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EDITED BY

Cesar Lopez-Camacho,
University of Oxford, United Kingdom

REVIEWED BY

Elnaz Faghfuri,
Ardabil University of Medical Sciences, Iran
Qunying Mao,
National Institutes for Food and Drug
Control, China

*CORRESPONDENCE

Yi Sang

✉ ndsfy001889@ncu.edu.cn

Chenxi Li

✉ pamelalee@nwafu.edu.cn

[†]These authors have contributed equally to
this work

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Global research on RNA vaccines for COVID-19 from 2019 to 2023: a bibliometric analysis

Ziyi Chen^{1,2†}, Zhiliang Liu^{3†}, Yali Feng⁴, Aochen Shi², Liqing Wu²,
Yi Sang^{2*} and Chenxi Li^{1,2*}

¹Center for Molecular Diagnosis and Precision Medicine, The First Affiliated Hospital, Jiangxi Medical College, Nanchang University, Nanchang, China, ²Jiangxi Key Laboratory of Cancer Metastasis and Precision Treatment, the First Hospital of Nanchang, Nanchang, China, ³Department of Pathology, Jiangxi Cancer Hospital, Nanchang, China, ⁴Department of Pathology, Jiangxi Provincial Chest Hospital, Nanchang, China

Background: Since the global pandemic of COVID-19 has broken out, thousands of pieces of literature on COVID-19 RNA vaccines have been published in various journals. The overall measurement and analysis of RNA vaccines for COVID-19, with the help of sophisticated mathematical tools, could provide deep insights into global research performance and the collaborative architectural structure within the scientific community of COVID-19 mRNA vaccines. In this bibliometric analysis, we aim to determine the extent of the scientific output related to COVID-19 RNA vaccines between 2019 and 2023.

Methods: We applied the Bibliometrix R package for comprehensive science mapping analysis of extensive bibliographic metadata retrieved from the Web of Science Core Collection database. On January 11th, 2024, the Web of Science database was searched for COVID-19 RNA vaccine-related publications using predetermined search keywords with specific restrictions. Bradford's law was applied to evaluate the core journals in this field. The data was analyzed with various bibliometric indicators using the Bibliometrix R package.

Results: The final analysis included 2962 publications published between 2020 and 2023 while there is no related publication in 2019. The most productive year was 2022. The most relevant leading authors in terms of publications were Ugur Sahin and Pei-Yong, Shi, who had the highest total citations in this field. The core journals were Vaccines, Frontiers in Immunology, and Viruses-Basel. The most frequently used author's keywords were COVID-19, SARS-CoV-2, and vaccine. Recent COVID-19 RNA vaccine-related topics included mental health, COVID-19 vaccines in humans, people, and the pandemic. Harvard University was the top-ranked institution. The leading country in terms of publications, citations, corresponding author country, and international collaboration was the United States. The United States had the most robust collaboration with China.

Conclusion: The research hotspots include COVID-19 vaccines and the pandemic in people. We identified international collaboration and research

expenditure strongly associated with COVID-19 vaccine research productivity. Researchers' collaboration among developed countries should be extended to low-income countries to expand COVID-19 vaccine-related research and understanding.

KEYWORDS

COVID-19, SARS-CoV-2, RNA vaccines, web of science, bibliometrics

Introduction

Since 2019, the global COVID-19 pandemic has affected the lives of billions of people worldwide (1). To deal with this situation, countries worldwide began to develop vaccines, including traditional inactivated vaccines, recombinant protein, live-attenuated vaccines, RNA vaccines, etc. (2–15). On October 2nd, 2023, the Nobel Assembly at the Karolinska Institutet decided to award the 2023 Nobel Prize in Physiology or Medicine jointly to Katalin Karikó and Drew Weissman for their discovery of nucleoside base modifications, which made it possible to develop an effective mRNA vaccine against COVID-19 (16). RNA vaccines have received widespread attention due to their high efficacy, specificity, versatility, rapid and large-scale development capabilities, low-cost production potential, and safety (17, 18). RNA vaccines have been developed for several decades (19, 20), and since COVID-19 has broken worldly, the RNA vaccines platform has enabled fast vaccine development in response to this pandemic (21). RNA vaccines provide flexibility in the design and expression of vaccine antigens, simulating the structure and expression of antigens during natural infections. RNA is necessary for protein synthesis and unconformity into the genome, and it is transiently expressed, metabolized, and eliminated by the body's natural mechanism (22), so it is considered relatively safe. Many clinical trials have proven RNA-based preventive infectious disease vaccines and RNA therapeutic agents to be safe and well-tolerated (23–29). Generally speaking, vaccination with RNA can trigger a robust innate immune response. RNA guides the expression of vaccine antigens in host cells and has intrinsic adjuvant effects (30–32). One advantage of the RNA vaccine manufacturing platform is that it can quickly produce many vaccines targeting new pathogens, regardless of the encoded pathogen antigen (33). The bibliometric analysis of published articles provides insights into research prospects, gaps, and future directions in the research field. This study examined scientific publications related to RNA vaccines for COVID-19 through bibliometric analysis and trend analysis.

Results

Search strategy

We conducted a literature search on the Web of Science Core Collection (WoSCC) database (<https://www.webofscience.com/wos/>

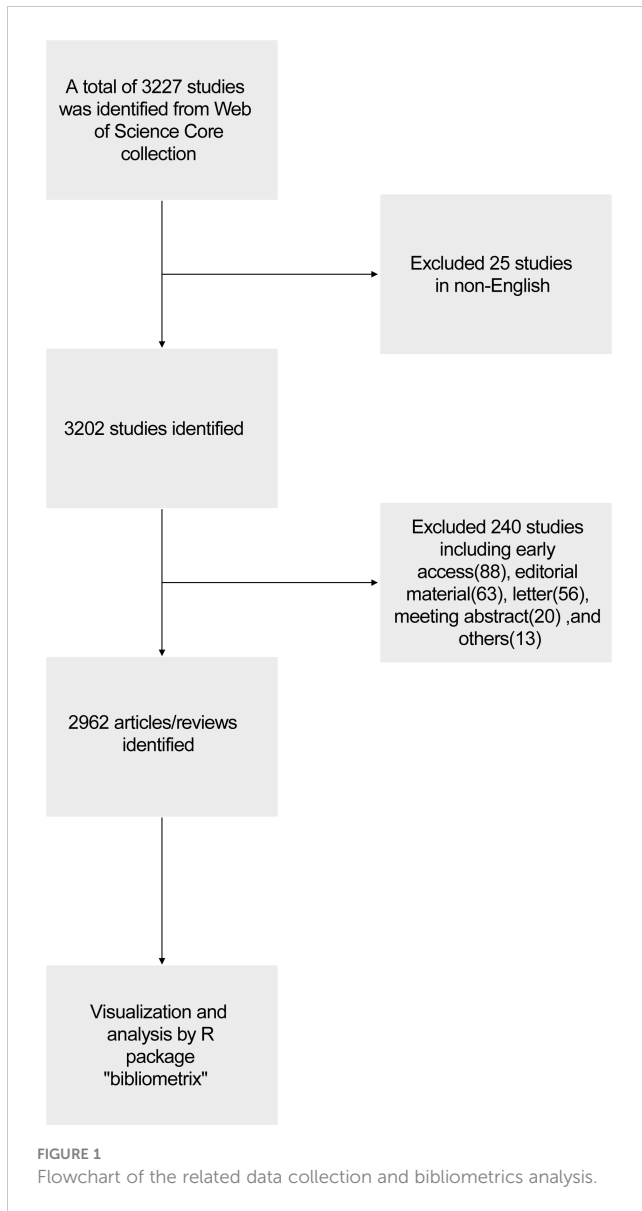
[woscc/basic-search](#)) on January 11th, 2024. The search formula was $TS = ((RNA\ vaccine\ AND\ COVID-19)\ OR\ (RNA\ vaccine\ AND\ SARS-COV-2))$, the published year was set before 2024, and the type of documents was set to articles and reviews. The language filter was set in English (Figure 1). According to our search strategies, there were 2962 studies of RNA vaccines for COVID-19 between 2020 and 2023 (0 publication in 2019), including 1956 articles and 1006 reviews. The analyzed publications were written by 23141 authors (93 with single-authored documents and 23048 with multi-authored documents) from 104 countries and 908 journals.

Characteristics of the year of publication

Figure 2A shows that the number of annual related publications increased rapidly year by year from 2020 to 2022. In 2020, 271 articles were published, while 795 in 2021, 1144 in 2022, and 752 in 2023. The most productive year was 2022 ($n = 1144$) with the annual scientific growth rate of 143.9%. The total number of citations per article and the average citations per year have decreased (Figure 2B). In 2020, the average number of citations per article was 123.5, 45.9 in 2021, 17.3 in 2022, and 2.48 in 2023. The total average number of citations per year was 24.7 in 2020, 11.5 in 2021, 5.8 in 2022, and 1.2 in 2023.

Characteristics of the countries

We filtered and visualized 104 countries that published more than ten articles and constructed a collaborative network based on the number and relationship of publications in each country. From Figure 3A, we can point out that the United States has the highest literature output ($n=4163$) on COVID-19 RNA vaccines, and the number is significantly higher than that of China ($n=1844$) and Italy ($n=936$). Notably, there is much active cooperation between different countries. For example, the United States closely cooperates with China, the United Kingdom, Germany, and Italy; India actively cooperates with Saudi Arabia (Figure 3B). It shows that the United States has the most significant number of SCPs and MCPs, which indicates that the United States has the most researches on COVID-19 RNA vaccines and cooperation with other countries in this regard, followed by China on both SCP and MCP (Figure 3C).



Characteristics of the affiliations

In **Figure 4A**, Harvard University has the highest number of institutions that receive and publish articles ($n=249$), followed by

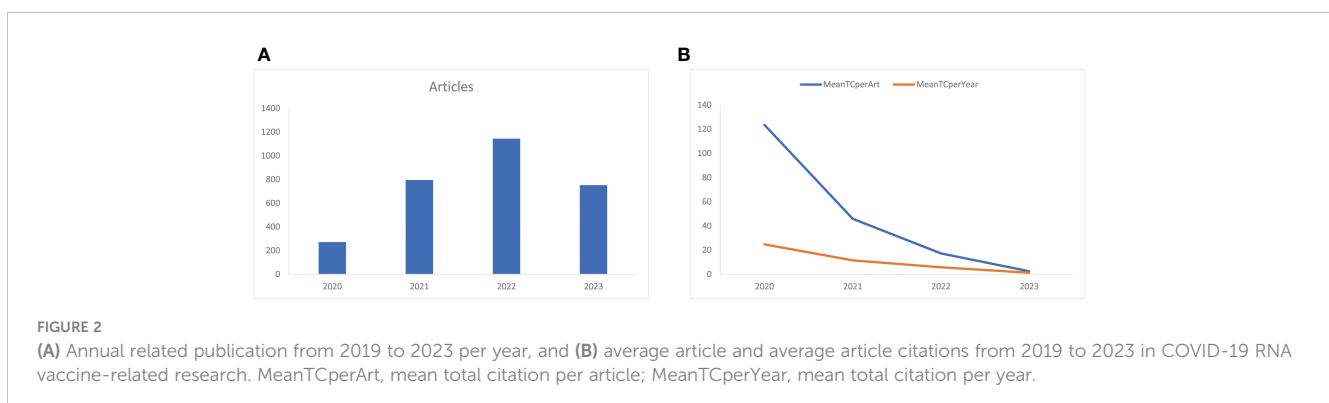
the University of California System ($n=160$) and Harvard Medical School ($n=76$). Half the top 20 most relevant affiliations were from the United States, followed by the United Kingdom, China, France, and Israel. Subsequently, we selected 34 institutions based on visualization with a minimum number of publications equal to 5. We constructed a collaborative network based on the number of publications and relationships of each affiliation (**Figure 4B**). As shown in **Figure 4B**, Harvard University and Harvard Medical School cooperated the most, and Tel Aviv University and Sheba Medical Center also had active cooperation. In addition, we noticed that Harvard University had published the most papers and collaborated with the most significant number of affiliations.

Characteristics of the top 20 most productive authors

The number of academic publications by an author can represent research activities and contributions in the field to some extent. As shown in **Table 1**, Ugur Sahin was the most influential author from University Medical Center, Johannes Gutenberg University, between 2020 and 2023 on COVID-19 RNA vaccines, who had published 14 articles in this field, whose h-index is 9, g-index is 14, m-index is 2.6. He also has the highest number of total citations ($n=14203$). Pei-Yong Shi's h-index ($n=12$) is a close second. Pei-Yong Shi published 16 articles in this field between 2020 and 2023; his g-index is 16, and his m-index is 2.4. Notably, we can find that Pei-Yong Shi and Ugur Sahin had the most significant academic influence on COVID-19 RNA vaccines.

Characteristics of the top 20 journals and co-cited journals

Followed by *Frontiers in Immunology* ($n=105$, 3.54%) and *Viruses-Basel* ($n=58$, 2.94%), the *Vaccines* published the most articles on COVID-19 RNA vaccines ($n=171$, 5.77%) throughout four years. However, the *New England Journal of Medicine*, *Nature*, and *Science* were the most cited journals. Bradford's law was applied to assess the core journals in the field of COVID-19 RNA vaccines. As shown in **Figure 5A**, the core journals in COVID-19 RNA vaccines were *Vaccines*, *Frontiers*



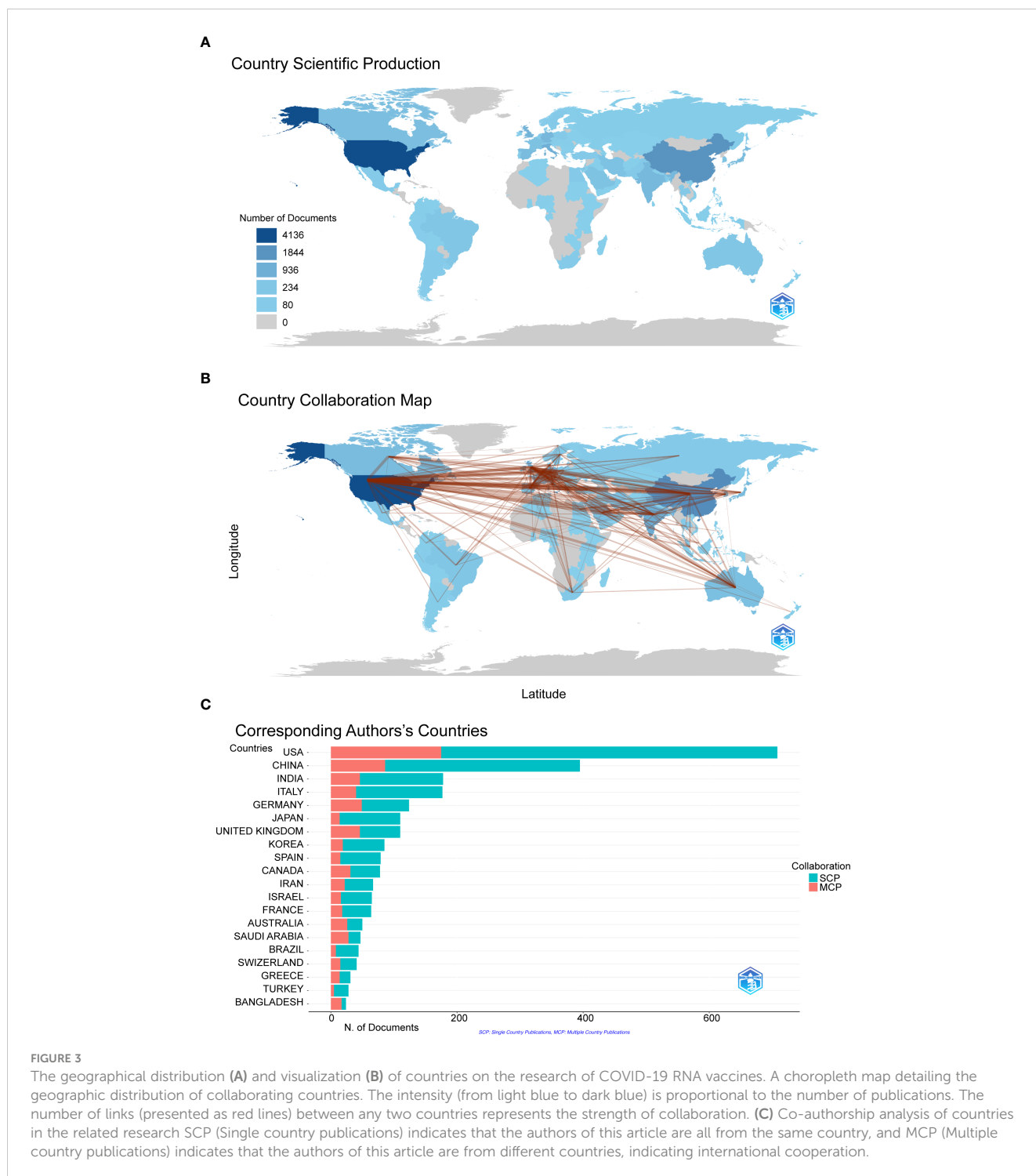


FIGURE 3

The geographical distribution (A) and visualization (B) of countries on the research of COVID-19 RNA vaccines. A choropleth map detailing the geographic distribution of collaborating countries. The intensity (from light blue to dark blue) is proportional to the number of publications. The number of links (presented as red lines) between any two countries represents the strength of collaboration. (C) Co-authorship analysis of countries in the related research SCP (Single country publications) indicates that the authors of this article are all from the same country, and MCP (Multiple country publications) indicates that the authors of this article are from different countries, indicating international cooperation.

in Immunology, Viruses-Basel, Clinical Infectious Diseases, Journal of Medical Virology, etc. As for co-cited journals in Figure 5B, journals were categorized into different clusters. The nodes with different colors in the graph represent different clusters. The node size represents the number of articles published in the journal, and the thickness of the lines represents the number of connections between nodes. Frontiers in Immunology, Vaccines, and Journal of Medical Virology were the top three most influential journals in this field. This result can

help scholars to select the best-fit journals for submitting their research findings. Also, Table 2 lists the top 20 most-cited publications on COVID-19 RNA vaccines. All these productions were published between 2020 and 2023, and 65% obtained more than 1000 citations. Table 2 shows that the New England Journal of Medicine was the highest-cited journal with the highest h-index, m-index, and total citations. Frontiers in Immunology has the highest g-index. These indexes showed the importance of these two journals on COVID-19 RNA vaccines.

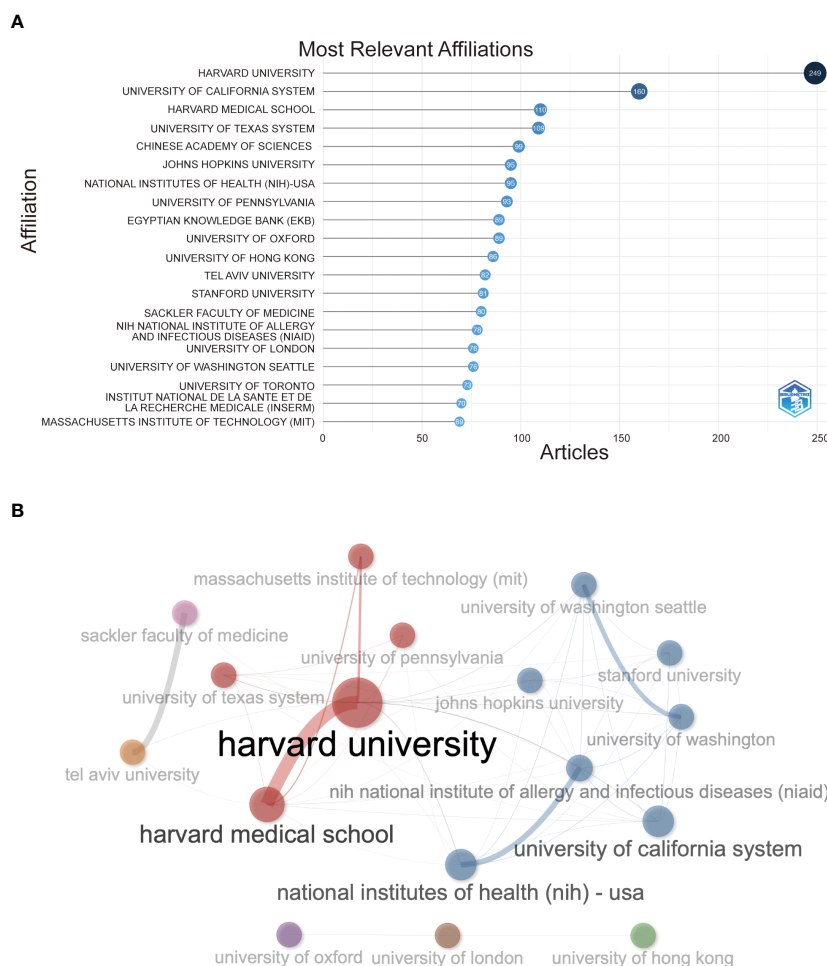


FIGURE 4 (A) Top 20 most relevant affiliations on the research of COVID-19 RNA vaccines. (B) Network map of co-authorship between affiliations with more than 5 citations.

Relations between journals (left), authors (middle), and affiliations(right)

The relations between journals, authors, and affiliations were visualized using the three-field plot (TFP). In this instance, the significant features were represented in the diagram by rectangles with different colors. The height of the rectangles in the diagram of the TFP depended on the rate or value of the summation of the relations arising between the component the rectangle represents (journals, authors, and affiliations) and the diagram of other elements. The more relations the component or element had, the higher the rectangle represented. Figure 6 shows the TFP analysis of publications on COVID-19 RNA vaccines centered on relations between the journals, authors, and affiliations. The diagram demonstrated the top journals, authors, and affiliations relations in publications on COVID-19 RNA vaccines and their related studies during these four years.

Characteristics of the top 20-most cited articles and co-cited references

The top 20 most cited articles were published in 11 journals between 2020 and 2023 (Table 3). Seven articles were published in The New England Journal of Medicine, and four were published in Nature. With 8609 citations, the top-cited article was published by Fernando P Polack from the New England Journal of Medicine in 2020. The total citations per year were 1721.80, and the normalized total citation was 69.69. The following one was published by Edward E Walsh and received 1574 citations, whose total citations per year was 314.80, and the normalized total citation was 12.74.

There are 50 references of co-citation with more than five citations. As shown in Figure 7, Wrapp d 2020 (34) has the highest number of connections with other references, followed by Hoffmann m 2020 (35). Polack fp 2020 (24) has the highest value of PageRank to get other references, which shows the importance of a node to get other nodes, followed by Baden Ir 2021 (36).

TABLE 1 The author's impact in relevant field.

Element	h_index	g_index	m_index	TC	NP	PY_start
SAHIN U	13	14	2.6	14203	14	2020
SHI PY	12	16	2.4	4269	16	2020
LIU Y	10	16	2.0	502	16	2020
TÜRECI Ö	10	10	2.0	13602	10	2020
LEE J	9	17	1.8	305	17	2020
LI X	9	14	1.8	383	14	2020
LUSTIG Y	9	12	2.3	1277	12	2021
CHEN Y	8	13	1.6	644	13	2020
DORMITZER PR	8	8	1.6	13681	8	2020
KUMAR A	8	13	1.6	335	13	2020
SINGH S	8	12	2.0	296	12	2021
SWANSON KA	8	8	1.6	13847	8	2020
ZHANG Y	8	15	2.0	511	15	2021
BARIC RS	7	9	1.4	908	9	2020
CHAN EWY	7	7	2.3	193	7	2022
CHUI CSL	7	7	2.333	193	7	2022
GAO GF	7	8	1.4	338	8	2020
KIM J	7	15	1.75	588	15	2021
KUMAR S	7	13	1.4	330	13	2020
LAI FTT	7	7	2.333	193	7	2022

H-index means a scientist has published at least h papers, whose citation frequency is no less than h, within a certain period. G-index means that the maximum paper order g with a cumulative citation of at least g square times, which is ranked relatively high by the number of citations, means that the cumulative citation number corresponding to the (g+1) th order paper will be less than the square of (g+1). M-index means h-index divided by the author's academic age.

Keyword co-occurrence, clusters

Keywords are always the core research content highly condensed and summarized by researchers, which can reflect the central theme of the research. Therefore, keyword co-occurrence analysis is a crucial way to determine the main research direction and hot research topics of a specific discipline. Among Figure 8B, the most frequent author's keywords were "covid-19" (n = 1166, 25%), "sars-cov-2" (n = 1054, 22%), "vaccine" (n = 323, 7%), "coronavirus" (n = 183, 4%), "vaccines" (n = 174, 4%), and "vaccination" (n = 170, 4%). The overall keyword network visualization is presented in Figure 8. It can be seen that the frequency of the words COVID-19 and SARS-COV-2 has significantly increased from 2020 to 2023.

Discussion

In this study, R studio quantitative analysis software was used to analyze the references related to the COVID-19 RNA vaccines and summarize the research results and progress. Quantitative analysis of annual publication quantity, country, author, institution, journal, and other essential information are also included. According to the

number of articles published on the COVID-19 RNA vaccines in 2020, the number of documents published in this field is 271, showing an overall increasing trend. The higher the number of citations in a paper, the more excellent its impact on the field and the higher its quality. The total number of citations in this field increases between 2020 and 2022. The number of related articles in 2023 is lower than in 2022.

Through statistical analysis of the number of papers published by countries/regions and institutions, it can be determined that the key countries/regions and research institutions that have published many COVID-19 RNA vaccine literature and have a significant influence can determine their cooperation relationship. The United States and China are major countries conducting research on RNA vaccines for COVID-19, and the United States ranks first. Half of the top 20 research institutions are in the United States, followed by the United Kingdom, China, France and Israel. We noticed the close cooperation among five countries: the United States, China, the United Kingdom, Germany, and Italy. In addition, the United States has active collaborations with China, the United Kingdom, and Germany. The United States is undoubtedly the main driving force for the development of this field. The publications and cooperation between countries are significantly higher in developed countries than in developing countries. Regarding research affiliations, 50% of

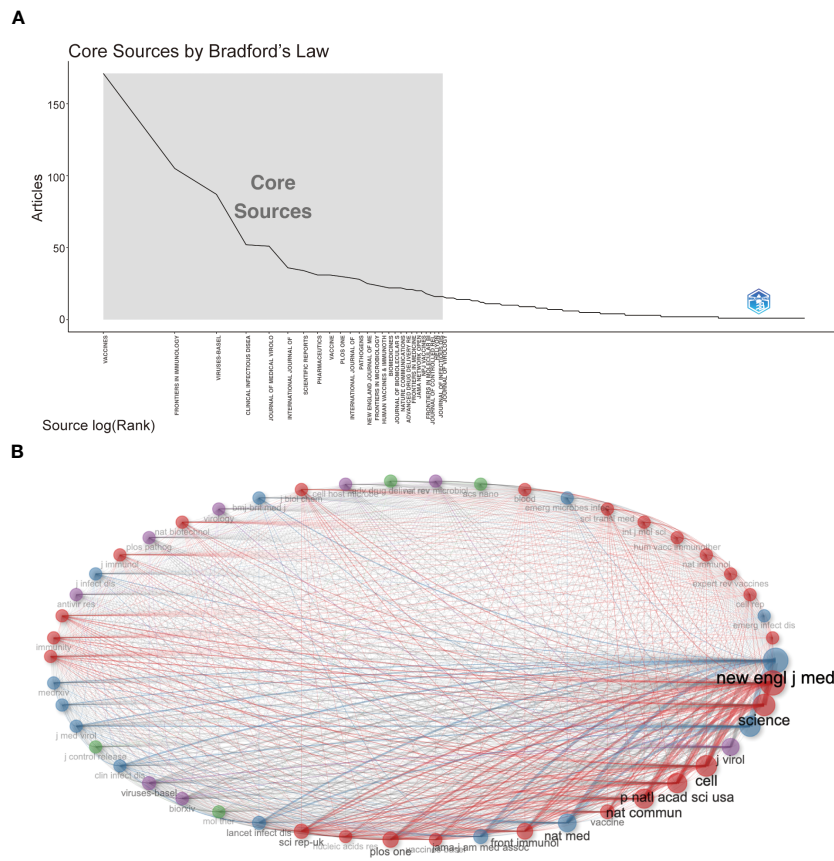


FIGURE 5 (A) Journals (Sources) clustering through Bradford's law. (B) Co-cited Journals of COVID-19 RNA vaccines.

the top 20 most relevant affiliations were from the United States, which may be one of the essential reasons for the rapid development of the United States in this field. Regarding institutions, Harvard University is the most prolific institution, followed by the University of California System and Harvard Medical School. Affiliations like Tel Aviv University and Sheba Medical Center have an excellent cooperative relationship. Also, we found that Harvard University published the most papers and collaborated with the most institutions, which will be detrimental to the long-term development of academic research. Although some countries have cooperative relations, the frequency, breadth, and intensity of cooperation between institutions are not ideal. For example, there is only a small amount of collaboration between institutions in the United States and China. This situation will hinder the development of the research field in the long run. Therefore, we strongly recommend that research institutions in various countries carry out extensive cooperation and communication to jointly promote the development of RNA vaccines for COVID-19. Close collaboration and communication between countries and institutions are conducive to eliminating academic barriers and further developing research related to the COVID-19 RNA vaccines.

From the perspective of the author, SAHIN U, SHI PY, LIU Y, TÜRECI Ö, and LEE J published the most articles. Professor Uğur Şahin, who had the highest number of total citations, had published

14 papers, 9 of which were concerned with the immunogenicity and effectiveness of COVID-19 mRNA vaccines, and pointed out that BNT162b2 has neutralizing activity on different COVID-19 variants. They also found that BNT162B2 can elicit the response of TH1 cells and antibodies. In addition, the safety of these vaccines has also been proved (37–46). Pei-Yong Shi, whose h-index was second only to Uğur Şahin, has published 16 articles during these four years, most of which pointed out the safety and immunogenicity of COVID-19 RNA vaccines. These vaccines can induce the persistent response of the human germinal center. He also found that some SARS-CoV-2 variants resist these RNA vaccines (25, 27, 37, 39, 47–56).

Most of the research on COVID-19 RNA vaccines was published in Vaccines (IF=7.8, Q1), indicating it is currently the most productive journal in this research field. Among the journals, the journal with the highest impact factor is the New England Journal of Medicine (IF=158.5, Q1), followed by Nature (IF=64.8, Q1). As for the co-cited journals, we could find that most of them are high-impact Q1 journals. These journals are high-quality international journals providing support for the study of COVID-19 RNA vaccines.

The top 20 most cited articles were mainly published between 2020 and 2021, and all seven were published in the New England Journal of Medicine, indicating the influence of the New England Journal of Medicine in this regard. In addition, the first four articles

TABLE 2 The journal's impact on COVID-19 RNA vaccines.

Journal	h_index	g_index	m_index	Total citations	Number of publications	Starting Publishing year
NEW ENGLAND JOURNAL OF MEDICINE	24	25	4.8	17419	25	2020
NATURE	9	9	1.8	4109	9	2020
SCIENCE	13	14	3.25	2938	14	2021
NATURE MEDICINE	13	14	3.25	2393	14	2021
VACCINES	22	40	4.4	2100	171	2020
FRONTIERS IN IMMUNOLOGY	18	43	3.6	2015	105	2020
CELL	8	9	1.6	1619	9	2020
JOURNAL OF MEDICAL VIROLOGY	17	37	3.4	1390	51	2020
VIRUSES-BASEL	19	34	3.8	1256	87	2020
NATURE REVIEWS IMMUNOLOGY	6	6	1.2	1190	6	2020
NATURE REVIEWS MATERIALS	2	2	0.4	1140	2	2020
ACS CENTRAL SCIENCE	3	3	0.6	1131	3	2020
ADVANCED DRUG DELIVERY REVIEWS	14	21	3.5	1073	21	2021
NATURE COMMUNICATIONS	14	22	2.8	995	22	2020
CLINICAL INFECTIOUS DISEASES	16	29	4	939	52	2021
ANNALS OF THE RHEUMATIC DISEASES	7	7	1.75	854	7	2021
JAMA CARDIOLOGY	5	5	1.25	843	5	2021
JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION	5	5	1.25	793	5	2021

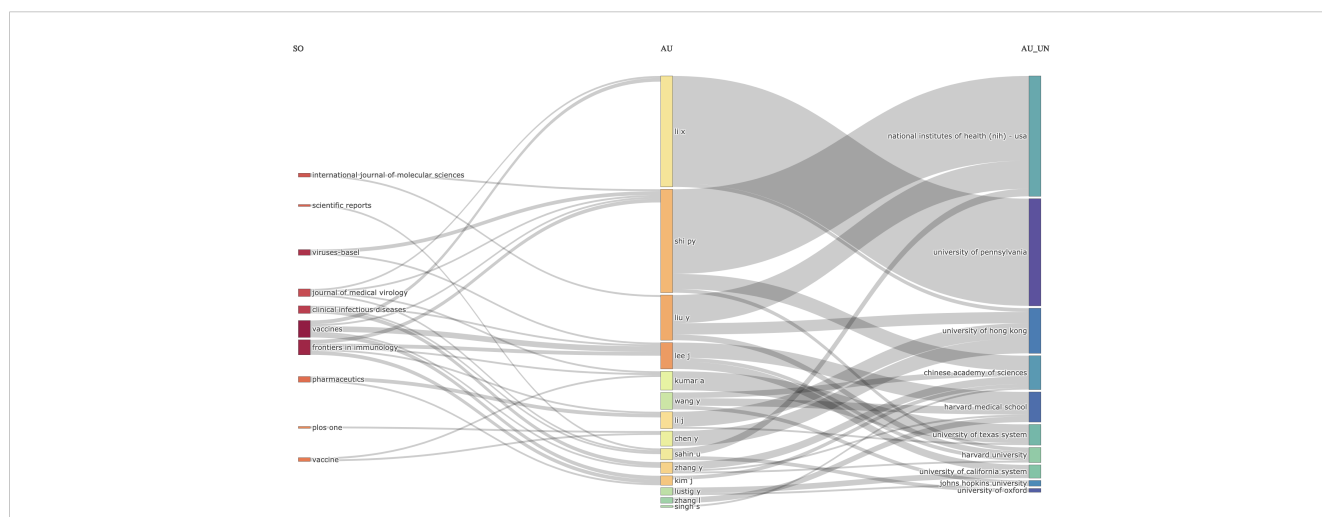


FIGURE 6 Three-Fields Plot revealed the relations between journals (left), authors (middle), and affiliations (right) for research in COVID-19 RNA vaccines.

TABLE 3 Main characteristics of the top 20-most cited articles.

NO.	Articles	Journals	IF	First Author	Total Citations (TC)	TC per Year	Normalized TC.	Publication Year
1	Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine	NEW ENGL J MED	158.5	POLACK FP	8609	1721.8	69.69	2020
2	Safety and Immunogenicity of Two RNA-Based Covid-19 Vaccine Candidates	NEW ENGL J MED	158.5	WALSH EE	1574	314.8	12.74	2020
3	COVID-19 vaccine BNT162b1 elicits human antibody and TH1 T cell responses	NATURE	64.8	SAHIN U	1070	214.0	8.66	2020
4	Safety and Immunogenicity of SARS-CoV-2 mRNA-1273 Vaccine in Older Adults	NEW ENGL J MED	158.5	ANDERSON EJ	959	191.8	7.76	2020
5	Phase I/II study of COVID-19 RNA vaccine BNT162b1 in adults	NATURE	64.8	MULLIGAN MJ	940	188.0	7.61	2020
6	Lipid nanoparticles for mRNA delivery	NAT REV MATER	83.5	HOU XC	938	234.5	20.44	2021
7	Covid-19 Breakthrough Infections in Vaccinated Health Care Workers	NEW ENGL J MED	158.5	BERGWERK M	886	221.5	19.31	2021
8	Research and Development on Therapeutic Agents and Vaccines for COVID-19 and Related Human Coronavirus Diseases	ACS CENTRAL SCI	18.2	LIU C	826	165.2	6.69	2020
9	Pathogenesis and transmission of SARS-CoV-2 in golden hamsters	NATURE	64.8	SIA SF	823	164.6	6.66	2020
10	Protection of BNT162b2 Vaccine Booster against Covid-19 in Israel	NEW ENGL J MED	158.5	BAR-ON YM	764	191.0	16.65	2021
11	Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine through 6 Months	NEW ENGL J MED	158.5	THOMAS SJ	710	177.5	15.47	2021
12	Potential Interventions for novel coronavirus in China: A systematic review	J MED VIROL	12.7	ZHANG L	644	128.8	5.21	2020
13	Coronavirus Infections in Children Including COVID-19: An Overview of the Epidemiology, Clinical Features, Diagnosis, Treatment and Prevention Options in Children	PEDIATR INFECT DIS J	3.6	ZIMMERMANN P	641	128.2	5.19	2020
14	Immunological Considerations for COVID-19 Vaccine Strategies	NAT REV IMMUNOL	100.3	JEYANATHAN M	612	122.4	4.95	2020
15	Infection and Rapid Transmission of SARS-CoV-2 in Ferrets	CELL HOST MICROBE	30.3	KIM YI	603	120.6	4.88	2020
16	Safety of the BNT162b2 mRNA Covid-19 Vaccine in a Nationwide Setting	NEW ENGL J MED	158.5	BARDA N	596	149.0	12.99	2021
17	Cutaneous reactions reported after Moderna and Pfizer COVID-19 vaccination: A registry-based study of 414 cases	J AM ACAD DERMATO	13.8	MCMAHON DE	516	129.0	11.24	2021

(Continued)

TABLE 3 Continued

NO.	Articles	Journals	IF	First Author	Total Citations (TC)	TC per Year	Normalized TC.	Publication Year
18	Altered TMPRSS2 usage by SARS-CoV-2 Omicron impacts infectivity and fusogenicity	NATURE	60.9	MENG B	502	167.3	29.08	2022
19	Efficacy of the BNT162b2 mRNA COVID-19 Vaccine in Patients with Chronic Lymphocytic Leukemia	BLOOD	20.3	HERISHANU Y	450	112.5	9.81	2021
20	Immune Cell Profiling of COVID-19 Patients in the Recovery Stage by Single-Cell Sequencing	CELL DISCOV	33.5	WEN W	426	85.2	3.45	2020

are all about the safety and effectiveness of the COVID-19 RNA vaccines. It can be seen that the safety and effectiveness of RNA vaccines have always been a hot topic in the discussion of the COVID-19 RNA vaccines.

Vaccines, Frontiers in Immunology, and Virus Basel are the journals that publish the most articles about the COVID-19 RNA vaccines. However, regarding influence, the New England Journal of Medicine has the highest h-index, m-index, and total citations, proving that it currently has the most significant influence in this field. Frontiers in Immunology has the highest g-index, proving its importance in the field of COVID-19 RNA vaccines. Frontiers in Immunology, Vaccines, and Journal of Medical Virology were the top three most influential journals in this field, which may be listed in the journal consideration for the relevant researchers.

According to the keywords, COVID-19, SAR-COV-2, and vaccine are currently the most concerning topics conducive to further research. The research hotspots in this field mainly include COVID-19, SAR-COV-2, and vaccine. We hope this work can provide new ideas for promoting scientific research and clinical applications of COVID-19 RNA vaccines.

In general, this study is the first comprehensive analysis that summarizes the research of the COVID-19 RNA vaccines using literature metrology methods. Our research findings provide valuable information for researchers in this field to understand the basic

knowledge landscape, current research hotspots, and future opportunities and identify potential collaborators in the future.

The wide application of the COVID-19 RNA vaccines provides a good platform for the development of RNA vaccine, not only contributes to the research and development of COVID-19 RNA vaccines but also proves the effectiveness and safety of RNA vaccine to a certain extent and provides sufficient theoretical and technical support for the future application of RNA vaccine in other fields, such as cancer treatment.

Limitations

Firstly, to ensure high-quality bibliometric analysis, the analysis of this study is based on articles in the Web of Science database, one of the most commonly used scientific publication databases. However, some studies may be omitted as they are published in non-SCI journals or other databases. Secondly, bibliometric analyses cannot completely replace system retrieval. Third, metrology cannot evaluate the quality of a single study because the citation index is time-dependent, meaning that recent articles may be less cited than earlier, even if they are more valuable. These limitations may slightly impact the overall results but are unlikely to alter the main trends presented in this article. In general, our

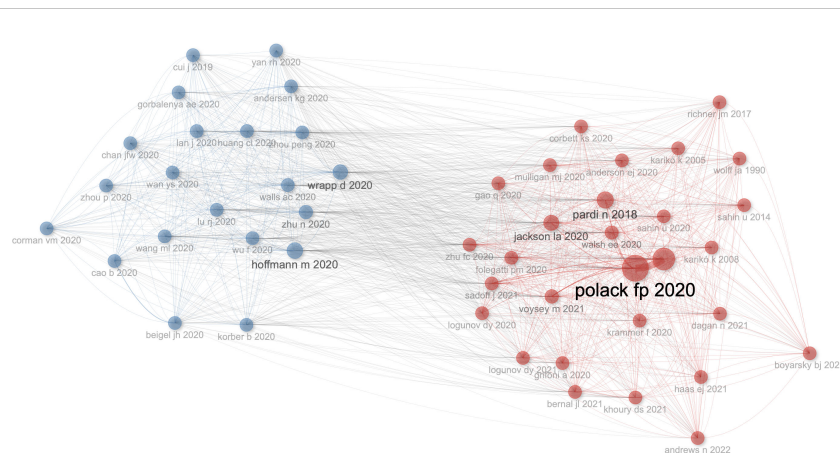
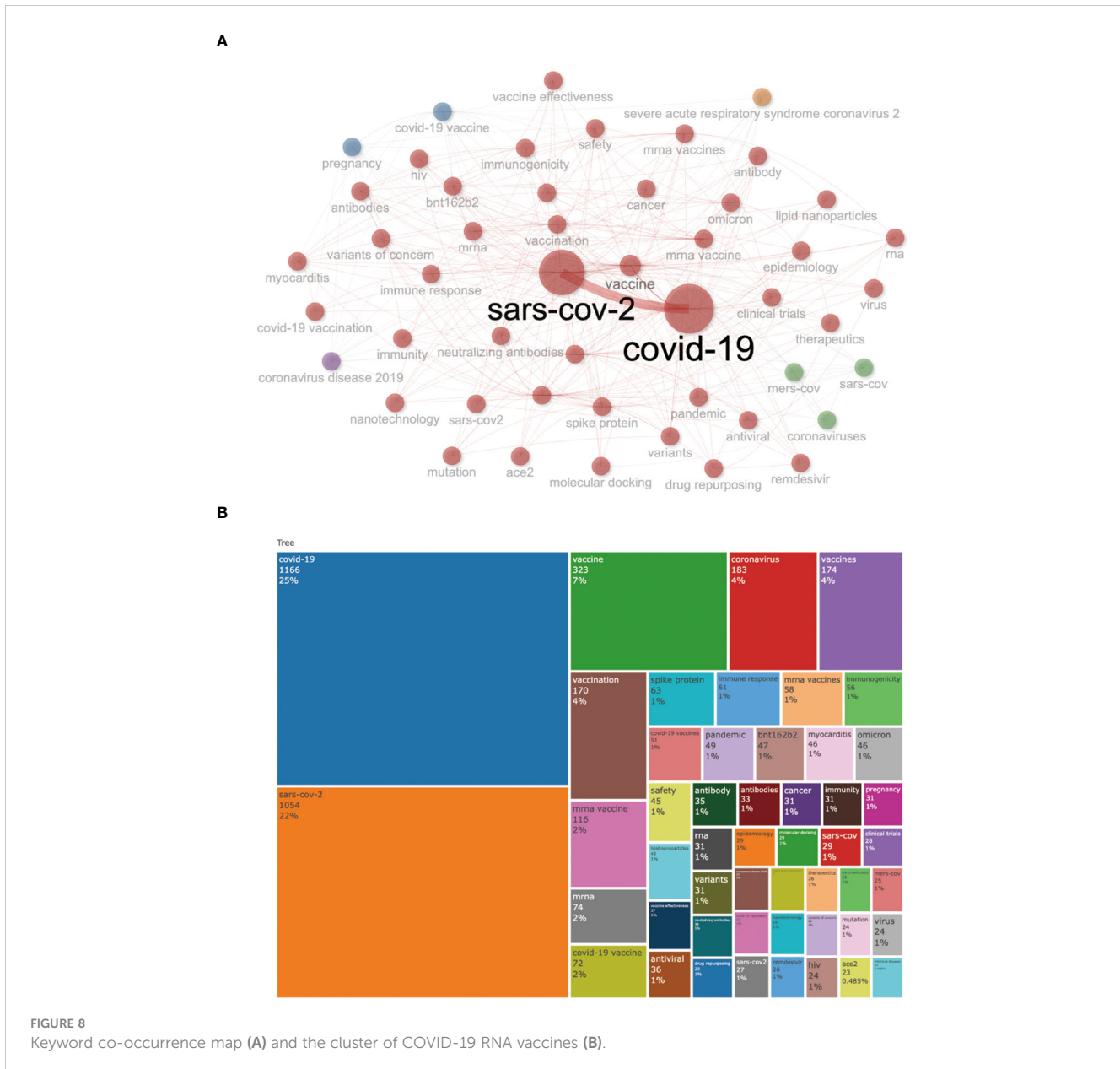


FIGURE 7 Network map of co-citation between references with more than five citations.



research has provided a basis for understanding the research topics of the COVID-19 RNA vaccines and the production and application of the RNA vaccine.

Methods

Eligibility criteria and data source

In this study, research articles on RNA vaccines for COVID-19 published between 2020 and 2023 as original articles or reviews in English were considered eligible. Web of Science core collection database was used.

Search strategy

In the advanced search option of the Web of Science database, using an appropriate combination of Boolean and wildcard search operators, the following keywords were searched: “Corona Virus Disease 2019”, “COVID-19”, “RNA”, and “vaccines”. The search was performed on January 11th, 2024, and the entire search strategy is presented in $TS = ((RNA\ vaccine\ AND\ COVID-19)\ OR\ (RNA\ vaccine\ AND\ SARS-COV-2))$, the type of documents is set to “articles” and “reviews”. The language of articles is set as English only. Then, all the resulted information, including full records and cited references, was downloaded in txt format.

Bibliometric analyses

Data management and bibliometric analyses were conducted using the Bibliometrix package (version 3.1.4) (57) and Biblioshiny (57) web apps under R (version 4.0.2). We retrieved all the main information and features included in the study. Publications and citation trends were constructed over four years. From 2020 to 2023, the most influential countries on COVID-19 RNA vaccine research were retrieved and presented as a cluster collaboration network. The cooperative world map represents world research cooperation, with the minimum edge set at 10. In addition, we identified the most productive institutions based on the highest number of paper contributions to the topic over the past four years. We used leading eigenvalue clustering algorithms to construct a collaborative network between institutions with more than five citations. We determined the author with the highest contribution based on the highest number of papers and the top 20 co-citation networks of influential authors. The 20 most cited references and the most influential journals were also identified, and some characteristics were searched, such as h-index, g-index, m-index, the total number of citations, the number of papers on the subject published in the journal, and the year when the journal began to publish COVID-19 RNA vaccine-related topics. In order to observe the inflow and outflow of journals, authors, and affiliated institutions that have contributed to the COVID-19 RNA vaccines in the past four years, a three-field plot was constructed. A tree chart was prepared to display keywords published on this topic from 2020 to 2023.

Conclusions

RNA vaccine has essential research value and application prospects in COVID-19. The rapid increase in the number of publications shows that the research on the RNA vaccine for COVID-19 has attracted more attention from scholars worldwide. The main countries are the United States and China. However, cooperation and communication between countries and institutions still need to be strengthened. On the one hand, studying the immunogenicity and safety of RNA vaccines will help us to prevent COVID-19 variants infection and reduce vaccine side effects (58). On the other hand, compared with traditional vaccines, RNA vaccines have significant advantages in preventing COVID-19. Therefore, the study of COVID-19 RNA vaccines has essential application value in preventing COVID-19 infection and alleviating symptoms in the future (59). In addition to the related

prevention research of COVID-19, attention can also be paid to the transformation of research achievements, that is, the clinical application of RNA vaccines in other diseases (58).

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding authors.

Author contributions

ZC: Conceptualization, Visualization, Writing – original draft. ZL: Software, Validation, Writing – review & editing. YF: Writing – review & editing. AS: Writing – original draft. LW: Writing – review & editing. YS: Conceptualization, Funding acquisition, Supervision, Writing – original draft. CL: Conceptualization, Software, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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