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RESEARCH ARTICLE

Mapping the trajectory of antibiotic resistance from ESBL-producing to carbapenem-resistant Enterobacteriaceae: A bibliometric study from 2000 to 2025

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Abstract

Background: Antibiotic resistance in Gram-negative bacteria, particularly Carbapenem-Resistant Enterobacteriaceae (CRE), is a major global health threat. The increasing prevalence of resistance mechanisms, including ESBL and carbapenemases, necessitates systematically analysing research trends. **Objective:** This study aims to map global research trends on Enterobacteriaceae resistance, focusing on geographical distribution, institutional contributions, and thematic developments. **Method:** A bibliometric analysis of 649 publications from PubMed (2000–2025) was conducted using VOSviewer to examine international collaborations, citation networks, and keyword co-occurrences. **Result:** The United States (134 publications, 20.65%) was the most productive country, followed by China, France, and the UK. A total of 168 institutions, 194 journals, and 3,417 authors contributed to this field. Keyword analysis identified “Enterobacteriaceae” and “ESBL” as dominant terms, reflecting the focus on beta-lactam resistance. **Conclusion:** Research on Enterobacteriaceae resistance is globally extensive, with major contributions from leading countries and institutions. The findings underscore the urgency of strengthening antimicrobial resistance surveillance, infection control, and novel therapeutic strategies.

Introduction

Antibiotic resistance has emerged as a formidable challenge in modern medicine, with all known classes of antibiotics facing an array of resistance mechanisms (Darby *et al.*, 2023). Identifying pathogens exhibiting multidrug resistance (MDR) has complicated treatment strategies, necessitating urgent attention from the global health community (van Duin & Paterson, 2020). Among these, Gram-negative bacteria (GNB) have demonstrated alarming increases in resistance levels to most available antibiotic classes, significantly complicating the management of infections they cause (Exner *et al.*, 2017).

A critical factor in this resistance landscape is the production of extended-spectrum beta-lactamases

(ESBLs), enzymes capable of hydrolysing a broad spectrum of beta-lactam antibiotics, including penicillins, third-generation cephalosporins, and monobactams (Munita & Arias, 2016). Additionally, AmpC beta-lactamases contribute to resistance by hydrolysing most penicillins and many cephalosporins, as well as combinations of beta-lactams with beta-lactamase inhibitors (Jacoby, 2009). The emergence of carbapenemases, which possess the broadest spectrum of activity against beta-lactams, has further exacerbated the situation, rendering carbapenem resistance (CR) a primary global health concern (Tamma *et al.*, 2023). Carbapenems are often regarded as the last line of defence against difficult-to-treat GNB infections, making the rise of carbapenem-resistant

Enterobacteriaceae (CRE) particularly alarming, with *Escherichia coli* and *Klebsiella pneumoniae* being the predominant pathogens involved (Mancuso et al., 2021).

The medical implications of carbapenemase-producing Enterobacteriales are profound, as these organisms can effectively hydrolyse carbapenem antibiotics, leading to treatment failures. Notably, some strains resist carbapenems despite lacking intrinsic resistance mechanisms, complicating the clinical landscape (Shropshire et al., 2021). The structural modifications of carbapenems, which include a pyrrolidine ring attached to the beta-lactam core, enhance their stability against enzymatic degradation by various beta-lactamases (De Rosa et al., 2021). This structural resilience highlights the crucial need for ongoing vigilance in antimicrobial therapy, as these resistance mechanisms can substantially reduce the efficacy of available antibiotics (Davies & Davies, 2010).

A comprehensive understanding of the evolving landscape of antimicrobial resistance is crucial for effectively addressing the diagnostic, therapeutic, and preventive challenges posed by CRE infections. Several factors contribute to this phenomenon, including genetic variability, environmental conditions, and the misuse of antibiotics. Consequently, maintaining current insights into resistance patterns and infection control strategies is vital for optimising patient care.

In alignment with advancements in medical research, bibliometrics has emerged as a pivotal analytical tool for tracking scientific trends, identifying key research focuses, and mapping future directions in the study of antimicrobial resistance. This methodology not only elucidates publication patterns over recent decades but also reveals thematic evolution and paradigm shifts within the field. The present study aims to conduct a comprehensive bibliometric analysis of the academic literature concerning the transition from ESBL-producing Enterobacteriaceae to carbapenem-resistant Enterobacteriaceae from 2000 to 2025. This analysis will encompass quantitative and qualitative evaluations of relevant publications, trends in research topics, keyword evolution, contributions from leading institutions and authors, and the geographical distribution of research efforts. Through this systematic approach, the authors aim to enhance our understanding of research developments in bacterial resistance and provide a robust scientific foundation for informing future research policies and control strategies.

Methods

Data sources and search strategy

This study conducted a comprehensive online literature search utilising the PubMed database as the primary source of scientific references. The search was conducted in a temporal scope from 2000 to 2025 to ensure comprehensive data that reflects research developments during that period. In the search process, a combination of relevant keywords was used, namely "ESBL" (Extended-Spectrum Beta-Lactamase), "carbapenem resistance," and "Enterobacteriaceae", to obtain publications that specifically discussed the dynamics of antibiotic resistance in this group of bacteria. All articles that met the search criteria were collected and stored in text format, resulting in 649 publications that will be further analysed in this study.

Data analysis

VOSviewer software is used as the primary tool in bibliometric analysis, focusing on several key aspects, namely mapping collaborative interactions between countries and regions, and analysing citation and co-citation networks involving journals and individual authors. In the visual representation generated by VOSviewer, each node represents one entity- a publication, author, country, or academic institution. The dimensions and colouring of the nodes not only reflect the number of entities in a specific category, but also serve as indicators of their classification in the context of the analysis. Meanwhile, the thickness of the connecting lines between nodes indicates the strength of the collaborative relationship or the intensity of the co-citation relationship between entities, thus allowing for the identification of interaction patterns and dynamics within academic networks in a research field.

Results

Country analysis

A total of 55 countries or regions have contributed scientific publications in this field, reflecting the broad involvement of the global academic community in antimicrobial resistance research (Figure 1). Mapping international collaborations through network analysis provides an intuitive illustration of the distribution patterns of publications and partnerships between countries, enabling the identification of key research centres and the dynamics of cross-border scientific interactions.

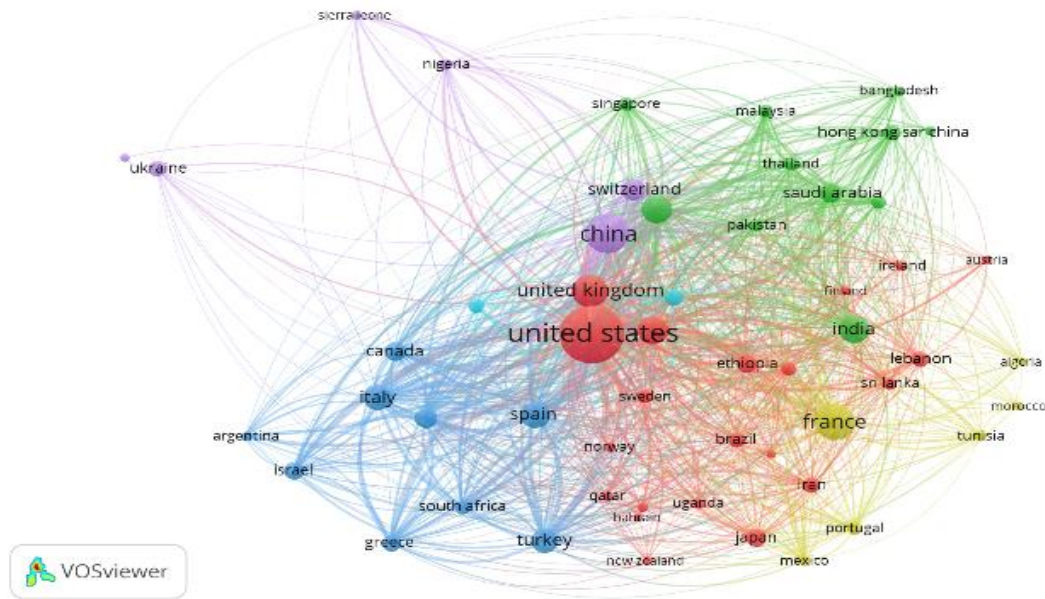


Figure 1: Network map of country analysis

In the analysis of contributions by country, the United States ranked first with a total of 134 publications, accounting for 20.65% of the total literature analysed, making it the dominant actor in the development of this field. Next in position was China with 63 publications (9.7%), followed by France with 52

publications (8.01%), and the United Kingdom with 42 publications (6.4%), confirming the strategic role of these countries in advancing research on antibiotic resistance and the management of infections caused by resistant pathogens (Table I).

Table I: Top country based on total publications in each cluster

| Country | Total publication | Links | Total links strength | Avg. pub. year |
|-------------------|-------------------|-------|----------------------|----------------|
| Cluster I | | | | |
| USA | 134 | 54 | 25,680 | 2017.24 |
| UK | 42 | 54 | 8,957 | 2017.95 |
| Germany | 31 | 54 | 5,712 | 2017.42 |
| Ethiopia | 14 | 53 | 2,203 | 2021.57 |
| Japan | 14 | 52 | 1,767 | 2019.29 |
| Iran | 10 | 53 | 1,693 | 2021.10 |
| Lebanon | 10 | 52 | 1,636 | 2018.70 |
| Brazil | 9 | 53 | 1,424 | 2016.11 |
| Egypt | 7 | 53 | 1,994 | 2020.29 |
| Sweden | 7 | 53 | 1,388 | 2016.86 |
| Sri Lanka | 6 | 52 | 1,641 | 2020.83 |
| Ireland | 5 | 52 | 787 | 2023.40 |
| Cluster II | | | | |
| Taiwan | 33 | 53 | 8,303 | 2016.76 |
| India | 32 | 53 | 4,758 | 2016.84 |
| Saudi Arabia | 16 | 53 | 3,889 | 2020.62 |
| Hongkong | 11 | 52 | 2,416 | 2019.09 |
| Malaysia | 8 | 51 | 1,959 | 2021.25 |
| Singapore | 8 | 53 | 2,191 | 2015.88 |
| South Korea | 8 | 52 | 2,273 | 2014.88 |

| Country | Total publication | Links | Total links strength | Avg. pub. year |
|--------------------|-------------------|-------|----------------------|----------------|
| Thailand | 8 | 53 | 2,272 | 2019.62 |
| Pakistan | 6 | 52 | 1,510 | 2021.67 |
| Cluster III | | | | |
| Spain | 30 | 54 | 8,686 | 2016.83 |
| Italy | 27 | 54 | 7,072 | 2018.07 |
| Turkey | 23 | 54 | 6,153 | 2016.61 |
| Australia | 18 | 54 | 5,747 | 2018.11 |
| Canada | 15 | 53 | 3,743 | 2017.60 |
| Israel | 13 | 52 | 2,785 | 2016.00 |
| Greece | 12 | 53 | 3,702 | 2015.33 |
| South Africa | 9 | 53 | 2,982 | 2018.67 |
| Cluster IV | | | | |
| France | 52 | 53 | 8,909 | 2017.75 |
| Portugal | 7 | 53 | 1,736 | 2017.43 |
| Mexico | 5 | 52 | 1,340 | 2019.00 |
| Tunisia | 5 | 52 | 995 | 2018.20 |
| Cluster V | | | | |
| China | 63 | 54 | 9,720 | 2019.46 |
| Switzerland | 19 | 53 | 4,581 | 2019.42 |
| Ukraine | 10 | 45 | 438 | 2021.10 |
| Nigeria | 5 | 52 | 1,089 | 2021.20 |
| Cluster VI | | | | |
| Netherland | 12 | 54 | 3,161 | 2017.50 |
| Denmark | 9 | 52 | 1,391 | 2017.78 |

Organisation analysis

Most of the publications in this field come from the contributions of 168 academic and research institutions, which collectively form a dynamic scientific ecosystem. Among these institutions, the Institut

National de la Santé et de la Recherche Médicale (Inserm) ranks first as the most productive entity in producing scientific publications, followed by the Assistance Publique-Hôpitaux de Paris (AP-HP) and JMI Laboratories, which also play a significant role in the development of related research (Figure 2; Table II).

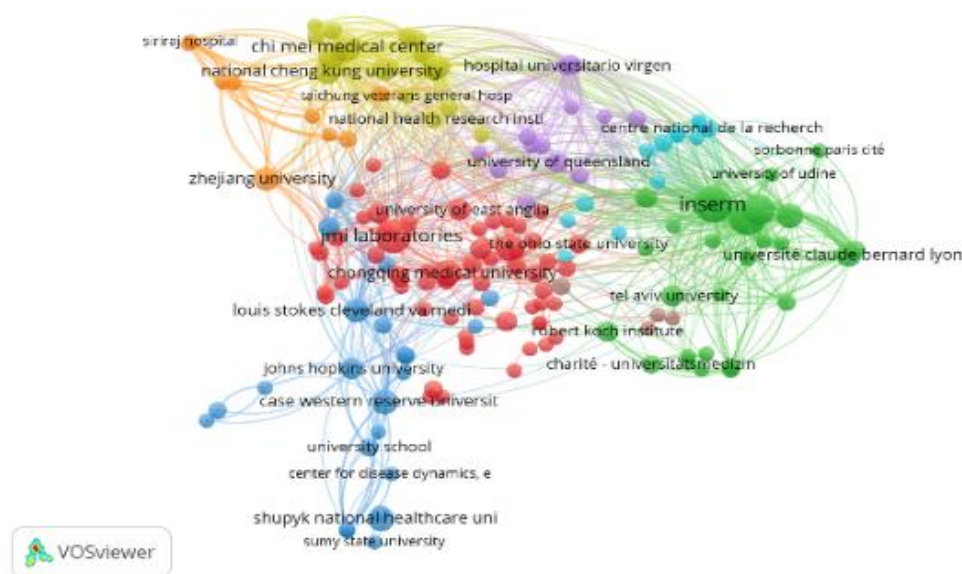


Figure 2: Network map of organisation analysis

Table II: Top organisation based on total publications in each cluster

| Organisation | Country | Total publication | Links | Total links strength | Citations |
|---------------------------------------|---------|-------------------|-------|----------------------|-----------|
| Cluster I | | | | | |
| JMI Laboratories | USA | 16 | 47 | 1766 | 1186 |
| Public Health England | UK | 11 | 46 | 1526 | 637 |
| Chongqing Medical University | China | 10 | 47 | 674 | 197 |
| Cluster II | | | | | |
| Inserm | France | 19 | 47 | 3467 | 905 |
| Assistance Publique-Hopitaux de paris | France | 17 | 47 | 3201 | 741 |
| Universitie Paris Cite | France | 13 | 47 | 3051 | 696 |
| Delegation Paris 7 | France | 9 | 46 | 2611 | 640 |
| Cluster III | | | | | |
| Chi Mei Medical Centre | Taiwan | 11 | 46 | 2070 | 275 |
| National Taiwan University Hospital | Taiwan | 10 | 46 | 3144 | 674 |
| National Cheng Kung University | Taiwan | 9 | 46 | 1766 | 328 |

Sources analysis

A total of 194 scientific journals have contributed to disseminating research in this field, with 51 of them individually publishing more than three publications. In the visual representation of bibliometric analysis, the size of the nodes indicates the number of publications produced and the degree of co-citation linkages

between the journals. Meanwhile, the connecting lines between nodes reflect the citation relationships and the degree of linkages in the scientific reference network, allowing for the identification of academic communication patterns and the influence of a journal on the development of related disciplines (Figure 3; Table III).

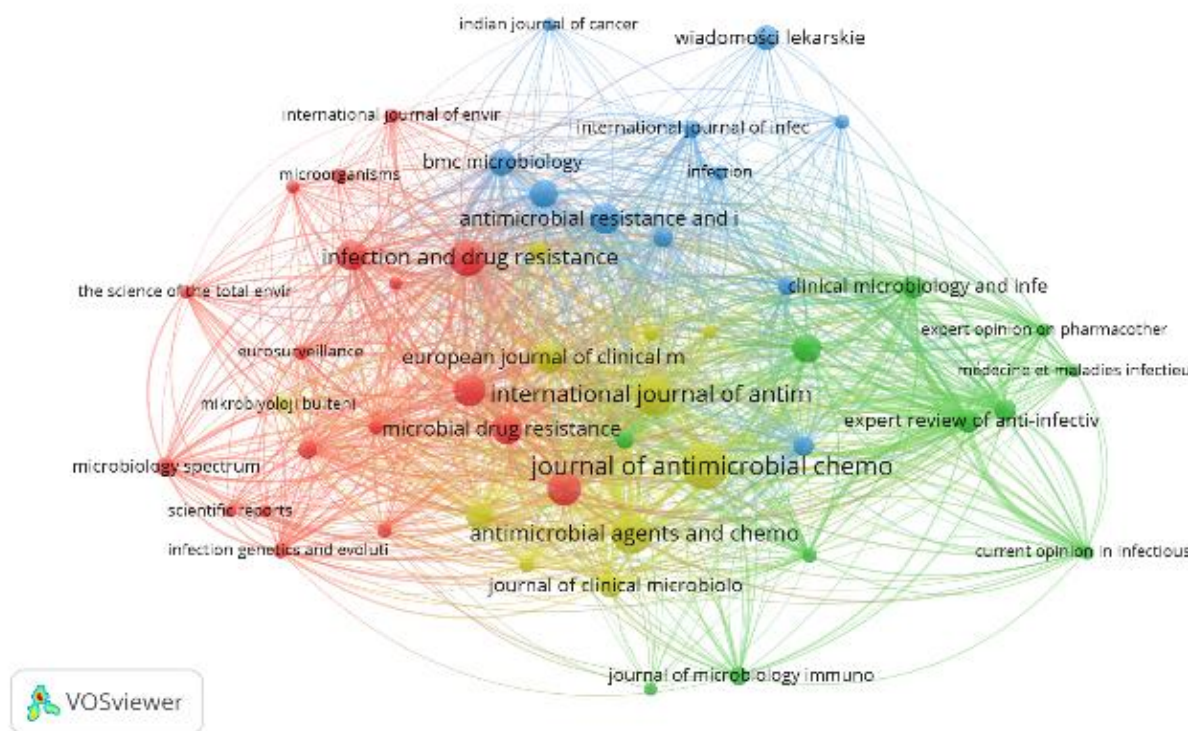


Figure 3: Network map of source analysis

Table III: Top source based on total publications in each cluster

| Source | Total publication | Average citations | H-index | Scopus rank |
|---|-------------------|-------------------|---------|-------------|
| Cluster I | | | | |
| Infection and Drug Resistance | 22 | 20.68 | 65 | Q2 |
| Journal of Global Antimicrobial Resistance | 19 | 18.26 | 50 | Q2 |
| PlosOne | 17 | 32.94 | 435 | Q1 |
| Antibiotics | 15 | 27.13 | 77 | Q1 |
| Antimicrobial Resistance and Infection Control | 15 | 20.93 | 66 | Q1 |
| Microbial Drug Resistance | 15 | 21.80 | 78 | Q2 |
| BMC Infectious Diseases | 13 | 19.38 | 129 | Q1 |
| BMC Microbiology | 11 | 25.64 | 137 | Q2 |
| Journal of Infection and Public Health | 7 | 26.14 | 65 | Q1 |
| Frontiers in Microbiology | 6 | 21.67 | 233 | Q1 |
| Microbiology Spectrum | 6 | 8.33 | 87 | Q1 |
| International Journal of Infectious Diseases | 5 | 38.80 | 131 | Q1 |
| Cluster II | | | | |
| Journal of Antimicrobial Chemotherapy | 36 | 59.36 | 221 | Q1 |
| International Journal of Antimicrobial Agents | 27 | 71.52 | 154 | Q1 |
| Antimicrobial Agents and Chemotherapy | 26 | 60.58 | 289 | Q1 |
| European Journal of Clinical Microbiology and Infectious Diseases | 16 | 24.50 | 122 | Q1 |
| Diagnostic Microbiology and Infectious Disease | 14 | 49.14 | 105 | Q2 |
| Journal of Medical Microbiology | 12 | 36.17 | 131 | Q2 |
| Journal of Clinical Microbiology | 9 | 65.22 | 285 | Q1 |
| Drugs | 7 | 215.14 | 188 | Q1 |
| American Journal of Infection | 6 | 100.83 | 20 | 0 |
| The Journal of Infection in Developing Countries | 5 | 17.20 | 61 | Q3 |
| Cluster III | | | | |
| Clinical Microbiology and Infection | 9 | 51.44 | 198 | Q1 |
| Expert Review of Anti-infective Therapy | 9 | 45.00 | 96 | Q1 |
| Clinical Infectious Diseases | 8 | 109.00 | 387 | Q1 |
| Journal of Microbiology, Immunology and Infection | 6 | 23.50 | 73 | Q1 |
| Future Microbiology | 5 | 16.00 | 102 | Q2 |

Author analysis

A total of 3,417 authors have contributed to the development of research in this field through their involvement in producing scientific publications. To gain a deeper understanding of the dynamics of academic collaboration, a special analysis was

conducted focusing on authors who have published more than three articles. This approach aims to identify more structured patterns of scientific interaction, map collaborative networks among leading researchers, and highlight individuals who have significantly influenced the development of the related scientific discourse (see Figure 4; Table IV).

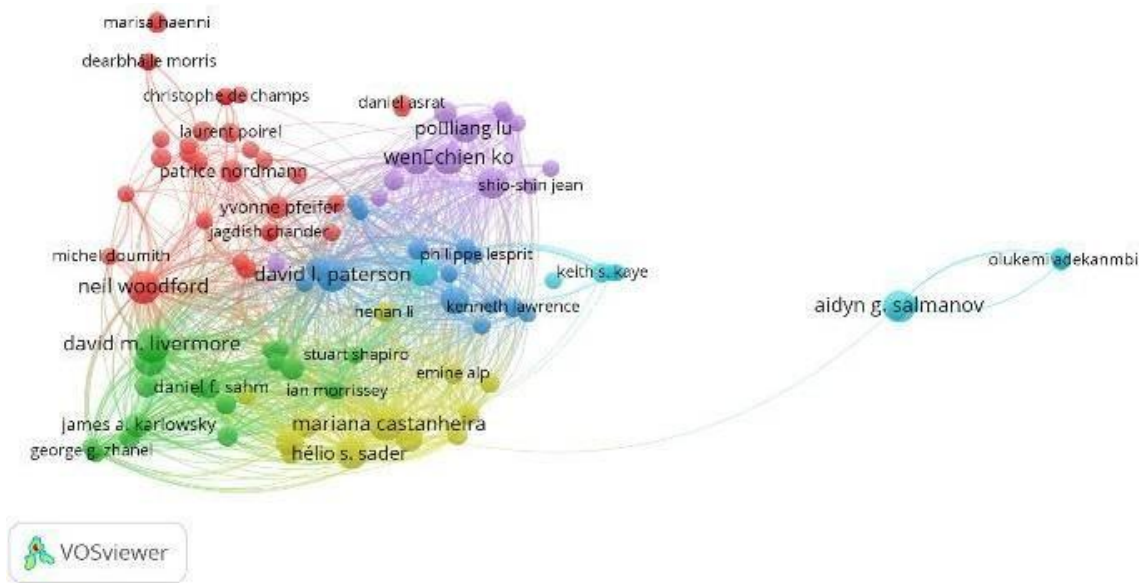


Figure 4: Network map of author analysis

Table IV: Top author based on total publications in each cluster

| Author | Total publication | Average citations | H-index |
|----------------------|-------------------|-------------------|---------|
| Cluster I | | | |
| David M. Livermore | 12 | 97.83 | 111 |
| Neil Woodford | 11 | 92.18 | 120 |
| Shazad Mustaq | 9 | 94.00 | 23 |
| James A. Karlowsky | 6 | 159.83 | 79 |
| Daniel F. Sahm | 5 | 62.6 | 74 |
| Marina Warner | 5 | 131.00 | 11 |
| Robert E. Badal | 5 | 40.00 | 32 |
| Cluster II | | | |
| David L. Paterson | 10 | 522.80 | 144 |
| Matteo Bassetti | 8 | 90.12 | 115 |
| Robert A. Bonomo | 8 | 473.75 | 123 |
| Patrice Nordmann | 5 | 35.40 | 168 |
| Patrick N. A. Harris | 5 | 71.40 | 44 |
| Yvonne Pfeifer | 5 | 134.80 | 13 |
| Cluster III | | | |
| Mariana Castanheira | 11 | 73.64 | 89 |
| Aidyn G. Salmanov | 10 | 8.10 | 2 |
| Helio S. Sader | 9 | 79.33 | 104 |
| Ronald N. Jones | 8 | 108.50 | 157 |
| Robert K. Flamm | 7 | 48.57 | 59 |
| Rodrigo E. Mendes | 5 | 82.60 | 64 |
| Cluster IV | | | |
| Wen-chien ko | 10 | 22.80 | 83 |
| Po-ren hsueh | 9 | 73.78 | 122 |
| Po-liang lu | 8 | 82.00 | 56 |
| Yin-Ching Chuang | 8 | 21.12 | 25 |
| Hung-jen tang | 5 | 19.40 | 2 |

Keyword analysis

Keywords serve as conceptual representations that reflect the core themes and primary focuses of a scientific publication and a field, enabling researchers to identify development trends and topics of concern

within a particular field (Zupic & Čater, 2015). In this study, a co-occurrence network mapping was conducted to analyse the relationships between keywords, where each keyword is represented as a node in the resulting visual network (see Figure 5; Table V).

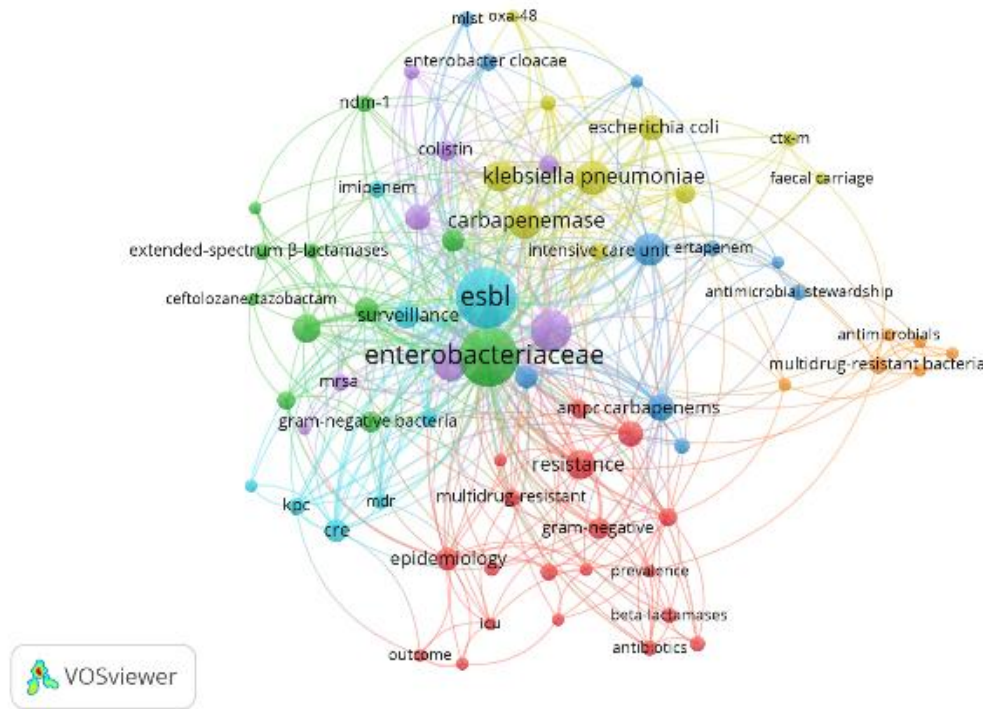


Figure 5: Network map of keyword analysis

Table V: Top keyword based on total occurrences

| Keyword | Occurrences | Average publication year |
|------------------------------|-------------|--------------------------|
| ESBL | 61 | 2016 |
| Enterobacteriaceae | 59 | 2015 |
| Antimicrobial resistance | 29 | 2015 |
| Carbapenemase | 20 | 2015 |
| <i>Klebsiella pneumoniae</i> | 20 | 2014 |
| Antibiotic Resistance | 19 | 2017 |
| Carbapenem | 18 | 2015 |
| Carbapenem resistance | 17 | 2016 |
| Resistance | 15 | 2016 |
| Carbapenemases | 14 | 2015 |

The size of each node indicates the frequency of occurrence of the keyword in the analysed literature,

providing insight into the level of relevance and dominance of a concept in related scientific studies. This network consists of 443 nodes connected through 716 connections, forming a complex structure that illustrates thematic relationships in antimicrobial resistance research. According to the analysis results, the keywords that appear most frequently in the literature are "Enterobacteriaceae" and "ESBL" (Extended-Spectrum Beta-Lactamase), confirming that both terms are central elements in the scientific discourse under study.

Discussion

The bibliometric analysis in this study provides a comprehensive overview of global research trends on Enterobacteriaceae resistance to beta-lactam antibiotics, with a particular focus on Extended-Spectrum Beta-Lactamase (ESBL) and Carbapenem-Resistant Enterobacteriaceae (CRE). Over the past two

decades, this research field has undergone significant growth, reflecting a growing global concern over antibiotic resistance and its impact on public health. The rising number of publications underscores the urgent need for novel therapeutic strategies and policy interventions. Moreover, the global distribution of research efforts indicates a widespread recognition of antimicrobial resistance as a critical healthcare challenge.

Geographical distribution and research networks

The analysis identified contributions from 55 countries, highlighting the extensive global engagement in tackling this urgent healthcare challenge. The United States emerged as the most prolific country, accounting for 134 publications (20.65%), followed by China (9.7%), France (8.01%), and the United Kingdom (6.4%). The prominence of these nations can be attributed to their well-established research infrastructures, strong governmental and institutional support, and active international collaborations. Furthermore, the data reveals strategic contributions from countries such as Ethiopia, Iran, and Brazil, which have experienced a more recent surge in publications, with average publication years beyond 2020, indicating their emerging role in antibiotic resistance research.

The co-authorship network analysis demonstrated strong international collaboration patterns, particularly among high-output countries. This interconnectedness facilitates knowledge exchange, promotes multidisciplinary approaches, and accelerates innovations in antibiotic resistance mitigation strategies. The presence of well-defined research clusters further indicates the thematic diversification of studies within this field, encompassing aspects such as epidemiology, molecular mechanisms of resistance, and therapeutic interventions. These collaborative efforts contribute to the acceleration of discovery and enhance the effectiveness of intervention strategies.

Institutional contributions and research productivity

The analysis of institutional contributions revealed 168 research organisations actively engaged in this domain. Among these, the Institut National de la Santé et de la Recherche Médicale (Inserm) in France emerged as the leading institution with 19 publications, followed by the Assistance Publique-Hôpitaux de Paris (AP-HP) and JMI Laboratories (USA). These institutions have played a pivotal role in advancing scientific knowledge and establishing evidence-based approaches to combat bacterial resistance. The contributions from these institutions are crucial in shaping policy recommendations and guiding clinical practices worldwide.

Institutional collaborations were mapped through network analysis, identifying eight major global research groups. These groups serve as hubs of innovation and knowledge dissemination, with some institutions acting as key bridges that link different geographic regions. For example, French institutions displayed strong ties with European and North American research centres. At the same time, emerging contributors such as Chongqing Medical University (China) and Chi Mei Medical Centre (Taiwan) reflected increasing Asia involvement. This interconnectedness allows for a more comprehensive understanding of resistance mechanisms and facilitates the development of more effective countermeasures.

Journal impact and citation network

The research findings have been disseminated across 194 scientific journals, with 51 publishing more than three articles. The citation network analysis underscores the influence of high-impact journals in shaping the discourse on antibiotic resistance. Notably, PlosOne (Q1, H-index: 435), Antibiotics (Q1, H-index: 77), and BMC Infectious Diseases (Q1, H-index: 129) have served as key platforms for publishing groundbreaking research in this field. Highly cited sources suggest a well-established knowledge base, providing critical insights into bacterial resistance mechanisms and potential countermeasures.

The impact of citations on different journals further indicates the broader scientific influence of specific studies. For instance, journals such as Clinical Infectious Diseases (Q1, H-index: 387; Avg. Citations: 109) and Drugs (Q1, H-index: 188; Avg. Citations: 215.14) have significantly contributed to clinical decision-making and policy formulation in antimicrobial stewardship. These journals provide a strong foundation for further research and serve as key references for policymakers and healthcare practitioners seeking evidence-based solutions to combat bacterial resistance.

Authorship network and key contributors

Exactly 3,417 authors were identified in this research domain, emphasising the breadth of scientific engagement. Among them, David M. Livermore (12 publications, Avg. Citations: 97.83, H-index: 111) and David L. Paterson (10 publications, Avg. Citations: 522.80, H-index: 144) emerged as leading contributors, consistently publishing influential works on antimicrobial resistance. The co-authorship analysis revealed strong collaborations between researchers, forming clusters that drive research forward through interdisciplinary partnerships. These collaborations enhance the quality and impact of research findings,

leading to more effective intervention strategies against bacterial resistance.

Keyword co-occurrence and research trends

The keyword co-occurrence analysis identified 443 nodes with 716 connections, highlighting the complexity and interrelatedness of research themes. The most frequently occurring terms include "Enterobacteriaceae" (59 occurrences), "ESBL" (61 occurrences), "Antimicrobial Resistance" (29 occurrences), and "Carbapenemase" (20 occurrences). These findings suggest a continued emphasis on understanding resistance mechanisms, epidemiological trends, and the development of novel therapeutic strategies. The growing complexity of interactions between genetic factors, antibiotic use, and environmental influences underscores the need for a holistic approach in tackling bacterial resistance.

The temporal distribution of keywords indicates an evolving research focus. While foundational terms such as "*Klebsiella pneumoniae*" and "Carbapenemases" appeared earlier (avg. publication year: ~2014), newer research themes, including "Antibiotic Resistance" and "Carbapenem Resistance," have gained traction in recent years (~2016-2021). This shift underscores the scientific community's increasing urgency in addressing emerging threats posed by multidrug-resistant (MDR) pathogens and highlights the dynamic nature of research in this field.

Implications and future research directions

The continuous rise in publications and collaborations underscores the need to expand global surveillance systems to monitor resistance patterns and prevent outbreaks. Developing innovative therapeutic approaches, including bacteriophage therapy and antimicrobial peptides, is crucial in overcoming resistance challenges. Strengthening policy implementation and antimicrobial stewardship programs will play a pivotal role in controlling antibiotic misuse. Moreover, fostering interdisciplinary collaboration between microbiologists, pharmacologists, epidemiologists, and policymakers will ensure a more integrated and practical approach to mitigating bacterial resistance. Open-access data-sharing initiatives should also be encouraged to facilitate real-time responses to emerging resistance threats and enhance global preparedness against bacterial infections.

Methodological considerations and limitations

While this study provides valuable insights, certain methodological limitations must be acknowledged. The

exclusive reliance on PubMed may have led to the omission of relevant studies indexed in other databases such as Web of Science and Scopus. Future studies should incorporate multiple databases to achieve a more comprehensive analysis. The language restrictions in this study, which focused only on English-language publications, may have excluded impactful research available in other languages. Expanding linguistic inclusion criteria could improve the representativeness of global contributions. Additionally, the reliance on article titles, abstracts, and keywords may have overlooked relevant studies that did not explicitly mention key terms. Adopting a full-text analysis approach could enhance retrieval accuracy and ensure that all pertinent research is considered in future bibliometric studies.

Conclusion

This bibliometric analysis provides a detailed examination of global research trends on Enterobacteriaceae resistance to beta-lactam antibiotics. The findings highlight the major contributors, institutional collaborations, key research themes, and evolving trends within the field. Addressing antibiotic resistance remains a critical challenge, necessitating sustained efforts in research, policy, and clinical practice. Moving forward, fostering interdisciplinary collaborations, expanding surveillance frameworks, and promoting innovation in antimicrobial development will be instrumental in mitigating the impact of resistant bacterial infections on global health.

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