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-third (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 diseases. 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-CoV (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 research, 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):

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

- 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-
The most productive journals publishing coronavirus-related articles during the period from 1990-2019 are listed in Table 1. The journal with the highest number of articles is the Journal of Virology, followed by Virology and Journal of General Virology.

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 1,747 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 Boeheemen 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, Bjorkner 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 | Nature | 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 | | 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.
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 Sum of cited times in WoS | 186 | 119 | 250 | 603 | 586 | 573 | 449 | 426 | 374 | 371 | 336 | 342 | 423 | 542 | 502 | 58 | 513 | 547 |

| Year (y) | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Number of Article Sum of cited times in WoS | 2001 | 62 | | | | | | | | | | | | | | | | | |
| of | 2002 | 21 | 59 | | | | | | | | | | | | | | | | |
| the | 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 | 1096 | 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 | 247 | | | | | | | | | |
| 2012 | 231 | 236 | 939 | 1244 | 1542 | 1380 | 1383 | 1248 | 1151 | 1312 | 915 | 292 | | | | | | | | |
| 2013 | 225 | 232 | 1016 | 1255 | 1667 | 1227 | 1327 | 1265 | 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 | 1108 | 1109 | 1080 | 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) = 684 | 4700 | 8402 | 6759 | 5054 | 3997 | 3130 | 2571 | 2271 | 2227 | 2695 | 4338 | 5700 | 5605 | 3974 | 3673 | 4117 | 1 |
+|Citations + | 305 | 369 | 833 | 1189 | 1159 | 1022 | 875 | 800 | 745 | 707 | 678 | 765 | 965 | 1044 | 1040 | 1084 | 1089 | 1 |
B=(Articles) = 0 | 566 | 1942 | 1416 | 4072 | 1052 | 463 | 13 | 9 | | | | | | | | | | | |
+cArticles + | 5.9 | 20.3 | 14.8 | 42.6 | 11.0 | 4.8 | 0.1 | 0.1 | | | | | | | | | | | |

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 Tur-}

Key: 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.

Available at: [http://ijph.tums.ac.ir](http://ijph.tums.ac.ir)
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).
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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