A Worldwide Bibliometric Analysis of Publications on Coronavirus in the Past 3 Decades: A Bibliometric Article

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Abstract

Background: Coronaviruses caused three pandemics and impact public health globally in the 21st century. However, limited data were for the evaluation of the trend of coronavirus researches. We aimed to analyze quantitatively, qualitatively, and visually evaluate global scientific publications on coronavirus by using bibliometric analysis.

Methods: Coronavirus-related research from 1990-2019 was retrieved from the Web of Science Core Collection database (WoS). Microsoft Excel and VOS viewer software were used to assess the characteristics of publications.

Results: Overall, 9,553 publications on coronavirus were retrieved on 12 Mar 2020. The United States took a leading position in coronavirus-related research and accounted for more than one-thirds (36.7%) of all publications. The most productive journal in this field was Journal of Virology (1,056, 11.1%), and the most productive institution was University of Hong Kong (394, 4.1%). The main hot topics in coronavirus field were virus infection and protein. Active collaborations between countries were observed.

Conclusion: Over the past three decades, coronavirus research has gradually increased due to two global outbreaks. Through this global bibliometric evaluation, some relevant evidence could be provided. Corresponding to the impact of novel coronavirus (COVID-19), a large number of articles can be expected to appear in the next few years, and international cooperation should be strengthened to solve the problem.

Keywords: Bibliometric analysis; Coronavirus; COVID-19

Introduction

Coronaviruses (CoV) were discovered in the mid-1960s (1). Since then, humans have been facing an endless battle with emerging infectious diseas-es. Coronaviruses are a large family of viruses that cause illness ranging from mild (moderate) respiratory symptoms, like the common cold, to

more severe diseases such as Severe Acute Respiratory Syndrome (SARS-CoV) and Middle East Respiratory Syndrome (MERS-CoV). There were three times that coronavirus outbreaks have emerged from animal reservoirs to cause severe disease, death and global transmission concerns in the 21st century (2).

First, severe acute respiratory syndrome appeared in China in Nov 2002 with 8,096 laboratory-confirmed cases and caused 774 deaths (9.6% mortality rate). Most cases were in China, Hong Kong and Taiwan, but it still spread to 29 countries (3). And then, in 2012, the Middle East respiratory syndrome-Coronavirus (MERS-CoV) was found in Saudi Arabia. Until Jan 2020, there were 2,519 laboratory-confirmed cases and 866 deaths (mortality rate 34%), which spread in 27 countries and were mostly concentrated in Saudi Arabia (4,5).

Finally, there is the latest outbreak named coronavirus disease 2019 (COVID-19), which is different from the other human coronavirus. Accumulated to Jun 2020, the laboratory-confirmed cases have reached 12,000,000 and caused 500,000 deaths (4.4% mortality rate). It has led to rapid spread of the community and even to 203 countries (6). Many countries have already adopted lock policies. The impact is getting deeper and wider.

To explore the historical trajectory of the three fatal human coronaviruses in the past twenty years, there will be a pandemic period about eight to ten years. Once it occurs, physicians, scientists, and public health experts will study and explore the treatment strategies and vaccines through viral sources, exposure pathways, modes of transmission, etc. However, bibliometric analysis of this type of research is currently lacking.

Bibliometric was first used by Alan Pritchard in a paper published in 1969, title Statistical Bibliography or Bibliometrics? defined as "the application of mathematical and statistical methods to books and other media of communication" (7) and "the quantitative analysis of the bibliographic features of a body of literature"(8). To better understand global research trends and characteristics of publications on coronavirus-related re-

search, we carried out this study to demonstrate the worldwide research productivity, trends, and citations in the past 3 decades by bibliometric analysis.

Methods

Data source

For this bibliometric search, we selected and performed in the Web of Science Core Collection database (WoS) of Thomson Reuters (Clarivate) to identify research articles on the topic of coronavirus. The choice of WoS was based on the comprehensive publication data and is the widely accepted and frequently used database for the analysis of scientific publications. WoS is the world's largest publisher-neutral citation index and research intelligence platform. Furthermore, WoS has been previously used in many published bibliometric studies. The data for this study were retrieved from the WoS on 12 Mar 2020.

Search strategy

The search was conducted in two steps:

– First, we combined the following terms to ensure all relevant manuscripts were identified using option "Topic" (in the title, the abstract and/or in the keywords of the publications), as follows:

Coronavirus: The search criteria were topic ("coronavirus"), refined by, document type (article), language (English), index (Science Citation Index-Expanded), and time (1990-2019).

SARS-CoV: The search criteria were topic ("coronavirus" AND ("SARS" OR "Severe Acute Respiratory Syndrome")), refined by, document type (article), language (English), index (Science Citation Index-Expanded), and time (1990-2019).

MERS-Cov: The search criteria were topic ("Middle East Respiratory Syndrome Coronavirus" OR "MERS-CoV"), refined by, document type (article), language (English), index (Science Citation Index-Expanded), and time (1990-2019).

– Second, the text file data downloaded from WoS were imported into and analyzed in Microsoft Excel 2020.

Data Analysis

The title, citation number, publication year, authorship, country of origin, impact factor (IF) of the journal, journal, and topic of each manuscript were analyzed. To analyze the citation number of published articles and the impact factors of published journals, we obtained the citation number of each paper from WoS and IF of published journals from the 2019 journal citation report (JCR) (Clarivate Analytics, Philadelphia, USA).

In this study, calculated impact factor (cIF) was similar to IF and was calculated according to the following equation (9,10):

$$cIF = \frac{(Citations_{y-1} + Citations_{y-2}) = A}{(Publications_{y-1} + Publications_{y-2}) = B}$$

- y-1: one year prior to the cIF year (= year -1)
- y-2: two years prior to the cIF year (=year-2)
- A= the number of times that all articles published in y-1 and y-2 were cited by indexed journals during cIF year.
- B= the total number of articles published in y-1 and y-2.
- A cIF of 1.0 mean that the articles published one or two years ago have been cited one time.

Ethical approval was not required in this study, because the data was all secondary data and no human subjects were enrolled.

Statistical analysis

Data analysis was performed using descriptive statistics in Microsoft Excel 2010. The analysis involved the calculation of relative frequencies, percentages, sum and average.

In addition, VOSviewer version 1.6.14 for Microsoft Windows (Centre for Science and Technology Studies, Leiden University, The Netherlands) (http://www.vosviewer.com/) was used for constructing and visualizing the bibliometric diagrams (11).

Results

Trends in global publications

Regarding the coronavirus research, 9,553 articles were indexed in the WoS over the past three decades. From Figure 1a we can see the coronavirus studies have risen sharply due to the outbreak of SARS in 2002, from 119 in 2002 to 603 in 2004, and a declination showed as SARS vanished. After discovering MERS-CoV in 2012, it rose rapidly again, growing from 342 in 2012 to about 550 in recent years.

In general, the most productive countries in this field are the United States (3,509, 36.7%), followed by China (2,135, 22.5%) and the United Kingdom (654, 6.8%); from those two outbreaks of SARS and MERS, China (1,231, 35.8%) contributed the most to SARS research, followed by the United States (1,213, 35.3%) and Taiwan (257, 7.5%) (Fig. 1b). To MERS the United States contributed the most (470, 41.9%), followed by Saudi Arabia (243, 21.7%) and China (239, 21.3%) (Fig. 1c).

High-Contribution Journals, Institutes, and Authors

From 1990 to 2019, 9,553 articles related to coronavirus were published, among which the most were published in the Journal of Virology (1,056, 11.1%), followed by Virology (401, 4.2%) and Advances in Experimental Medicine and Biology (241, 2.5%). In terms of Mean Citation per Article, Journal of Virology was the highest (48.1), followed by Emerging Infectious Diseases (44.9) and Virology (36.1). That the impact factor of the ten most popular Journals in 2019 showed Emerging Infectious Diseases (7.185) is highest, followed by Journal of Virology (4.324) and Journal of General Virology (2.809) (Table 1).

Contributing the most articles are from University of Hong Kong (394, 4.1%), followed by Chinese Academy of Sciences (311, 3.3%) and Utrecht University (246, 2.6%). The most pub-

lished authors in this field are Yuen, K.Y. (172, 1.8%), followed by Perlman, S. (148, 1.5%) and Baric, R.S. (139, 1.5%) (Table 2).
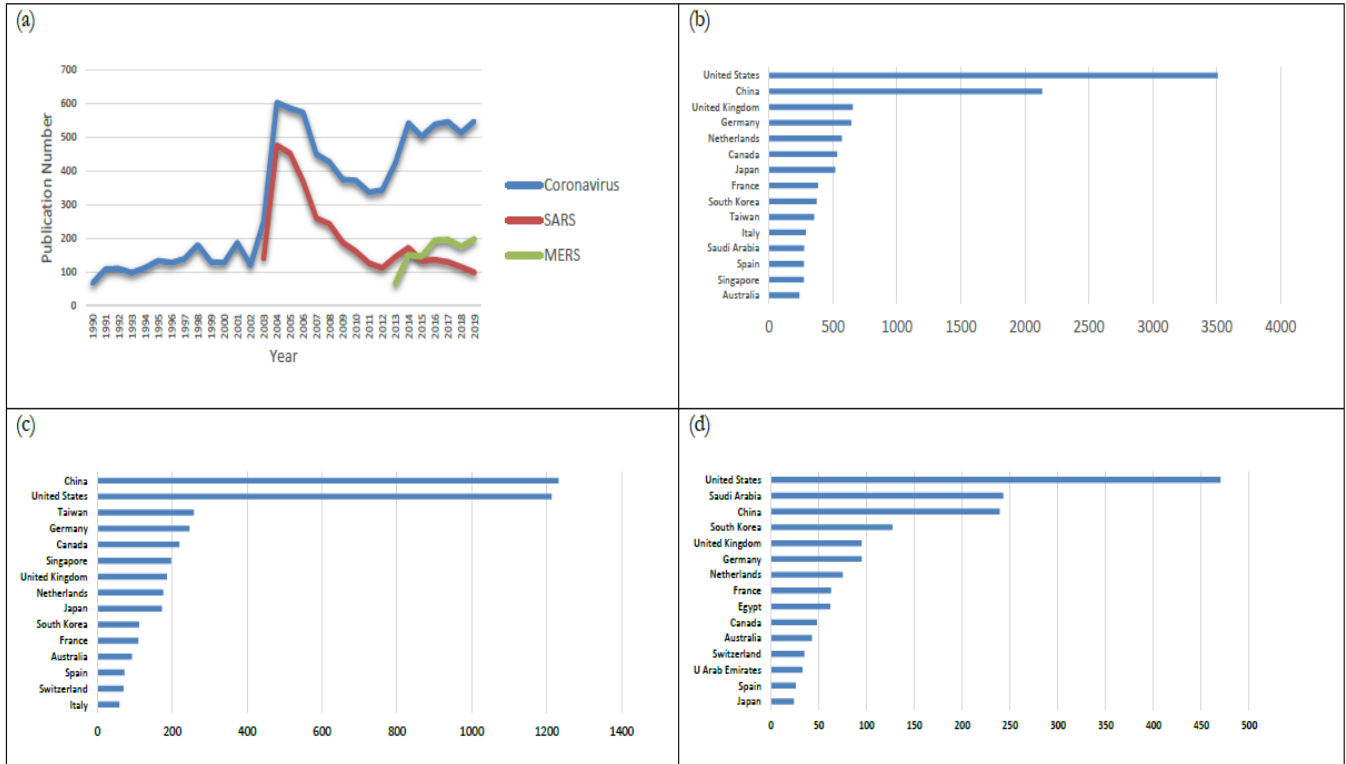
Fig. 1: (a) Growth of worldwide publications on coronavirus and on SARS, MERS-CoV during the past three decades; (b) The sum of coronavirus-related articles from the top 15 countries/regions; (c) The sum of SARS-related articles from the top 15 countries/regions. (d) The sum of MERS-related articles from the top 15 countries/regions

Table 1: Top 10 most productive journals publishing coronavirus-related articles during the period from 1990-2019

Rank	Journal	Articles	%	Total Citation	Mean Citation per Article	IF
1	Journal Of Virology	1056	11.1	50747	48.1	4.324
2	Virology	401	4.2	14482	36.1	2.657
3	Journal Of General Virology	241	2.5	8043	33.4	2.809
4	Advances in Experimental Medicine and Biology	241	2.5	1521	6.3	2.126
5	Plos One	215	2.3	3709	17.3	2.776
6	Virus Research	193	2.0	3765	19.5	2.736
7	Emerging Infectious Diseases	192	2.0	8623	44.9	7.185
8	Archives Of Virology	192	2.0	3827	19.9	2.261
9	Veterinary Microbiology	168	1.8	3381	20.1	2.791
10	Journal of Virological Methods	153	1.6	2998	19.6	1.746

Table 2: Top 10 authors and institutes publishing coronavirus-related articles during the period from 1990-2019

Author	Articles	%	Institute	Articles	%
Yuen, K.Y.	172	1.8	University of Hong Kong	394	4.1%
Perlman, S.	148	1.5	Chinese Academy of Sciences	311	3.3%
Baric, R.S.	139	1.5	Utrecht University	246	2.6%
Enjuanes, L.	138	1.4	University of California System	245	2.6%
Drosten, C.	116	1.2	National Institute of Health NIH USA	242	2.5%
Rottier, P.J.M.	113	1.2	University of North Carolina	211	2.2%
Weiss, S.R.	107	1.1	Centers for Disease Control Prevention USA	201	2.1%
Chan K.H.	106	1.1	University of North Carolina Chapel Hill	182	1.9%
Woo, P.C.Y.	96	1.0	University of Texas System	174	1.8%
Saif, L.J.	94	1.0	Chinese University of Hong Kong	163	1.7%

Most Cited Articles

In the past three decades, the most cited article is Ksiazek TG, Erdman D, Goldsmith CS, et al(12) have been highly cited 1,835 times in WoS, followed by Drosten C, Günther S, Preiser W, et al (13) cited 1747 times, and by Rota PA, Oberstar MS, Monroe SS, et al.(14) cited 1,488 times. Of the top ten cited articles, seven were focused on SARS and only one was on MERS. There are five articles completed on transnational collaboration, and four were published in the New England Journal of Medicine (Table 3).

Table 3: Top 10 most cited articles publishing coronavirus-related articles during the period from 1990-2019

Rank	Title	Authors	Country	Source	Year	Citations
1	A novel coronavirus associated with severe acute respiratory syndrome	Ksiazek TG, Erdman D, Goldsmith CS, et al.	United States, Vietnam, Hong Kong, Thailand, Singapore, Taiwan	New England Journal of Medicine	2003	1835
2	Identification of a novel coronavirus in patients with severe acute respiratory syndrome	Drosten C, Günther S, Preiser W, et al.	Germany, France, Netherlands	New England Journal of Medicine	2003	1747
3	Characterization of a novel coronavirus associated with severe acute respiratory syndrome	Rota PA, Oberste MS, Monroe SS, et al.	United States, Germany, Netherlands	Science	2003	1488
4	Coronavirus as a possible cause of severe acute respiratory syndrome	Peiris JS, Lai ST, Poon LL, et al.	Hong kong	Lancet	2003	1443
5	Community study of role of viral infections in exacerbations of asthma in 9-11 year old children	Johnston SL, Pattemore PK, Sanderson G, et al.	United Kingdom	British Medical Journal	1995	1331
6	Isolation of a Novel Coronavirus from a Man with Pneumonia in Saudi Arabia	Zaki AM, van Boheemen S, Bestebroer TM, Osterhaus AD, Fouchier RA.	Saudi Arabia, Netherlands	New England Journal of Medicine	2012	1295
7	The genome sequence of the SARS-associated coronavirus	Marra MA, Jones SJ, Astell CR, et al.	Canada	Science	2003	1274
8	Cloning of a human parvovirus by molecular screening of respiratory tract samples	Allander T, Tammi MT, Eriksson M, Bjerkner A, Tiveljung-Lindell A, Andersson B.	Sweden, Singapore	Proceedings of the National Academy of Sciences of the United States of America	2005	1028
9	Psychological stress and susceptibility to the common cold	Cohen S, Tyrrell DA, Smith AP.	United Kingdom	New England Journal of Medicine	1991	1007
10	Angiotensin-converting enzyme 2 is a functional receptor for the SARS coronavirus	Li W, Moore MJ, Vasilieva N, et al.	United States	Nature	2003	969

Analysis of citations

CIF keeps stable annually, except for the two peaks caused by SARS during 2004 to 2007 and MERS from 2014 to 2016 (Table 4).

Of the 9,553 publications on coronavirus-related research, 5.1% (485) of articles were cited 100 times or more, and 53.6% (5,124) of articles were cited 10

times or more. 5.9% (566) of articles were cited zero times at the time of the data extraction (Table 5).

Table 4: Citation analysis (2001-2019)

	Year (y)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of Article		186	119	250	603	586	573	449	426	374	371	336	342	423	542	502	538	546	513	547
Sum of the times cited in WoS	2001	62																		
	2002	21	59																	
	2003	354	330	1221																
	2004	406	412	4288	1286															
	2005	481	466	4088	4314	802														
	2006	418	467	2726	3861	2898	447													
	2007	311	315	2114	3178	3182	1872	380												
	2008	350	385	1892	2663	3056	2301	1696	329											
	2009	233	280	1469	1910	2229	1868	1851	1279	226										
	2010	245	286	1252	1874	2105	1908	1882	1649	922	208									
	2011	254	290	1035	1449	1685	1634	1611	1424	1165	1106	243								
	2012	231	236	939	1244	1542	1380	1383	1248	1151	1312	915	292							
	2013	225	232	1016	1255	1667	1227	1327	1075	1341	1274	1421	869							
	2014	244	250	1002	1339	1746	1428	1386	1370	1108	1322	1215	1622	2916	978					
	2015	232	225	797	1062	1320	1153	1178	1134	937	1215	1130	1500	2784	2916	632				
	2016	234	194	797	979	1270	1105	1109	1050	952	1160	1066	1530	2682	3301	2304	696			
	2017	155	187	675	870	1048	906	893	848	751	970	948	1295	2135	2701	2124	1850	488		
	2018	174	180	540	752	1034	873	856	833	707	888	826	1168	1771	2232	1962	2007	1666	381	
	2019	165	166	599	790	973	856	828	801	703	861	795	1161	1996	2683	2165	2415	2407	1710	507
A=(Citations$_{y-1}$+Citations$_{y-2}$)				684	4700	8402	6759	5054	3997	3130	2571	2271	2227	2695	4538	5700	5605	3974	3673	4117
B=(Articles$_{y-1}$+Articles$_{y-2}$)				305	369	853	1189	1159	1022	875	800	745	707	678	765	965	1044	1040	1084	1059
cIF=(A/B)				2.24	12.7	9.85	5.68	4.36	3.91	3.58	3.21	3.05	3.15	3.97	5.93	5.91	5.37	3.82	3.39	3.89

Table 5: Citations distribution

Number of Citations	Articles	%
0	566	5.9
1-5	1942	20.3
6-10	1416	14.8
11-50	4072	42.6
51-100	1052	11.0
101-500	463	4.8
501-1000	13	0.1
>1000	9	0.1

Collaborations

To demonstrate collaborations, we conducted a co-authorship analysis in terms of countries/regions using VOSviewer. As shown in Fig. 2a, the 55 countries formed 6 clusters and there were active collaborations between the countries and the clusters. The United States was at the center of research on coronavirus-related research and was in close collaboration with Saudi Arabia, Egypt, United Arab Emirates, and Turkey. Substantially, there is closed cooperation with China, Australia and Singapore as well.

Figure 2b presents nine clusters in international cooperation research on SARS, with China and the United States as the dual-core. In Fig. 2c, transnational research on MERS is divided into seven clusters, with the United States as the core, and China and Saudi Arabia also performing very well.
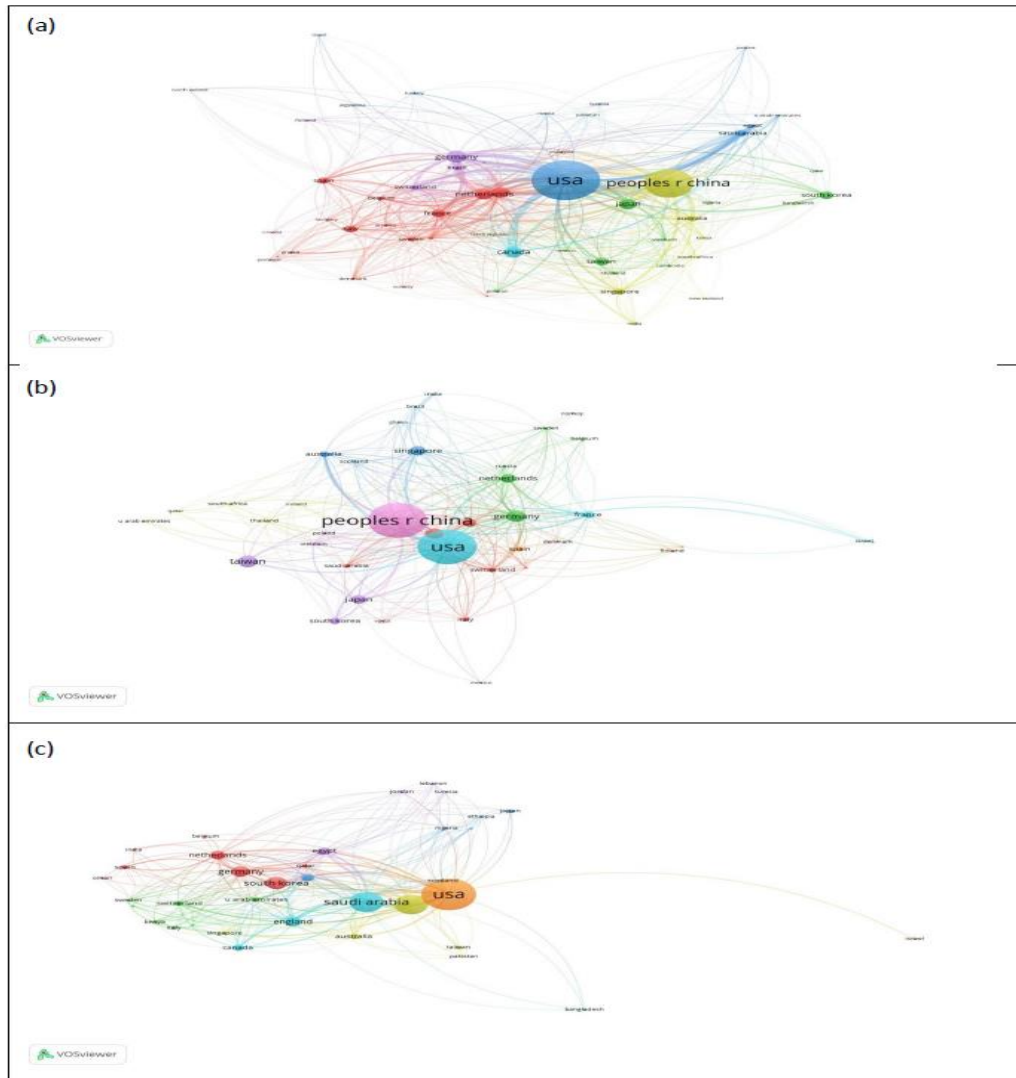
Fig. 2: (a) Network map showing the relations between various countries in coronavirus-related research field. A network map was showed that 55 countries appeared more than 10 times (out of 123 countries); (b) Network map showing the relations between various countries in SARS-related research field. A network map was showed that 39 countries appeared more than 5 times (out of 90 countries); (c) Network map showing the relations between various countries in MERS-related research field. A network map was showed that 37 countries appeared more than 5 times (out of 75 countries)

Analysis of Keywords

Keywords related to coronavirus research were analyzed by VOSviewer and shown in Fig. 3. According to Fig. 3a, 130,484 keywords were extracted from the 9,553 articles. A network map was generated for keywords with the co-occurrence more than 300 times, which includes 120 keywords in the map. These keywords were classified into four clusters: Cluster 1 which consists of 50 keywords (red points) is mainly about virus, infection, and disease. Cluster 2 which consists of 44 keywords (green points) is mainly about protein, cell, and mechanism.

Cluster 3 which consists of 20 keywords (blue points) is mainly about analysis, gene, and sequence. Cluster 4 which consists of 6 keywords (yellow points) is mainly about SARS. In coronavirus studies, SARS and MERS demonstrated similar results (Fig. 3b & Fig. 3c).
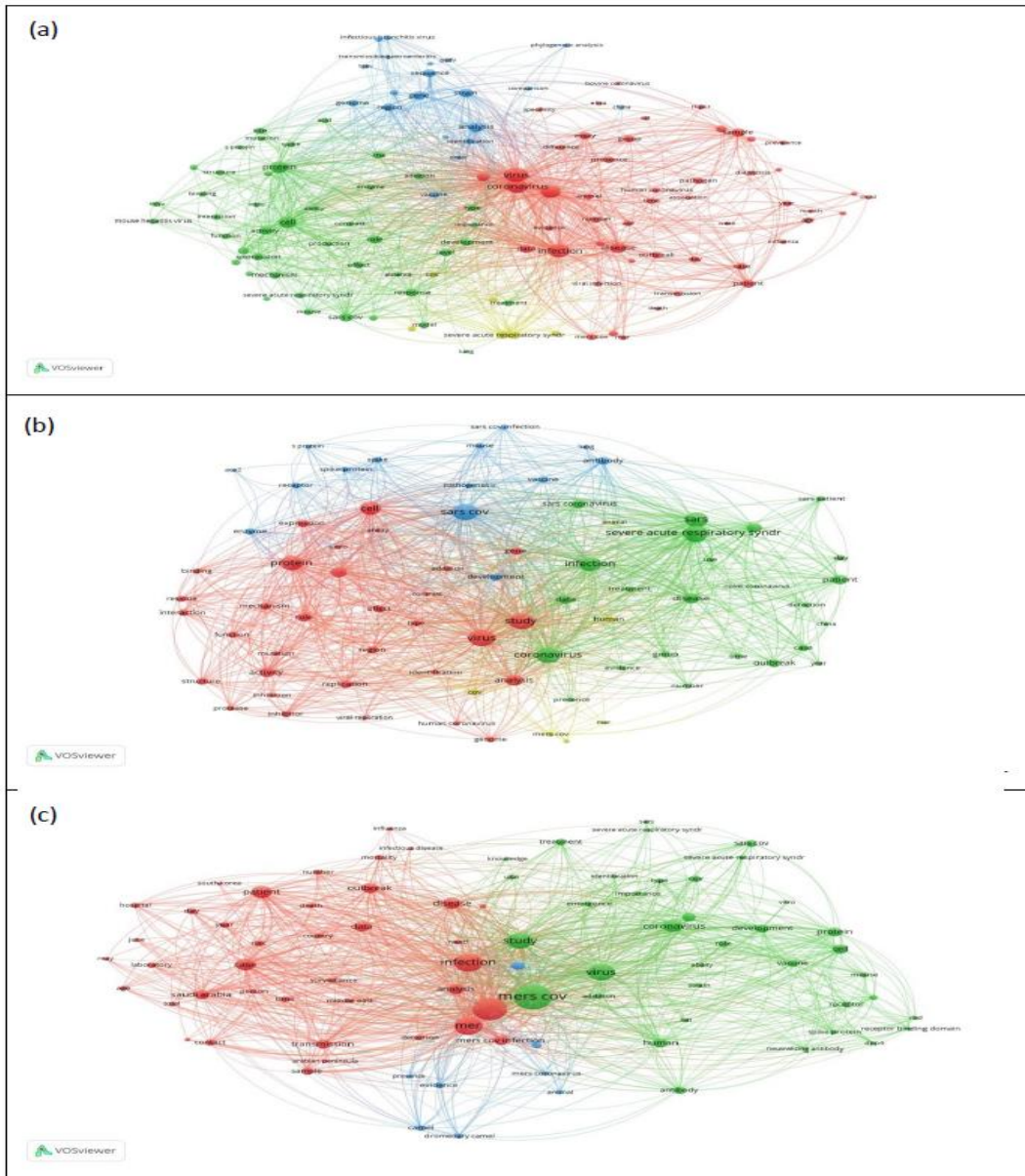
Fig. 3: (a) The analysis of key word co-occurrence on coronavirus-related research. A total of 130,484 keywords were extracted from the 9,553 articles. With a threshold of ≥300 occurrences of a keyword, 120 keywords were included in the network map; (b) The analysis of key word co-occurrence on SARS-related research. A total of 55,939 keywords were extracted from the 3,444 articles. With a threshold of ≥150 occurrences of a keyword, 76 keywords were included in the network map; (c) The analysis of key word co-occurrence on MERS-related research. A total of 21,635 keywords were extracted from the 3,444 articles. With a threshold of ≥50 occurrences of a keyword, 84 keywords were included in the network map

Discussion

The United States and China play an important role in coronavirus research. Of all, the United States has published 1/3 coronavirus research and 1/5 from China. The results of this study are consistent with another study (15). Regarding publications on SARS research, China and the

United States are two cores, each accounting for 1/3; on MERS, the United States is the largest contributor in the world, followed by Saudi Arabia and China, which are similar to the results of those studies (16-18). Of the top 10 most cited articles from 1990 to 2019, four were published in the New England Journal of Medicine, two in Science, and others in high impact factor journals such as Lancet, British Medical Journal, and Nature. This finding is logical because the highest citation frequency is related to the largest academic impact of the publications.

In the present study, several phenomena have been found: 1) The global impact from these two emergencies has inspired many clinicians, epidemiologists, medical virologists, public health experts, policymakers, and academics, etc., to devote themselves in this field of research, resulting in peak publication and citation rates in years. 2) Due to the outbreak, the suffering countries have strengthened their research on coronaviruses. For example, that most SARS cases are concentrated in Asia, such as China, Hong Kong, Taiwan, and Singapore, caused these countries and neighboring countries to involve actively in related research. Likewise, MERS resulted in Saudi Arabia, United Arab Emirates, Egypt, Turkey and other Middle Eastern countries. They not only put more attention on coronaviruses research but also strengthened transnational cooperation in the related field. 3) Through keyword analysis using abstract and title, we found that the focus of research has shifted from disease outbreaks, case descriptions, infection pathways, symptoms to virus structure, mechanisms, and vaccine-related research.

Coronavirus pandemic occurs less than every ten years; especially the outbreak of COVID-19 in 2019 is more serious than before. It has been declared a global pandemic by the WHO on Mar 12, 2020. Applying the same method to conduct a pilot study of COVID-19, we found that China published the most, followed by the United States, Canada and European countries such as Italy, Germany, and the United Kingdom. Outbreak, infection, and case are the main key words. As the epidemic trend changes, it will bring different evolutions. In addition, there will be expected more and more countries devoted to this field of research in the future.

There were some limitations in our study. First, we used WoS database to search publications, which may not include studies available only in other databases. Second, delayed publication collections from WoS could also cause bias in the study. The number of research output in 2019 may be increasing because WoS is still open for new journals issues from this year.

Conclusion

Over the past three decades, coronavirus research has gradually increased due to two global outbreaks. From diagnosis, research on the infection pathways and symptoms has gradually shifted to the virus structure, expression, and mechanism. Based on the bibliometric method, we will continue to analyze the public health issues on COVID-19 in the future.

A public health emergency like COVID-19, which triggered public health emergencies this year, has caused global panic. Through this global bibliometric evaluation, some relevant evidence could be provided. Corresponding to the impact of COVID-19, a large number of articles can be expected to appear in the next few years, and international cooperation should be encouraged.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Conflict of interest

The authors have neither financial nor personal conflicts of interest to declare.

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