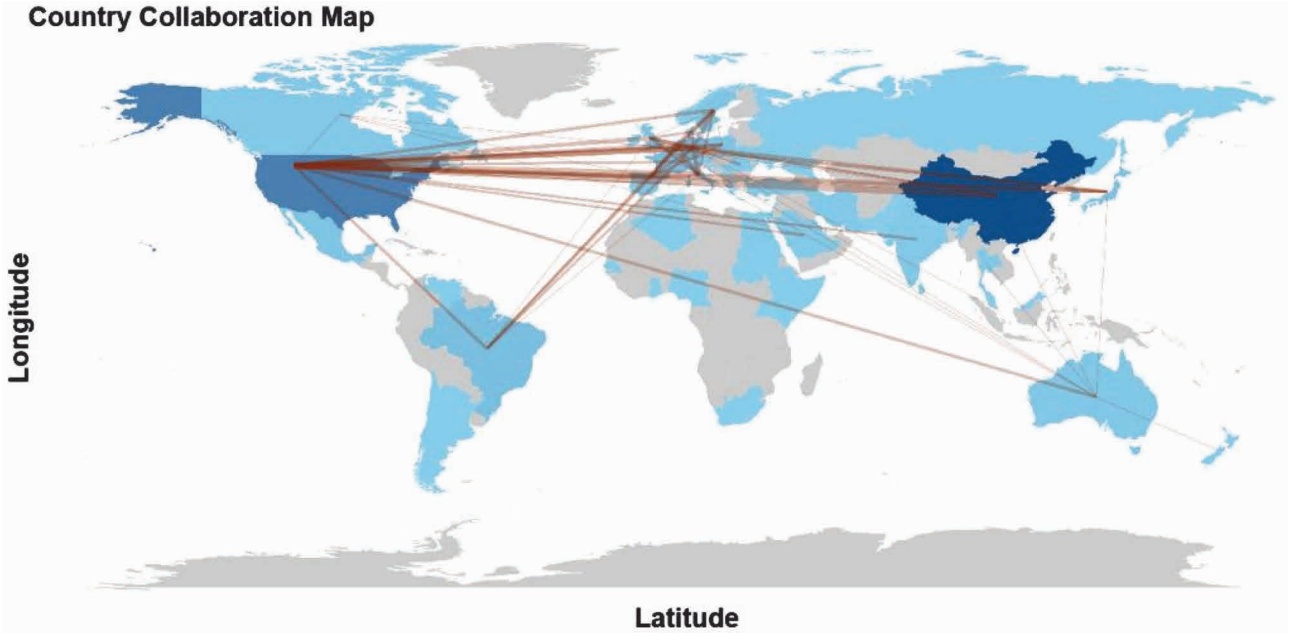

Figure 8. Countries' collaboration world map in uremia research. (Node size: publication output of each country; link thickness: intensity of collaboration.)

Table 1. Major international collaborations in uremia research (2021–2025)

From	To	Frequency
USA	ITALY	15
CHINA	USA	14
USA	GERMANY	10
USA	FRANCE	9
USA	BELGIUM	8

Note: The table presents the top country-to-country collaborative links and their frequencies, with China–USA and USA–Italy among the strongest partnerships.

broadened perspectives and facilitated resource sharing across the global research community.

DISCUSSION

The findings highlighted a strong trend of multi-author collaboration, with Asian countries, particularly China, playing a leading role, while Europe and the United States also remain major contributors. The predominance of multi-author publications and the high average number of authors per article highlight the collaborative and interdisciplinary nature of this field. The large number of unique keywords and the relatively high citation counts indicate both thematic diversity and considerable academic influence, underscoring the growing scientific and clinical relevance of uremia. However, the decline in publication growth rate suggests that traditional research areas may be reaching a saturation point, emphasizing the importance of emerging directions such as biomarkers, gut microbiota, and precision medicine to sustain future advances.

China's prominent position in uremia research is driven by multiple structural factors. First, the country has a very large CKD population. Data from the China Chronic Disease and Risk Factor Surveillance (CCDRFS) indicated that in the time interval 2018–2019, approximately 82 million people in China were living with CKD, creating continuous clinical and research demand.[19] In comparison, the latest statistics from the Centers for Disease Control and Prevention (CDC) and the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) reported that about 35.5 million adults (≈14%) in the United States have CKD.[20] Second, China's ESKD care system has rapidly expanded and improved over the past decade, providing favorable conditions for clinical and translational research.[21] Third, national strategies such as Healthy China 2030 have prioritized both population health and research capacity building, indirectly supporting the nephrology research ecosystem.[22]

The decline in publication output requires cautious interpretation. One explanation may be the reduction in CKD prevalence. A study suggested that CKD prevalence in China decreased by about

30% between 2013 and 2023, largely due to improved environmental protection and the inclusion of CKD in national surveillance programs.[19] In addition, traditional research areas—such as dialysis-related studies and CKD epidemiology—may have reached saturation. Meanwhile, attention has shifted toward emerging directions such as multi-omics, microbiota, and precision medicine. These fields require longer study cycles and higher complexity, which may temporarily lower publication numbers but are expected to increase long-term academic impact. Moreover, indexing delays in bibliographic databases may underestimate recent publications in time-series analysis.[23]

In the bibliometric network, certain institutions and scholars occupy central positions. Claudio Ronco has made outstanding contributions in dialysis and critical care nephrology.[24-26] Kamyar Kalantar-Zadeh is highly influential in renal nutrition, dialysis strategies, and epidemiology, with a high H-index and prolific publication record placing him at the center of the network.[27-29] Peter Stenvinkel is a leading figure in the classification of uremic toxins and has conducted important work on inflammation and gut microbiota dysregulation in kidney disease populations.[30,31] Together with other international researchers, these scholars form key nodes of the global uremia research network.

Our keyword analysis showed that "chronic kidney disease," "uremia," "inflammation," and "mortality" were the most frequent terms, consistent with other bibliometric studies in nephrology.[32,33] Cluster analysis further revealed that acute kidney injury, microbiota, and inflammation were positioned in the upper-right quadrant (high centrality and high impact), confirming them as current hotspots, which aligns with the results of Sinan *et al*..[33,34] Liu *et al.* demonstrated that replacement therapy and patient-level clinical issues remain a research focus in dialysis studies, consistent with our finding that "hemodialysis patients" occupy a high-impact but lower-centrality position.[35] However, bibliometric results across subfields differ; for example, in studies linking kidney disease with cardiovascular disease, "cardiorenal disease" emerged as a dominant keyword.[36] Compared with these narrower subfields, our findings suggest that uremia research is undergoing a broader thematic transformation, extending to inflammation, gut microbiota, and metabolic abnormalities. Some emerging themes, such as protein carbamylation and microbiota, showed potential importance in cluster analysis but remain underdeveloped.

Although China, the USA, and several European countries demonstrated strong collaboration in uremia research, structural gaps remain in the network. At the country level, regions such as Africa, Latin America, and Central Asia were largely absent, reflecting very limited participation. The global nephrology community has noted persistent shortages of nephrology workforce, resources, and research capacity in low-income countries, limiting their integration into international networks.[37-38] In addition, some institutions and authors appeared as isolated nodes with weak connections to the central network, indicating low collaboration and limited influence. Interdisciplinary collaboration was also underrepresented, as clinical and basic research teams—even in hotspots such as inflammation or microbiota—often worked in silos rather than forming integrated frameworks. Future efforts should focus on promoting collaboration in resource-limited regions, strengthening the integration of peripheral nodes, and enhancing cross-disciplinary mechanisms to close these gaps and improve balance and efficiency in global uremia research.

This study systematically analyzed the global landscape of uremia research from 2021 to 2025. The results show that research hotspots are shifting from traditional areas such as CKD and hemodialysis toward emerging themes such as inflammation, biomarkers, and patient management. China, the USA, and Europe are the main contributors, while scholars such as Claudio Ronco, Kamyar Kalantar-Zadeh, and Peter Stenvinkel occupy core positions in the collaboration network. Keyword and cluster analyses highlighted the rising importance of inflammation, microbiota, and precision medicine. Overall, this study provides objective evidence of current hotspots and trends in uremia research and emphasizes the need to strengthen international and interdisciplinary collaboration.

This study has several limitations. First, the study period was restricted to 2021–2025, which may underestimate the long-term trends in uremia research and is subject to indexing delays. In addition, although citation counts and co-occurrence analyses can reveal structures and trends, they

cannot fully represent research quality or clinical relevance.

CONCLUSION

This study analyzed global uremia research from 2021–2025. Hotspots are shifting from CKD and hemodialysis to emerging themes such as inflammation, biomarkers, and patient management. Keyword and cluster analyses highlight the growing relevance of inflammation, microbiota, and precision medicine. These findings provide evidence of current trends and underscore the need for stronger international and interdisciplinary collaboration.

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ETHICAL COMPLIANCE

This study was based solely on bibliometric data extracted from publicly available databases. No human participants or animals were involved, and therefore institutional review board approval and informed consent were not required.

CONFLICT OF INTEREST

The authors declared that they have no conflicts of interest related to this work.

AUTHOR CONTRIBUTIONS

Jie Wei: Conception and design of the study, data collection, manuscript drafting. Pan Gao: Data collection, literature review, manuscript drafting. Jie Wei and Pan Gao contributed equally to this work, and should be considered co-first authors. Zhi Wang: Methodological support, data analysis, critical revision of the manuscript. Lei Fan: Assisted with data acquisition, statistical analysis, and figure/table preparation. Jin Zhao: Supervision, guidance throughout the study, critical revision of the manuscript, and corresponding author responsibilities.

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