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A Scientometric Study of the Intellectual Structure of Researchers' Publications: *Acinetobacter baumannii*

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ABSTRACT

Background and Aim: *Acinetobacter baumannii* is a major cause of nosocomial infections and is considered one of the most serious health threats worldwide. Several researchers have attempted to study and report this issue to find a solution. In this regard, the observation and monitoring of topic and conceptual priorities are thus crucial. This study aimed to identify and formulate the relationship among topic research priorities of *A. baumannii* to accurately understand the intellectual structure concerning *A. baumannii*.

Materials and Methods: This scientometric study is quantitative and applied, conducted by using the co-word analysis technique. A total of 10,898 records indexed at the WOSCC were retrieved and analyzed during 2002-2021, and 102 keywords out of 12,060 keywords were selected for analysis. Following the vocabulary homogenization process, the threshold was determined, and UCINET 6.528.0.0 2017, NetDraw (2017), VOSviewer 1.6.14, and SPSS-16 software were used to analyze and preprocess the data and visualize the maps.

Results: The keyword 'Multidrug Resistance (MDR)' was in first place among the most frequent keywords of *A. baumannii* articles. The main concepts of the documents published regarding *A. baumannii* were obtained using the hierarchical clustering with the Ward method (6 topic clusters). The largest cluster had 27 keywords and 680 links with a centrality of 25,185 and a density of 0.969. The distribution of clusters in the strategic diagram indicated that topic clusters were located in quadrants 1 and 3, including mature and central topics and emerging or marginal topics, respectively.

Conclusion: Identifying and monitoring significant topics and conceptual priorities of *the A. baumannii* area with scientometric techniques is an appropriate tool for determining the intellectual structure of the *A. baumannii* area, leading optimal and efficient decisions in officials' research financial policy.

Keywords: *Acinetobacter baumannii*, Co-word analysis, Keywords co-occurrence, Scientometrics, Science mapping, Strategic diagram

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1 Introduction

Acinetobacter baumannii is one of the most serious causes of nosocomial infections that always threaten global public health **(1, 2, 3, 4)**. Among nosocomial infections, *A. baumannii* is one of the most prevalent and important opportunistic pathogens and bacterial isolates collected from clinical samples, which is the cause of infection in vulnerable patients, particularly those admitted in the ICU and surgery units **(5, 6, 7, 8, 9, 10, 11, 12)**. This bacterium is a gram-negative, non-motile, non-fermentative, pleomorphic, strictly aerobic, and generally encapsulated bacillus that grows easily in normal laboratory media **(13, 14)**. As a nosocomial infectious bacterium, it has imposed many challenges over the past several decades due to its ability to cause serious infections and develop resistance rapidly to antibiotics. There is a direct relationship between the severity of diseases caused by this microorganism and its antibiotic resistance (14, 15, 16, 17). *A. baumannii* strains have shown resis-tance to most antibiotics reported so far, including carbapenem (2, 9, 18, 19). This antibacterial resistance has led to constant efforts to find new antibiotics (13, 17, 18, 19, 20). Widespread inappropriate administ-ration and use of antibiotics were among the most significant factors for emerging multiple antibiotic-resistant organisms (21). *A. baumannii* has become an international public health crisis due to the rapid development of drug resistance and the failure of common antibiotics to treat infections caused by it (13). The World Health Organization (WHO) has described antibiotic resistance as a "major global threat" in a new report (5, 22). This issue has led to many problems in other areas, including economics following the restrictions on treatment and health options (23,24).

The emergence and growth of multidrug-resistant bacteria are currently considered a new threat to human health. While creating severe public health concerns, these bacteria have also become a problem for modern health care sectors, which is why several researchers have addressed this research and scientific area to overcome this problem. It can be noted that scientific progress in various fields of human knowledge is due to the efforts of previous scientists (25).

The science production is primarily manifested in scientific papers and databases, which are the first source reflecting scientific advances and the criteria for measuring scientific activities (26). Undoubtedly, all researchers' endeavors are accepted internation-ally just when the results of studies, experiments, extensive clinical trials, and other related literature are published in the form of articles in prestigious international journals and indexed in citation data-bases. Web of Science (WOS) is the most trusted and authoritative database, so the scientific publications indexed in this citation database, as the oldest and most important citation index in the world, will be credible for researchers, organizations, and publica-tions. It is also the most comprehensive and core collection for scientometrics scientists to monitor and evaluate scholarly publications (27, 28). According to a data seeking in WOSCC during the sixth month of 2021 with only the keyword "*Acinetobacter baumannii*" in the topic, 10,898 records were indexed in this database, showing the importance of the topic of *Acinetobacter* from the active researchers' persp-ective.

Scientography, also known as science mapping, is a tool allowing the production of scientific maps and the representation of domain analysis by showing the structure and relations between its inherent elements to accurately display the researchers' intellectual reflection in scientific publications and literature. Bibliographic data of documents are considered the measurement unit for science mapping studies. Inventory clustering is a technique related to science mapping (25). Structure-mapping and scientometrics are considered the essential approaches for topic processing, understanding the growth of scientific research, following the dynamics and evolution of a scientific scope, discovering new research fields, creating a macro image of knowledge structure, and creating competition for that field scientists (29). A scientific map can provide insight into the current state of knowledge and be valuable over time to trace ideas in the scientific scopes and link different knowledge domains (30). Keywords Co-occurrence Analysis is also considered a quantitative technique for mapping the cross-links between concepts in various scientific works (37). The main idea of Keywords Co-occurrence Analysis is based on keywo-rds co-occurrence (32). Keywords Co-occurrence Analysis enables researchers to map the most accurate and comprehensible image of a particular topic domain using co-occurrence (33,34). The resea-rch topics considered by researchers and the complex intra-network patterns of keyword interaction and the conceptual structure of a research field are revealed by identifying and mapping a network of keywords, discovering and tracking network components, net-work analysis, and strategic diagram (32). Therefore, since no research has been conducted so far on the topic and conceptual mapping of *A. baumannii,* and given its importance, it is required to study this field. Providing an overview of the scientific position of the topic in the form of significant and frequent topic keywords considered by researchers in this field increases the effectiveness of current activities. Quantitative evaluation of scientific outputs in this field also allows research officials to utilize most financial and human resources for optimal research and scientific activities. Designating research priorities can lead and allocate resources for appropriate investment, consider the most important priorities, and ensure health resources' effective and efficient utilization, particularly for countries with limited resources (35,36). To that end, the study of literature on *A. baumannii* is required and very important to discover hidden patterns and useful knowledge on the disease causes and more effective treatment, follow up future studies, and orient the planning and decisions of stakeholders in this field to modify and improve conditions.

Challenging areas in medical sciences, e.g., *A. baumannii*, have been studied nationally and internat-ionally using scientometric techniques, which provide some examples of literature related to the present study. Danesh, Ghavidel and Emami **(37)** studied all papers on *A. baumannii* indexed in the WOSCC database during 1990-2019 using the co-citation analysis technique. According to their study for three decades of scientific activity, the global publication trend has grown exponentially, in which the journal of "Diseases Infectious Cli" was identified as the top journal, "Seifert, Harald" was introduced as the most effective researcher, and "Seifert, Harald * Higgins, Paul G." were identified as the top co-citation couple. The top researchers in *A. baumannii* were "Beceiro, Alejandro," "HSU Li Yang," and "Seifert, Harald," respectively, based on degree, betweenness, and closeness centrality indicators. In another study, Farshid *et al.* **(38)** explored the study areas of gastric cancer using the Keywords Co-occurrence Analysis and Hierarchical clustering in scientific outputs from 1997 to 2019. Their results from the analysis of the articles on cancer led to identifying emerging and underdeveloped scopes that can be a scientific basis for future researchers and policies. Baji *et al.* **(39)**, in a study based on co-word analysis and topic clustering, mapped the intellectual structure of health literacy in literature from 1993 to 2017. Their study suggested that in the intellectual structure of the area as mentioned above, which had eight topic clusters (Cluster: C), the highest centrality across the network was observed in the clusters of health care, psychiatry and psychology, public health, social sciences, communications, health services, and health education. Danesh and Ghavidel **(40)** also, in another study, visualized clusters and topic scope dynamics of HPV during 2013-2017 using the word co-occurrence on 17,278 keywords from 13,249 papers. The results showed that the keyword "CERVICAL CANCER" has the highest frequency. Most HPV studies were placed in the third area of the strategic diagram, i.e.; these topics were emerging or declining. In another study, Hasanzadeh *et al.* **(41)** assessed global studies on chronic heart failure during 2000-2015. In this study, a network of the most frequent keywords in this area was visualized, including "heart," "failure," "cardiac," "chronic," and "ventricular". Gholampour, Sabouri, and Noruzi **(42)** also visualized hot and emerging topics on biochemistry and molecular biology in Iran during 2008-2017 based on reviews of journals indexed in the WOS using keywords co-occurrence analysis and reference analysis techniques. They concluded that words such as "gene expression," "protein," "in vitro," "oxidative stress," "transplant," "apoptosis," and "cell" are among hot topics in Iran, and terms such as "chitosan," "nanocomposite," "antibacterial activity," "molecular dynamics," "stem cells," "mesenchymal stem cells," "mesenchymal stem cells," and "immobilization" indicate emerging topics in Iranian research over the study period.

Several studies in international literature have been conducted on various scientific areas of medical sciences, health, and treatment using diverse scientometric, science structure mapping, and co-words techniques, some of which are mentioned below. Chen and Guan **(43)** studied the biopharmaceuticals using co-word analysis and document co-citation analysis networks indexed in three databases. Their three most important research areas were "nanotechnology," "biotechnology," and "pharmacy." Xie **(44)** also studied co-word analysis and document co-citation of anticancer domain indexed in WOS from 2000 to 2014. The results indicated that five hot research topics, including "chemotherapy drugs," "drug delivery system," "bio-screening," "drug resistance research," and "enzyme inhibitor studies," were formed in the topic area. Research frontiers in the anticancer area also included nanoparticle drug delivery systems, controlled clearance, and metabolism. In another study, Nguyen **(45)** studied the scientometrics of non-biomedical therapeutic modalities using Co-word Analysis of Evidence from 1987 to 2017, in which the most commonly used words were "traditional medicine," "alternative medicine," "herbal medicine," and "unclassified medicine."

Furthermore, Baziyad *et al.* **(46)** mapped the intellectual structure of the epidemiological scope using Co-word Analysis in the Python programming language on 400 epidemiological papers indexed in WOS. The results indicated that four main clusters, i.e., genetic, illness, modeling, and prevention, were formed in the topic scope of epidemiology. Therefore, an intellectual structure for every field is required for managers and scholars. Intellectual structures present a comprehensive map of knowledge that can lead researchers and managers to have a better perspective of their expertise. Liu X *et al.* **(47)** studied the literature process and development on the antibiotic resistance of *A. baumannii* in studies indexed in WOS during 1991-2019 using scientometric techniques. They found that the scientific productions on *A. baumannii* are increasing year by year. The United States is the most influential country in this field, which produces a large part of scientific knowledge outputs in addition to high scientific collaboration with other countries.

Moreover, the University of Sydney is the leading producer, and "Bonomo Robert A." publishes most of the papers in this area. Most studies were published on antimicrobial agents and chemotherapy, and researchers were further interested in two topics, "Outbreak" and "Nucleotide sequence." Still, more recently, topics such as "Bacteriophage," "Biofilm," and "Colistin Resistance" have become more prominent in the literature. Pourhatami **(48)**, in a study on coronavirus during 2000-2020 by Co-word Analysis technique, identified the intellectual structure of coronavirus studies and described and presented the main topics of publications in this area. Most of the topic clusters in this area were located in the fourth area of the strategic diagram of the coronavirus scope.

In general, no paper was found that outlined the intellectual structure and addressed concepts and topics on *A. baumannii*. Topic domains of health have always been observed, monitored, and evaluated by scientometric researchers. The results of researchers' studies in scientific and research policy-making have been conductive and instructive. Furthermore, the analysis of Keywords Co-occurrence and scientometric criteria are a favorable technique for visualization and analysis of topic domains of medical science and social media. As mentioned above, this study aims to monitor the intellectual structure of researchers' desirable topics and identify and formulate the relations among research topic priorities on *A. baumannii*.

2.Materials and Methods

This quantitative and applied study is a sciento-metric study using the co-word analysis technique. In Keyword Co-occurrence Analysis or co-word analysis, the most important words or keywords of documents are used to study the conceptual structure of the research scope. Co-occurrence is performed based on the keywords of the title, abstract, or text of the papers, which is an appropriate technique for discovering the links of research fields, tracking structural modifications, and evolving the administrative network from the scientific scope **(49,50)**. Since the use of keywords applied in the title is common, the keywords of the title of papers on *A. baumannii* were also retrieved in this study. A co-word network comprises nodes that represent keywords and their inter-links. On the other hand, researchers in the needs assessment process do their best to prioritize social issues and extend a kind of rationality in using research resources and tools **(35,36)**. The data required for this study were collected from WOSCC due to the importance and global acceptance of WOS.

The statistical population of the present study consisted of all papers on *A. baumannii* that were indexed in the WOSCC between 2002 and 2021 (June 20, 2021, in the sixth month of 2021, the time of data acquisition). This period of nearly 20 years was selected because it seems that this period can well show the scientific structure of *A. baumannii*. The research steps are shown in Figure 1.

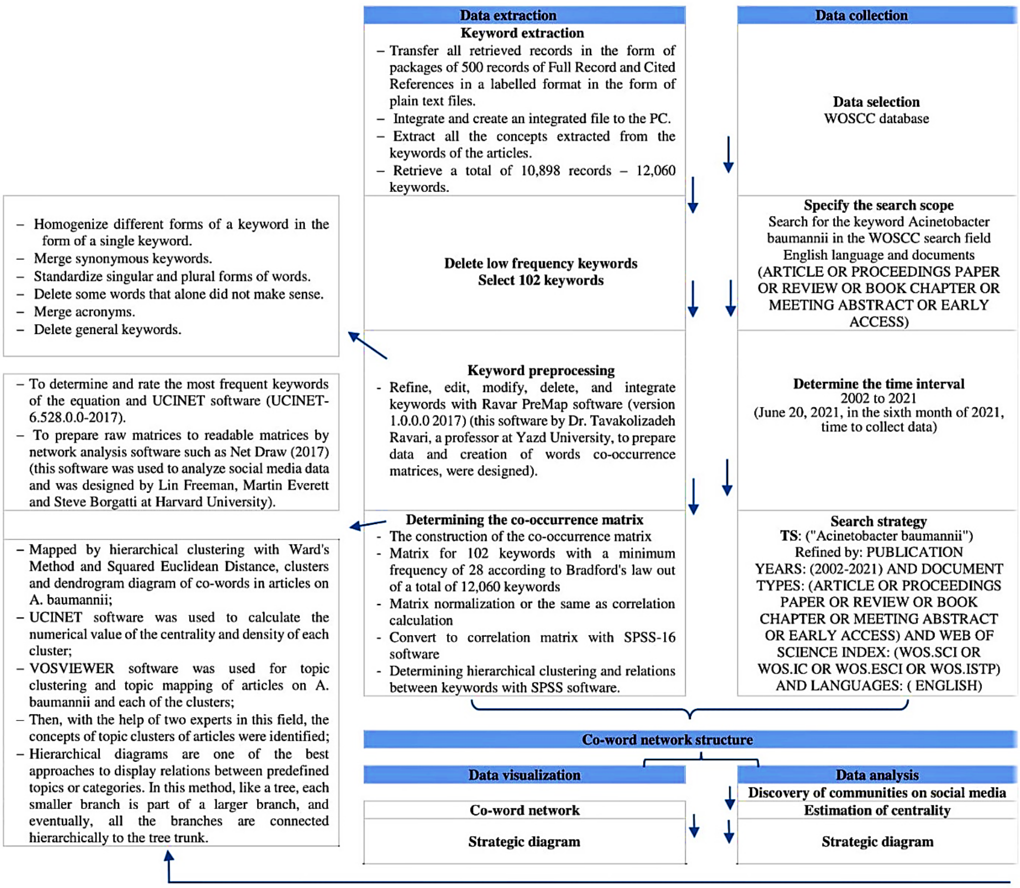


Figure 1. A comprehensive framework of the intellectual structure based on Co-word Analysis of the present study

Co-word Network

Keyword analysis generally identifies clusters of keywords that are often found in peer conceptual articles. The co-word network is mapped based on the normalized co-occurrence matrix. The co-occurrence matrix is derived from the keywords in the documents. The Jaccard index **(51)** calculates the similarity between two objects. Equation 1 shows the calculation of the Jaccard index:

Equation 1:

$$J_{ij} = \frac{C_{ij}}{C_i + C_j + C_{ij}}$$

Where C_{ij} is the number of co-occurrence keywords *i* and *j*. Also, C_i and C_j are the numbers of occurrences of the keywords *i* and *j*, respectively (51). The co-word network is mapped after mapping the co-occurrence matrix. Each of the keywords in the co-occurrence matrix plays the role of a node in the co-word network, and each normalized weight of the matrix is considered as the edge weight in the co-word graph (48).

Strategic Diagram

Another analysis technique used in this study is the strategic diagram, shown in Figure 2. In a strategic diagram, the x-axis represents the degree of centrality, and the y-axis represents the density. As shown in Figure 2, the strategy diagram can be delivered with four quadrants (Q), each with a different centrality and density. The clusters located in that have different positions. More precisely, the clusters located in the first quadrant have high centrality and density, are mature, and are placed in the core of the study area. This quadrant is called the "Main Stream." The clusters in the second quadrant are not central but are well-developed, and this quadrant is called the "Ivory Tower." Third-quadrant clusters called "Chaos/Unstructured" are marginal and received little attention; and ultimately, the topic clusters in the fourth quadrant or "Bandwagon," although central, are underdeveloped or immature **(48, 52, 53)**. Multiple papers in Co-word Analysis have used the clustering of keywords and strategic maps. Centrality and density were calculated using Equations 2 and 3, respectively.

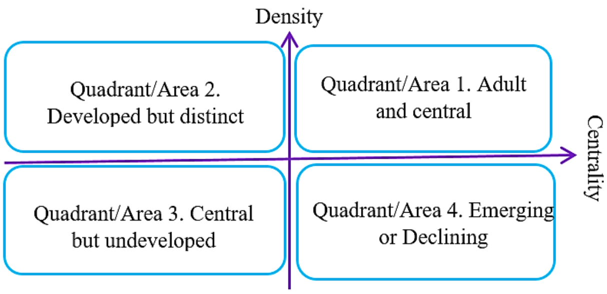


Figure 2. The four areas of a schematic strategic diagram (adopted from Melcer *et al.* (54))

The node centrality equals the total number of direct connections to a node. The greater the centrality for a particular keyword, the more the keyword is used in research. Moreover, network density is the ratio between the actual number of links and the maximum number of possible links that can be obtained from the network.

Equation 2:

$$C_L = \sum_{i \in L} \sum_{i \in M} W_{ij} \cdot e_{ij}$$

Where C_L is the centrality of population L, node *i* denotes population L, the list of other populations except population L is given by M, and *j* is the nodes in all populations M. Also, e_{ij} is a binary variable that is equal to 1 if there is an edge between nodes *i* and *j*. Otherwise, it is equal to 0. Finally, w_{ij} is considered an edge weight between nodes *i* and *j*.

Equation 3:

$$D_L = \frac{2E}{N(N-1)}$$

Where DL expresses the density of the population L, E is the total number of edges in L, and N is the total number of nodes in L.

3.Results

3.1 Frequency Distribution of Keywords of Articles on *A. baumannii* Based on Keywords Co-occurrence

Table 2 shows the twenty most common keywords in articles on *A. baumannii*. As observed in Table 1, the keyword "MULTIDRUG RESISTANCE (MDR)" with 773 repetitions has the highest frequency among keywords. Then the keywords "ANTIBIOTIC RESISTANCE" and "RESISTANCE" are jointly rated second and third with a frequency of 498. An overview of the high-frequency keyword network of articles on *A. baumannii*, which is about 102 keywords, is visualized in Map 1. The intensity and extent of the connection between the nodes (keywords) are significant.

Table 1. Keyword rating of articles on *A. baumannii* based on Keywords Co-occurrence

No.	Keyword	Frequency	No.	Keyword	Frequency
1	MULTIDRUG RESISTANCE (MDR)	773	11	NOSOCOMIAL INFECTION	240
2	ANTIBIOTIC RESISTANCE	498	12	CARBAPENEMS	239
3	COLISTIN	498	13	TIGECYCLINE	234
4	PSEUDOMONAS AERUGINOSA	428	14	GRAM-NEGATIVE BACTERIA	228
5	ANTIMICROBIAL RESISTANCE	352	15	RESISTANCE	226
6	CARBAPENEMASE	339	16	VENTILATOR-ASSOCIATED PNEUMONIA (VAP)	190
7	BACTEREMIA	292	17	INFECTION	181
8	INTENSIVE CARE UNIT (ICU)	291	18	DRUG RESISTANCE	164
9	CARBAPENEM RESISTANCE	284	19	PNEUMONIA	164
10	ANTIBIOTICS	241	20	POLYMYXINS	153

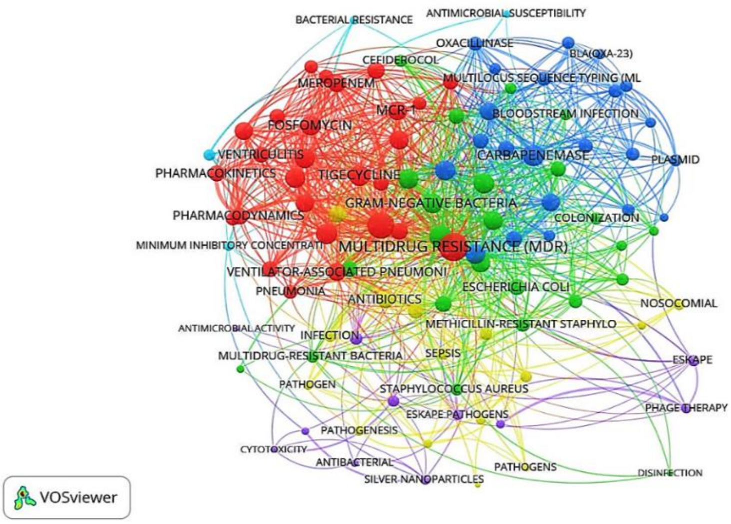


Figure 3. Overview of the high-frequency keyword network of articles on *A. baumannii*

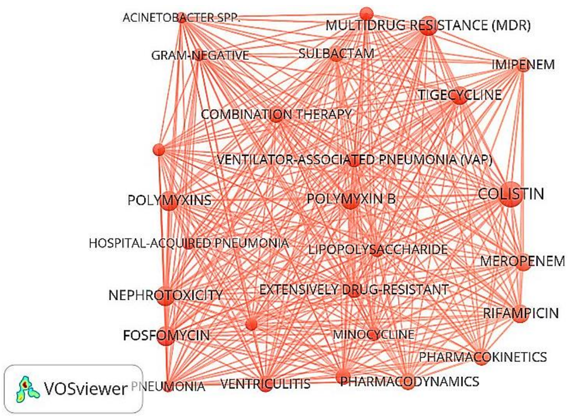
Figure 3 illustrates an overview of the most frequent keyword network of articles on *A. baumannii*. In this network, the connection between network keywords is specified by lines. In this map, each of the circles (nodes) represents a topic, and the lines indicate how the connection between the nodes. The number of connections is greater than the number of nodes. Larger nodes represent topics with a higher frequency than other topics. The color of the nodes indicates five topic clusters. Nodes with the same color are in a cluster. As can be seen, the keyword "MULTIDRUG RESISTANCE (MDR)" has the highest frequency among the keywords and is located in the most central position of the network, and the keywords with a lower frequency are seen in the margin of the network.

3.2 Concepts and Clusters of Keywords Co-occurrence Articles on *A. baumannii*

At this step, thresholds were determined by dividing the mean score for each variable. The thresholds allow upper or lower classifying for each index. This classification helps each factor fit into its own cell in the matrix. In order to map topic clusters of articles on *A. baumannii*, first the correlation matrix – obtained based on the frequency co-word matrix – was transferred to SPSS software and using hierarchical clustering – obtained by the Ward and the Euclidean squared distance – "clusters and dendrogram diagrams of co-words of articles on *A. baumannii*" were mapped, which are reported in Table 2. The average distance of objects in a cluster is first calculated in this method, which is based on the sum of squares of the differences between each data and a cluster with the average vector of that cluster **(55)**. In other words, a hierarchical diagram is one of the best methods to represent relations between predefined topics or categories. In this method, like a tree, each smaller branch is part of a larger branch, and eventually, all the branches are hierarchically connected to the tree's trunk. The advantage of the hierarchical clustering method is that discovering the hierarchical relations between objects is possible, and it is also easier to see the similarity between them visually **(55)**. At this step, the "clusters and dendrogram diagrams of co-words of the papers on *A. baumannii*" were mapped by identifying the inclusion threshold on the keywords with a frequency of >28 in the SPSS. Next, it is required to accurately identify and study the keywords in each cluster and compare them with the keywords in that cluster to determine the main topic of that cluster finally. In the maps for each cluster, each of the circles (nodes) represents a topic, and the lines indicate how the nodes connect. The number of connections is greater than the number of nodes. The central nodes represent the topics that attract the most attention, and the nodes at the edge of each map represent the least addressed topics in that cluster.

Table 2. Concepts and clusters from Keywords Co-occurrence Analysis of articles on *A. baumannii* according to co-word dendrogram diagram

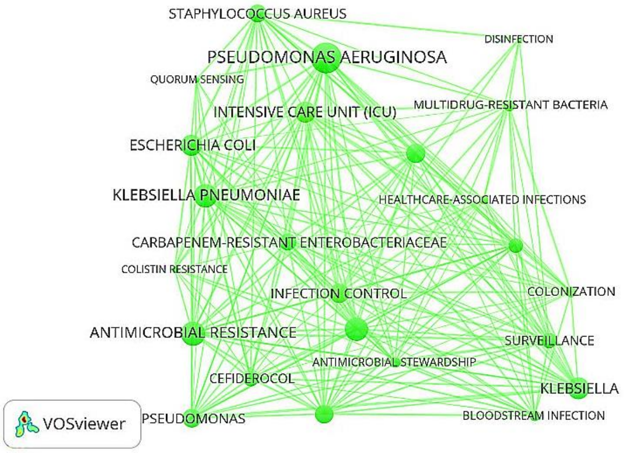
Cluster	Main keywords	Member No.	Link No.	Centrality	Density
C1	MULTIDRUG RESISTANCE (MDR); COLISTIN; TIGECYCLINE; VENTILATOR-ASSOCIATED PNEUMONIA (VAP); PNEUMONIA; POLYMYXINS; CARBAPENEM-RESISTANT; IMIPENEM; POLYMYXIN B; MEROPENEM; GRAM-NEGATIVE; SULBACTAM; PHARMACOKINETICS; COMBINATION THERAPY; PHARMACODYNAMICS; MENINGITIS; ACINETOBACTER SPP.; NEPHROTOXICITY; MINOCYCLINE; HOSPITAL-ACQUIRED PNEUMONIA; FOSFOMYCIN; RIFAMPICIN; EXTENSIVELY DRUG-RESISTANT; LIPOPOLYSACCHARIDE; MCR-1; VENTRICULITIS; AMINOGLYCOSIDES	27	680	25.185	0.969



Map 1. Keywords and conceptual interface Cluster 1: Keywords Co-occurrence of articles on *A. baumannii*

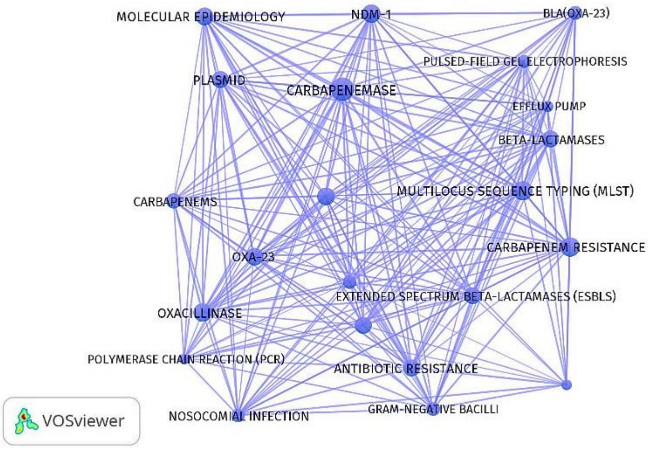
Cluster	Main keywords	Member No.	Link No.	Centrality	Density
C2	PSEUDOMONAS AERUGINOSA; ANTIMICROBIAL RESISTANCE; INTENSIVE CARE UNIT (ICU); GRAM-NEGATIVE BACTERIA; KLEBSIELLA PNEUMONIAE; ENTEROBACTERIACEAE; METHICILLIN-RESISTANT STAPHYLOCOCCUS AUREUS (MRSA); ESCHERICHIA COLI; INFECTION CONTROL; SURVEILLANCE; STAPHYLOCOCCUS AUREUS; COLISTIN RESISTANCE; PSEUDOMONAS; MULTIDRUG-RESISTANT BACTERIA; BLOODSTREAM INFECTION; COLONIZATION; HEALTHCARE-ASSOCIATED INFECTIONS; QUORUM SENSING; KLEBSIELLA; ANTIMICROBIAL STEWARDSHIP; DISINFECTION; CARBAPENEM-RESISTANT ENTEROBACTERIACEAE; CEFIDEROCOL; HOSPITAL-ACQUIRED INFECTION	24	420	17.5	0.761

Cluster	Main keywords	Member No.	Link No.	Centrality	Density



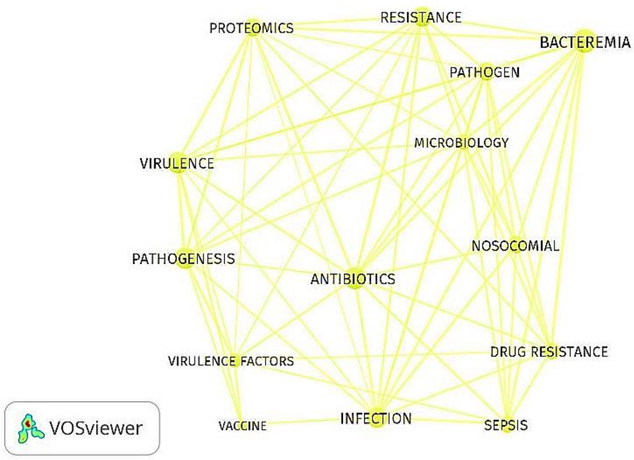
Map 2. Keywords and conceptual interface Cluster 2: Keywords Co-occurrence of articles on *A. baumannii*

C3	ANTIBIOTIC RESISTANCE; CARBAPENEMASE; CARBAPENEM RESISTANCE; NOSOCOMIAL INFECTION; CARBAPENEMS; BETA-LACTAMASES; METALLO-BETA-LACTAMASE; MULTILOCUS SEQUENCE TYPING (MLST); EXTENDED SPECTRUM BETA-LACTAMASES (ESBLS); MOLECULAR EPIDEMIOLOGY; OXA-23; POLYMERASE CHAIN REACTION (PCR); GRAM-NEGATIVE BACILLI; PULSED FIELD GEL ELECTROPHORESIS (PFGE); NDM-1; INTEGRON; EFFLUX PUMP; WHOLE-GENOME SEQUENCING; PLASMID; OXACILLINASE; PULSED-FIELD GEL ELECTROPHORESIS; BLA(OXA-23)	22	430	19.545	0.931



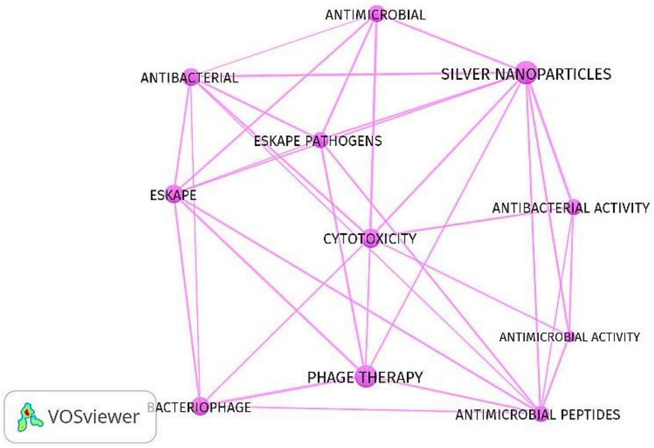
Map 3. Keywords and conceptual interface Cluster 3: Keywords Co-occurrence of articles on *A. baumannii*

C4	BACTEREMIA; ANTIBIOTICS; RESISTANCE; INFECTION; DRUG RESISTANCE; VIRULENCE; SEPSIS; VIRULENCE FACTORS; MICROBIOLOGY; NOSOCOMIAL; PATHOGEN; PATHOGENESIS; VACCINE; PROTEOMICS	14	132	9.867	0.705



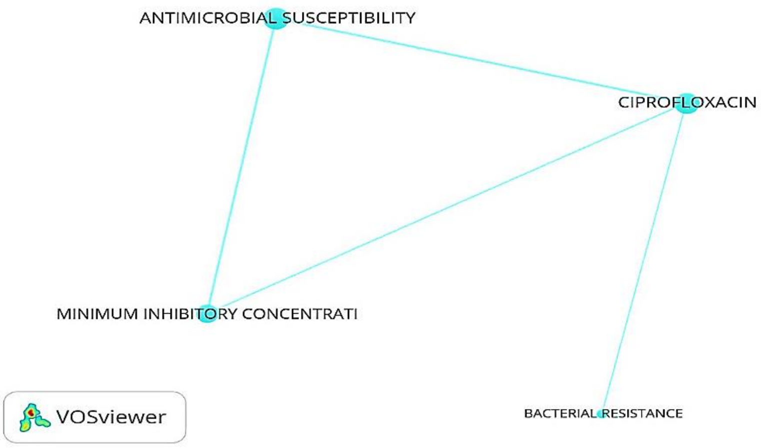
Map 4. Keywords and conceptual interface Cluster 4: Keywords Co-occurrence of articles on *A. baumannii*

Cluster	Main keywords	Member No.	Link No.	Centrality	Density
C5	ANTIMICROBIAL; ANTIBACTERIAL ACTIVITY; ANTIMICROBIAL PEPTIDES; ANTIMICROBIAL ACTIVITY; ANTIBACTERIAL; BACTERIOPHAGE; ESKAPE; SILVER NANOPARTICLES; ESKAPE PATHOGENS; PHAGE THERAPY; CYTOTOXICITY	11	68	6.182	0.618



Map 5. Keywords and conceptual interface Cluster 5: Keywords Co-occurrence of articles on *A. baumannii*

Cluster	Main keywords	Member No.	Link No.	Centrality	Density
C6	MINIMUM INHIBITORY CONCENTRATION (MIC); ANTIMICROBIAL SUSCEPTIBILITY; CIPROFLOXACIN; BACTERIAL RESISTANCE	4	8	2	0.667



Map 6. Keywords and conceptual interface Cluster 6: Keywords Co-occurrence of articles on *A. baumannii*

The dendrogram diagram provides valuable tips and information about clusters, words in clusters, and the word structure of the topic area. Data analysis of co-words of the papers on *A. baumannii* has led to the formation of topic Cluster 6 in the dendrogram. Topic clusters (C) of papers on *A. baumannii* provide useful data as follows (Table 2).

C1. Antibiotic and Multidrug-resistant Bacterial Infections in the Hospital Setting: This cluster had 27 keywords with 680 links to other keywords, and the cluster centrality and density were 25.185 and 0.969, respectively. The first cluster is the largest cluster formed in the study area, and the most frequent keyword in the field is "MULTIDRUG RESISTANCE (MDR)," then the third keyword, "Colistin," is located in this cluster. This cluster topic is found by assessing the keywords in Cluster 1.

C2. Nosocomial Infections: This cluster consists of 24 keywords with 420 links between keywords, indicating virulent and resistant bacteria in the hospital intensive care unit (ICU). The centrality and density of this cluster were 17.5 and 0.761, respect-tively. The fourth and fifth most frequent keywords in this cluster were "PSEUDOMONAS AERUGINOSA" and "ANTIMICROBIAL RESISTANCE," respectively. This cluster was named Cluster 2 due to these two keywords.

C3. Antibiotics and Bacterial Resistance Mechanisms to Antibiotics: This cluster had 22 keywords with 430 links. Its centrality and density are

19.545 and 0.931, respectively. The second and sixth most frequent and important keywords in this topic area, namely "ANTIBIOTIC RESISTANCE" and "CARBAPENEMASE," are located in this cluster.

C4. *Acinetobacter* as a Nosocomial Pathogen: This Cluster consisted of 14 members with 132 links. The centrality and density of this cluster were 9.867 and 0.705, respectively. The seventh most frequent keyword in the area was "CARBAPENEMASE" and the presence of the keywords "PATHOGEN" and "PATHOGENESIS" located in C4, which led to the name this cluster.

C5. Pathogen and Antimicrobial Resistance: This cluster had 11 keywords with 68 links, and its centrality and density were 6.182 and 0.618, respectively. The presence of keywords such as "ANTIMICROBIAL," "ANTIBACTERIAL," "ESKAPE," and other keywords determined the selection of the topic of this cluster.

C6. Antibacterial Drug Resistance Model: The smallest cluster was the studied C4 scope with four keywords and eight links, and its centrality and density were 2 and 0.667, respectively.

3.3 Topic Area Structure of *A. baumannii* using a Strategic Diagram

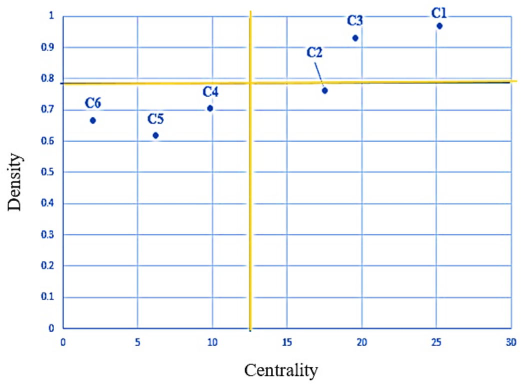


Figure 4. Strategic diagram of *A. baumannii* based on density and centrality

According to the areas presented in the schematic strategic diagram in Figure 2, the distribution of clusters in this study's strategic diagram (Figure 4) indicates that none of the clusters were placed in the first area. Clusters 1, 2, and 3 are located in the study area of *A. baumannii* in area 1 of the strategic diagram. None of the clusters had centrality and density to fit in the second area of the strategic diagram. Clusters 4, 5, and 6 are in the third area of the strategic diagram due to their low centrality and density. Finally, there are topic clusters that are central, undeveloped, and immature in the fourth area of the strategic diagram, in which no topic cluster existed in this area in the present study.

4.Discussion and Conclusion

This study attempted to provide a favorable view of the intellectual structure governing the literature regarding *A. baumannii*, using the Keywords Co-occurrence Analysis technique and applying hierarchical clustering and strategic diagram and scientific visualization software. The literature on *A. baumannii* showed that two studies were performed using scientometric techniques. Although Danesh, Ghavidel, and Emami **(37)** study generally has a topic similarity with the present study in scientometric techniques on *A. baumannii*, the present study has a different approach in applying scientometric techniques (e.g., publication growth process, publication growth rate, top journals, the most effective researchers, top co-citation author couples, and top researchers in the field of *A. baumannii*). It assesses the topics and concepts considered by researchers in the above topic. Liu X *et al.* **(47)** also studied *A. baumannii*, but their study was different from the present study in methodology and scientometric evaluation techniques such as product development trend, authors, countries, institutions, keywords, and citations. Therefore, the present study partially pointed out the topic and conceptual trends in different periods. The strength and advantage of the present study over the other two studies are that the topic, conceptual, and intellectual structure of researchers who are the creators of scientific publications based on clinical studies have been considered. This has identified mature, new, and important fields of study.

According to the study results, the keyword "MULTIDRUG RESISTANCE (MDR)" has the highest frequency among the papers on *A. baumannii*. The WHO introduced antibiotic-resistant bacteria as one of the most serious global health threats, accounting for a high percentage of annual hospital mortality **(56)**. According to the present study results "multiple drug resistance" has the highest frequency among the keywords of papers on *A. baumannii*. "MULTIDRUG RESISTANCE," which is simultaneously seen that different classes of antibiotics used in hospitals has been a concern in studies in this area. Hence, the above topic has occupied a large contribution of studies on *A. baumannii*.

Of course, each of the keywords listed in Table 1 is very significant in the studies on *A. baumannii*. The second most frequent keyword, "ANTIBIOTIC RESISTANCE," is very close to the first keyword (MULTIDRUG RESISTANCE), the third keyword, the antibiotic "Colistin," confirms this. This shows that experts are attempting to find the proper solution to overcome the most important human health challenges and concerns: antibiotic resistance. The present study is consistent with the research of Farshid *et al.* **(38)** on the study of gastric cancer, Danesh and Ghavidel **(40)**, Hasanzadeh *et al.* **(41)**, Gholampour, Sabouri, and Noruzi **(42)**, Xie **(44)**, Nguyen **(45)**, and Pourhatami **(48)** on the frequent keywords. The present study in mapping co-words is consistent with Baji *et al.* **(39)**, Danesh and Ghavidel **(40)**, Gholampour, Saboury, and Noruzi **(42)**, Chen and Guan **(43)**, Xie **(44)**, Baziyad *et al.* **(46)**, and Pourhatami **(48)**.

According to Co-word Analysis, the hierarchical clustering analysis to identify the intellectual structure governing the topic of *A. baumannii* led to the formation of 6 topic clusters. C1 seems to be important among the clusters since the most frequent and common keyword of *A. baumannii* is placed in this cluster. Keywords in this cluster refer to "antibiotics and multidrug-resistant bacterial infections in the hospital setting." C2 was related to "nosocomial infections." C3, "Antibiotics and Mechanisms of Bacterial Resistance to Antibiotics," has a core and important place due to the presence of two high-frequency keywords. C4 referred to nosocomial pathogen and *Acinetobacter*, while C5 referred to "pathogen and antimicrobial resistance" and C6 referred to the "antibacterial resistance model" in the area of *A. baumannii*. Hierarchical cluster analysis has been used in numerous studies in health. According to the topic clusters, the present study is consistent with studies of Farshid *et al.* **(38)**, Baji *et al.* **(39)**, Baziyad *et al.* **(46)**, Danesh and Ghavidel **(57)**, and Pourhatami **(48)**.

The results of the strategic diagram and distribution of clusters in the strategic diagram (Figure 3) suggested that the topics and concepts discussed in Clusters 1, 2, and 3 of studies on *A. baumannii* include: "Antibiotics and multidrug-resistant bacterial infections in the hospital setting," "Nosocomial infections," and "antibiotics and the bacterial resistance mechanisms to antibiotics", which placed in the first area of the diagram, are considered to be mature and central issues that play a pivotal and developed role. The absence of cluster in area 2 proves that none of the topics and concepts studied on *A. baumannii* have been developed but are distinct.

Area 3 clusters, i.e., clusters 4, 5, and 6, include: "*Acinetobacter* as a nosocomial pathogen," "pathogen and antimicrobial resistance," and "antibacterial resistance pattern," have lower centrality and density than other clusters, so they are considered marginal. They are either emerging or declining due to little consideration of them. According to the strategic diagram, none of the topic clusters are in the fourth area. Therefore, the study area does not have topics that are central and, at the same time, undeveloped and immature. In general, topic clusters are placed in areas 1 and 3 of the strategic diagram, which indicates either the topics of interest to the researchers in the field have received particular attention, in which sufficient studies have been conducted, and are several current topics that are declining, or they are emerging topics requiring further work and research. In addition, clusters 3 and 6 have a lot of conceptual affinities. This part of the findings is consistent with the results of Farshid *et al.* **(38)**, Danesh and Ghavidel **(40)**, and Pourhatami **(48)**.

The present study results allow researchers to be aware of the important and fundamental topics and conceptual priorities, the intellectual structure, and the research dynamics regarding *A. baumannii*. Knowledge of the concepts considered by researchers over time and research and topic situation leads future research programs quantitatively and qualitatively, general scientific policy, selection of research topic, explanation of novel and more effective research decisions, better use of financial and human resources, more appropriate investment for optimal research and scientific activities by research officials, planners, and decision-makers in the field of health, particularly *A. baumannii*.

5. Research Limitations

The existence of words or phrases in different or synonymous forms was one of the restrictions of this study, which required homogenization. Ravar PreMap software was used to solve this problem. Furthermore, some of the specialized keywords required the thematic expert for which two specialists in microbiology and physicians specializing in infection control were consulted.

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Authors' Contribution

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Conflict of Interest

The authors have no conflict of interest to declare relevant to this article's content.

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