Global scientific outputs of extracorporeal membrane oxygenation in COVID-19: A bibliometric overview

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Abstract

Aim: Although the number of global studies on ECMO, which is an important support system in the treatment of COVID-19 related respiratory failure, has increased in recent months, there is still no bibliometric study on the use of ECMO in COVID-19 in the literature. The aim of this study is to analyze the scientific articles on the use of ECMO in COVID-19 by statistical and bibliometric methods.

Method: Articles published between 2019–2022 about the use of ECMO in COVID-19 were obtained from the Web of Science (WoS) database and analyzed using statistical and bibliometric methods. Spearman correlation coefficient was used for correlation studies. Network visualization maps were used to identify effe analysis and trending topics.

Results: A total of 1197 publications were found. 758 (63.3%) of these publications were articles. The top 3 contributing countries to the literature were USA (257, 33.9%), Germany (102, 13.4%) and Japan (87, 11.5%). The top 3 most active institutions were League of European Research Universities (90), Harvard University (50), and Udice French Research Universities (39). The top 3 journals with the highest count of publications were ASAIO Journal (*n* = 36), Frontiers in Medicine (22), and Perfusion-UK (*n* = 20). According to the average count of citations per article, the most influential journals were JAMA (1319), Intensive Care Medicine (327), and Lancet (95.7), respectively. We have shared a summary of 758 articles in this comprehensive bibliometric study on the use of ECMO in COVID-19.

Conclusion: It can be said that the use of ECMO in COVID-19 has been the trending topic recently and most of the studies are from countries in the ELSO Awards of Excellence list which indicates that the follow-up of ECMO in certain centers and teams can also be influencing the publications. This article can be a useful resource for clinicians, scientists, and students concerning global output for ECMO use in COVID-19.

Keywords

Extracorporeal membrane oxygenation, COVID-19, bibliometric analysis, trends

Introduction

Extracorporeal membrane oxygenation (ECMO), also known as Extracorporeal Life Support (ECLS), is a life support device providing an extracorporeal artificial support to the respiratory system and/or circulatory system, supporting both the heart and lung in patients with acute cardiopulmonary failure who do not respond well to conventional treatments. ECMO provides support to the patient while the healthcare team tries to resolve the underlying disease or injury, or as a bridge to transplant.[1,2] There are basically two types of ECMO: veno-venous (V-V ECMO) or veno-arterial (V-A ECMO). While only respiratory support is provided in the V-V ECMO, both lung and heart support are provided in the V-A ECMO.[1–3]

After the successful implementation of ECLS in a patient with post-traumatic ARDS in 1972, ECMO is now widely used in adults, children, and neonates in many centers.[4] During the A/H1N1 pandemic in 2009, the use of ECMO in ARDS cases resulted in lower mortality rates in treated patients, which in turn increased the use of ECMO in many intensive care units worldwide for the management of severe acute respiratory syndrome (SARS), Middle East respiratory

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syndrome (MERS) and new types of coronavirus (COVID-19) outbreaks.[5–8]

Bibliometrics is the analysis of scientific outputs using statistical methods.[9,10] With the help of results of the analysis of many studies on a subject, researchers can dominate the literature by reading the summary from the analysis of thousands of articles in a short time.[11,12] In addition, bibliometric studies present past and current trends and provide researchers with additional ideas about new studies they can design.[13,14] Thanks to bibliometric research, the most active authors, journals, institutions, countries and the most cited influential studies on a subject or a field are revealed.[9–15] With the increase in the number of publications in the literature, studies based on statistical and bibliometric analysis have been carried out on many important medical issues, especially in recent years.[9–15]

Although the number of global studies has increased in recent months, there is still no bibliometric study in the literature concerning ECMO, which is a support system and has an important place in the recovery process in the treatment of COVID-19 related respiratory failure during the coronavirus pandemic. The aim of this study is to analyze the scientific articles published about ECMO use in COVID-19 between 2019 and 2022 using statistical and bibliometric methods. As a result we aimed to holistically summarize the issue of ECMO in COVID-19 by identifying the most influential researches, authors, journals, institutions and countries revealing cross-country collaborations and trending topics.

Material and methods

Web of Science (WoS) database (by Clarivate Analytics) was used for literature review. Only the Topic (Title, abstract and keywords) part of the studies were searched for publications. Extracorporeal membrane oxygenation (ECMO), Extracorporeal life support (ECLS) and COVID-19 related words were used as search keywords in WoS. With this search method, all articles with keywords in the title about *ECMO and COVID-19 (coronavirus, SARS-CoV-2 etc.)* were obtained and these articles were downloaded from the WoS database. The search process was determined as 2019–2022 (access date: 06.04.2022). Reproducibility codes for researchers to access similar documents (search findings may vary depending on different access dates): (TS = ("Covid-19") AND TS = ("extracorporeal membrane oxygenation")) OR (TS = ("Covid-19") AND TS = ("ECMO")) OR (TS = ("coronavirus") AND TS = ("extracorporeal membrane oxygenation")) OR (TS = ("coronavirus") AND TS = ("ECMO")) OR (TS = ("Sars-cov-2") AND TS = ("extracorporeal membrane oxygenation"))

OR (TS = ("Sars-cov-2") AND TS = ("ECMO")) OR (TS = ("n-CoV") AND TS = ("extracorporeal membrane oxygenation")) OR (TS = ("n-CoV") AND TS = ("ECMO")) OR (TS = ("Covid-19") AND TS = ("extracorporeal life support")) OR (TS = ("Covid-19") AND TS = ("ECLS")) OR (TS = ("coronavirus") AND TS = ("extracorporeal life support")) OR (TS = ("coronavirus") AND TS = ("ECLS")) OR (TS = ("Sars-cov-2") AND TS = ("extracorporeal life support")) OR (TS = ("Sars-cov-2") AND TS = ("ECLS")) OR (TS = ("n-CoV") AND TS = ("extracorporeal life support")) OR (TS = ("n-CoV") AND TS = ("ECLS")) Timespan:2019–2022. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI- S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI). VOSviewer (Version 1.6.16, Leiden University's Center for Science and Technology Studies) package program was used for bibliometric network visualizations.[16] The website (https://app.datawrapper.de) was used for world map drawing. Statistical analysis were performed with the SPSS (Version 22.0, SPSS Inc., Chicago, IL, USA) package program. The normal distribution of data was tested with the Kolmogorov-Smirnov and Shapiro-Wilks test. The correlation between the number of articles from the countries of the world and economic development indicators (Gross Domestic Product (GDP)) was examined in order to determine whether the economic potential has an effect on the publication efficiency on the subject of "The use of ECMO in COVID-19". The Gross Domestic Product and Gross Domestic Product Per Capita (GDP per capita) of the world countries, whose data were obtained from the World Bank, were examined.[17] Spearman correlation coefficient was used in accordance with the data distribution and $p < 0.05$ was considered statistically significant.

Results

As a result of the literature review, a total of 1197 publications on the use of ECMO in COVID-19 published in the WoS database between 2019 and 2022 were found. The distribution of these publications was article (758, 63.3%), review (166, 13.9%), letter (129, 10.8%), meeting abstract (57, 4.8%), and the remainder were editorial material, early access, and correction. Retracted articles in the WoS database are tagged in the "Retracted Publication" category. As a result of our literature search, there was no article in the Retracted Publication tag. However, 51 publications (42 articles) were tagged in the Early Access and 9 publications (no articles) were in the Correction category. Of the 758 articles, 34.2% ($n = 259$) were published in 2020, 53.5% ($n = 406$) in 2021, and 12.3% ($n = 93$) in 2022. Bibliometric analysis was carried out with 758 articles from 1197 publications

in total. Of these articles, 97.9% (742) were published in English, 1.4% (11) in German, and the remainder were published in other languages (Hungarian (1), Polish (1), Russian (1), Spanish (1) and Turkish (1)). The h-index of 758 articles was 47, the average count of citations per article was 28.47, and the total count of citations was 21,577 (excluding self-citations: 20,354).

Active Countries

The distribution of articles by countries is shown in Figure 1. The first 17 countries with the highest number of articles published were USA (257, 33.9%), Germany (102, 13.4%), Japan (87, 11.5%), China (85, 11.2%), UK (65, 8.5%), Italy (63, 8.3%), France (57, 7.5%), South Korea (30, 4%), Australia (26, 3.4%), Spain (23, 3%), Belgium (21, 2.8%), Netherlands (21, 2.8%), Switzerland (19, 2.5%), Turkey (15, 2%), Austria (13, 1.7%), Canada (13, 1.7%), India (13, 1.7%), respectively (Figure 1). Cluster analysis was performed among 44 countries that published at least 2 articles and 71 countries that published articles on the use of ECMO in COVID-19 and whose authors have international cooperation, and is shown in Figure 2(a) . According to the results of the clustering analysis, 6 different clusters related to international cooperation were formed (Cluster 1: Australia, Egypt, England, India, Kuwait, Pakistan, Qatar, Saudi Arabia, Scotland, South Africa, United Arab Emirates. Cluster 2: Austria, Belgium, Croatia, France, Israel, Italy, Norway, Slovenia, Sweden, Switzerland. Cluster 3: Canada, Denmark, Iran, Japan, China, South Korea, Spain, Taiwan. Cluster 4: Germany, Poland, Greece, USA, Hungary, Ireland. Cluster 5: Brazil, Chile, Mexico, Turkey, Wales. Cluster 6: Colombia, Czech Republic, Netherlands, Singapore). In addition, the total connection strength scores showing the cooperation power of 44 countries were calculated and the international collaboration density map was created according to these scores and is shown in Figure 2(b).

Correlation Analysis

There was a high correlation between the number of articles published by countries on the use of ECMO in COVID-19 and their GDP values, and a weak correlation between GDP per capita values. (respectively, 2018, 2019, 2020: r = 0.766, r = 0.771, r = 0.764, $p < 0.001$; 2018,2019,2020: r = 0.439, r = 0.449, r = 0.434, $p < 0.001$). The scatter plot showing the correlation between the logarithm of the GDP values of the countries and the count of articles they published is presented in Figure 3.

Active Authors

The top 11 most active authors on the use of ECMO in COVID-19 are Combes A. (11), Lorusso R. (11), Supady A. (10), Bode C. (9), Brodie D. (9), Kluge S. (9), Wengenmayer T. (9), Duerschmied D. (8), Ohmagari N. (8), Staudacher DL. (8), and Suzuki T (8).
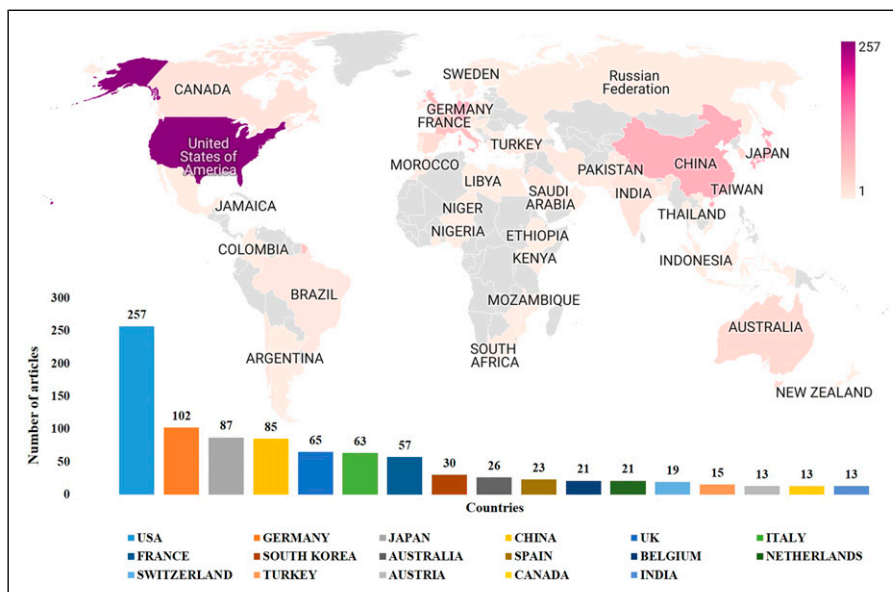

Figure 1. (a). World map showing the distribution of articles published on ECMO in COVID-19. By world countries (b). Top 17 countries in the world that have published the most articles on ECMO in COVID-19.
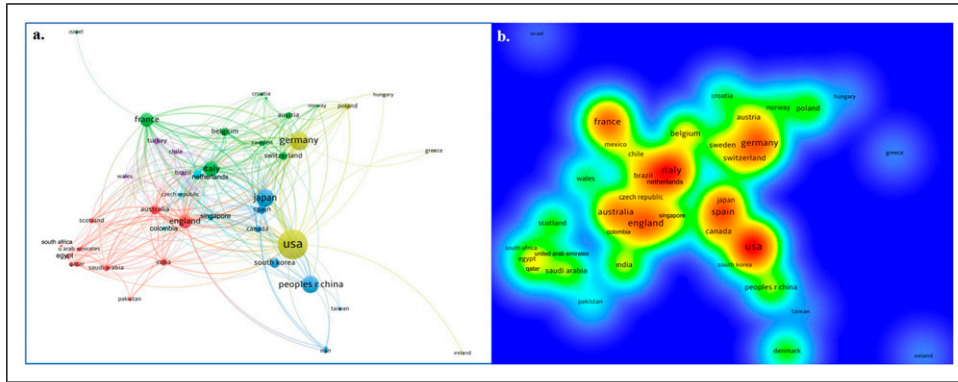
Figure 2. (a). Network visualization map of cluster analysis on international collaboration. Between countries on ECMO in COVID-19. Footnote: Colors indicate clustering. The size of. The circle indicates the large number of articles. (b). Density map for international collaboration. of countries on ECMO in COVID-19. Footnote: The strength of international collaboration score increases from blue to red (blue-green-yellow-red).
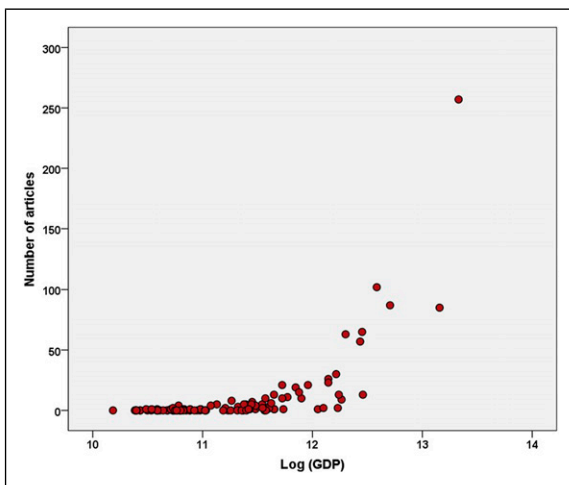

Figure 3. Scatter plot showing the relationship between the logarithm of countries' GDP values and the number of articles published by countries.

Active Institutions

The top 16 institutions that published most of the articles on the use of ECMO in COVID-19 are League of European Research Universities (90), Harvard University (50), Udice French Research Universities (39), Assistance Publique Hopitaux Paris (38), Universite De Paris (34), Institut National de la Sante et de la Recherche Medicale (33), Columbia University (25), Newyork Presbyterian Hospital (24), University of California System (21), University of Pennsylvania (21), Sorbonne Universite (20), University of Freiburg (20), University of Texas System (19), Huazhong University of Science Technology (18), Mayo Clinic (17), and University of London (17).

Active Journals

758 articles published on the use of ECMO in COVID-19 were published in 361 different journals. The first 67 most active journals that published 3 or more articles from these journals, the total count of citations received by the journals and the average count of citations per article are presented in Table 1. The citation network visualization map of these journals is presented in Figure 4.

Citation Analysis

Among the 758 articles published on the use of ECMO in COVID-19, the first 25 articles with highest count of citations among the total count of citations are presented in Table 2. In the last column of Table 2, the average count of citations per year is given.

Co-citation Analysis

There were a total of 12,159 studies cited in the references section of the 758 articles analyzed. Among these studies, the top 5 studies that received highest co-citations (more than 80 citations) were Zhou (2020) (Number of citation: NC = 134), Huang (2020) (NC = 118), Combes (2018) (NC = 117), Yang (2020) (NC = 111), and Barbaro (2020) (NC = 106), respectively.[18–22]

Trending Topics

1283 different keywords were used in all 758 articles published on the use of ECMO in COVID19. Among these keywords, 74 different keywords that were used in at least 5 different articles are shown in Table 3. The cluster network visualization map showing the results of

Table 1. The 67 most active journals that have published more than 3 articles on ECMO.

Journals	RC	C	AC	Journals	RC	C	AC
ASAIO journal	36	615	17.1	BMJ open	4	15	3.8
Frontiers in medicine	22	47	2.1	Cardiology in the young	4	5	1.3
Perfusion-UK	20	43	2.2	Clinical case reports	4	0	0
Journal of clinical medicine	18	45	2.5	ESC heart failure	4	32	8
Journal of cardiothoracic and vascular anesthesia	15	87	5.8	Heart and lung	4	10	2.5
Journal of cardiac surgery	14	37	2.6	Journal of critical care	4	21	5.3
Artificial organs	13	30	2.3	Intensive care medicine	4	1309	327.3
Medicine	13	24	1.8	Advances in therapy	3	4	1.3
Membranes	13	27	2.1	Annals of thoracic surgery	3	21	7
Cureus	10	20	2	BMJ case reports	3	3	1
Plos one	10	73	7.3	British journal of haematology	3	6	2
Journal of infection and chemotherapy	9	50	5.6	Clinical infectious diseases	3	87	29
Acute medicine and surgery	8	25	3.1	Critical care and Resuscitation	3	93	31
Critical care medicine	8	129	16.1	European review for medical and pharmacological sciences	3	30	10
Cureus journal of medical science	8	3	0.4	Heart surgery forum	3	0	0
Critical care	7	99	14.1	JAMA network open	3	18	6
Journal of Korean medical science	7	57	8.1	Journal of critical care medicine	3	4	1.3
European heart journal-case reports	6	8	1.3	Journal of medical internet research	3	41	13.7
JAMA-journal of the American medical Association	6	7913	1318.8	Journal of intensive care medicine	3	15	5
Journal of thrombosis and thrombolysis	6	37	6.2	Lancet	3	287	95.7
Respiratory medicine case reports	6	7	1.2	Lancet respiratory medicine	3	234	78
International journal of artificial organs	6	10	1.7	Open forum infectious diseases	3	27	9
American journal of case reports	5	21	4.2	Signa vitae	3	2	0.7
Chest	5	200	40	Thoracic and cardiovascular surgeon	3	22	7.3
Journal of artificial organs	5	23	4.6	Trials	3	10	3.3
Journal of pediatrics	5	235	47	World journal of clinical cases	3	4	1.3
Medicina-Lithuania	5	5	1	Wiener Klinische Wochenschrift	3	17	5.7
Respirology case reports	5	4	0.8	Indian journal of thoracic and cardiovascular surgery	3	3	1
American journal of Emergency medicine	4	30	7.5	Interactive cardiovascular and thoracic surgery	3	8	2.7
Anaesthesist	4	2	0.5	Internal and Emergency medicine	3	6	2
Annals of medicine and surgery	4	0	0	Internal medicine	3	10	3.3
Annals of surgery	4	76	19	International journal of cardiology	3	47	15.7
Annals of translational medicine	4	16	4	International journal of Environmental research and public health	3	13	4.3
Annals of intensive care	4	44	11	—	—	—	—

RC: Record Count, C: Number of Citation, AC: Average Citation Per Document.

clustering analysis performed between these keywords is shown in Figure 5. The trend network visualization map performed to reveal the trending topics is shown in Figure 6 and the citation network visualization map performed to reveal the most cited topics is shown in Figure 7.

Discussion

Mutation of the virus and disease severity varies throughout the pandemic. In relation to this, COVID-19 related to respiratory failure and treatment strategies also varied. In the pandemic, there has been an increase in the number of articles published in the literature over this period of more than 2 years. There are many articles in the literature not only related to the use of ECMO in COVID-19, but also on all topics related to COVID-19. It was determined in this article that there was an increase in the use of ECMO in COVID-19. While 259 articles were published in 2020, 406 articles were published in 2021.

When the publication distributions of the countries are examined, the first 17 countries that are most active
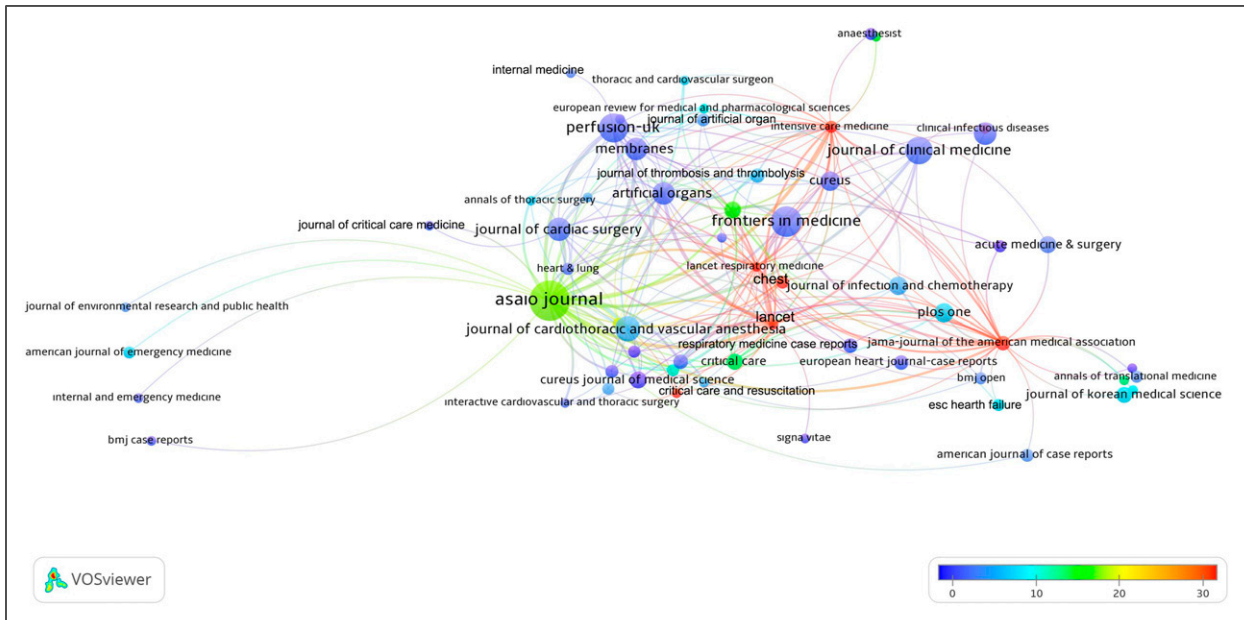
Figure 4. Network visualization map for citation analysis of active journals on ECMO in. COVID-19. Footnote: The average count of citations per article by journals increases from blue to red (blue-green-yellow-red). The size of the circle indicates the large number of articles.

in the production of articles on the use of ECMO in COVID-19 were USA, Germany, Japan, China, UK, Italy, France, South Korea, Australia, Spain, Belgium, Netherlands, Switzerland, Turkey, Austria, Canada, India reaspectively. While 14 of these countries were developed countries, only Turkey, China and India were a developing country. However, although these countries are developing, they are countries with large economies. According to the results of the correlation analysis in our study, there was high correlation between article productivity and GDP and the weak correlation between GDP per capita which shows the economic size of the countries. In the bibliometric studies conducted on many different medical issues in the literature, it has been concluded that economic potential is effective in publication productivity.[11-13] Life support systems such as ECMO are costly devices and the economic size of countries can be effective in using these systems. As the respiratory failure cases due to COVID-19 and the need for ECMO suddenly increased during the pandemic, access to ECMO may have been insufficient in countries with low economic potential. When the density map created according to the total cooperation score between the countries was evaluated, it was determined that the countries with highest cooperation were USA, Italy, England in UK, France, Germany, Spain, Australia and Netherlands respectively. A common feature of these countries is that they have hospitals working as ECMO centers in the ELSO Award of Excellence list.[23] When

the co-authorship collaborations of countries on the use of ECMO in COVID-19 were examined, it was seen that geographical-based collaborations did not have a significant effect on article production.

The journals that published the most articles on the use of ECMO in COVID-19 were determined as ASAIO Journal, Frontiers in Medicine, Perfusion-UK, Journal of Clinical Medicine, Journal of Cardiothoracic and Vascular Anesthesia, Journal of Cardiac Surgery, Artificial Organs, Medicine, and Membranes, respectively. We can suggest that authors who want to publish on the use of ECMO in COVID-19 should first consider these journals. When the citations of the journals were evaluated, the most influential journals according to the average count of citations per article were JAMA-Journal of the American Medical Association, Intensive Care Medicine, Lancet, Lancet Respiratory Medicine, Journal of Pediatrics, Chest respectively. The influential journals after these journals were Critical Care and Resuscitation, Clinical Infectious Diseases, Annals of Surgery, ASAIO Journal, Critical Care Medicine, International Journal of Cardiology, and Critical Care. We can recommend that researchers who want their articles to be cited more, should primarily consider these journals.

When the articles are evaluated according to the count of total citations and the average count of citations per year, the most influential study was published in JAMA by Wang et al. (2020) titled "Clinical characteristics of 138

Table 2. The top 25 most cited articles on ECMO by total number of citations.

No	Article	Author	Journal	PY	TC	AC
1	Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China	Wang D. et al.	JAMA-journal of the American medical Association	2020	6089	2029.7
2	Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected. Interim guidance	WHO	Pediatria i medycyna Rodzinna	2020	1865	621.7
3	Compassionate use of remdesivir for patients with severe COVID-19	Grein J. et al.	New England journal of medicine	2020	1419	473
4	Treatment of 5 critically Ill patients with COVID-19 with convalescent plasma	Shen C. et al.	JAMA-journal of the American medical Association	2020	1340	446.7
5	High risk of thrombosis in patients with severe SARS-CoV-2 infection: a multicenter prospective cohort study	Helms J. et al.	Intensive care medicine	2020	1263	421
6	Acute heart failure in multisystem ınflammatory syndrome in children in the context of global SARS-CoV-2 pandemic	Belhadjer Z. et al.	Circulation	2020	514	171.3
7	Myocardial localization of coronavirus in COVID-19 cardiogenic shock	Tavazzi G. et al.	European journal of heart failure	2020	503	167.7
8	COVID-19 in children and adolescents in Europe: a multinational, multicentre cohort study	Goetzinger F. et al.	Lancet child and Adolescent health	2020	474	158
9	Characteristics and outcomes of children with coronavirus disease 2019 (COVID-19) ınfection admitted to US and canadian pediatric intensive care units	Shekerdemian LS. et al.	JAMA pediatrics	2020	427	142.3
10	Intubation and ventilation amid the COVID-19 outbreak: Wuhan's experience	Meng L. et al.	Anesthesiology	2020	291	97
11	Extracorporeal membrane oxygenation support in COVID-19: an international cohort study of the Extracorporeal life support organization registry	Barbaro RP. et al.	Lancet	2020	244	81.3
12	COVID-19 associated pulmonary aspergillosis	Koehler P. et al.	Mycoses	2020	228	76
13	Intensive care admissions of children with paediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 (PIMS-TS) in the UK: a multicentre observational study	Davies P. et al.	Lancet child and Adolescent health	2020	188	62.7
14	Effect of hydrocortisone on 21-day mortality or respiratory support among critically Ill patients with COVID-19 a randomized clinical trial	Dequin PF. et al.	JAMA-journal of the American medical Association	2020	182	60.7
15	Comparison of hospitalized patients with ARDS caused by COVID-19 and H1N1	Tang X. et al.	Chest	2020	181	60.3
16	Multisystem inflammatory syndrome in children associated with severe acute respiratory syndrome coronavirus 2 infection (MIS-C): a multi-institutional study from New York city	Kaushik S. et al.	Journal of pediatrics	2020	165	55
17	Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome associated with COVID-19: a retrospective cohort study	Schmidt M. et al.	Lancet respiratory medicine	2020	164	54.7
18	Effect of intermediate-dose versus standard-dose prophylactic anticoagulation on thrombotic events, extracorporeal membrane oxygenation treatment, or mortality among patients with COVID-19 admitted to the intensive care unit the INSPIRATION randomized clinical trial	Sadeghipour P. et al.	JAMA-journal of the American medical Association	2021	161	80.5
19	Paediatric inflammatory multisystem syndrome: temporally associated with SARS-CoV-2 (PIMS-TS): Cardiac features, management and short-term outcomes at a UK tertiary paediatric hospital	Ramcharan T. et al.	Pediatric cardiology	2020	147	49
20	Initial ELSO guidance document: ECMO for COVID-19 patients with severe cardiopulmonary failure	Bartlett RH. et al.	ASAIO journal	2020	142	47.3
21	Effect of hydroxychloroquine on clinical status at 14 days in hospitalized patients with COVID-19 a randomized clinical trial	Self WH. et al.	JAMA-journal of the American medical Association	2020	141	47
22	Blood type and outcomes in patients with COVID-19	Latz CA. et al.	Annals of hematology	2020	132	44
23	The 2019–2020 novel coronavirus (severe acute respiratory syndrome coronavirus 2) pandemic: a Joint American college of Academic international medicine-world Academic council of Emergency medicine multidisciplinary COVID-19 working Group consensus paper	Stawicki SP. et al.	Journal of global infectious diseases	2020	127	42.3
24	Coronavirus disease 2019 in patients with inborn errors of immunity: An international study	Meyts I. et al.	Journal of Allergy and clinical immunology	2021	126	63
25	SARS-CoV-2 in Spanish ıntensive care units: Early experience with 15-day survival in vitoria	Barrasa H. et al.	Anaesthesia critical care and pain medicine	2020	108	36

PY: Publication year, TC: Total citation, AC: Average citations per year.

Table 3. The 74 most frequently used keywords in articles about extracorporeal membrane oxygenation (ECMO).

Keywords	Number of uses	Keywords	Number of uses	Keywords	Number of uses
COVID-19	444	Extracorporeal life support	11	Fulminant myocarditis	6
Extracorporeal membrane oxygenation	185	myocarditis	11	Hypoxemia	6
Sars-cov-2	138	acute respiratory distress syndrome (ARDS)	10	ICU	6
ECMO	111	Bleeding	10	Influenza	6
acute respiratory distress syndrome	94	Lung transplantation	10	Lung ultrasound	6
ARDS	79	Pulmonary embolism	10	risk factors	6
Coronavirus	51	Coronavirus disease	9	Venous thromboembolism	6
Coronavirus disease 2019	46	Prognosis	9	Clinical characteristics	5
mortality	36	VV-ECMO	9	Dexamethasone	5
mechanical ventilation	35	mechanical circulatory support	8	Impella	5
Pandemic	26	Prone position	8	Infection	5
respiratory failure	24	Shock	8	Inflammation	5
Critical care	23	Children	7	Japan	5
Case report	22	Heart failure	7	Pediatrics	5
Intensive care unit	21	MIS-C	7	Personal protective equipment	5
Severe acute respiratory syndrome coronavirus 2	20	multisystem inflammatory syndrome in children	7	Sedation	5
Cardiogenic shock	18	resource allocation	7	Severe acute respiratory syndrome	5
Outcome (s)	18	respiratory distress syndrome	7	Severe acute respiratory syndrome coronavirus 2 (sars-cov-2)	5
thrombosis	18	Coagulopathy	6	Severity	5
anticoagulation	16	COVID	6	stemi	5
Pneumonia	16	Critically ill	6	Survival	5
Pregnancy	16	Cytokine storm	6	tracheostomy	5
Extracorporeal membrane oxygenation (ECMO)	14	Cytosorb	6	treatment	5
Coronavirus disease 2019 (COVID-19)	13	Epidemiology	6	Veno-venous extracorporeal membrane oxygenation	5
Intensive care	13	Favipiravir	6	—	—

hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan.China".[24] The second most influential study is by World Health Organization (2020)'s article titled "Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected. Interim guidance" published in the Pediatria i Medycyna Rodzinna.[25] The third most influential study is by Grein et al. (2020)'s article titled "Compassionate use of remdesivir for patients with severe COVID-19" published in the New England Journal of Medicine.[26] The fourth most influential study is by Shen et al. (2020) titled "Treatment of 5 critically ill patients with COVID -19 with convalescent plasma" published in JAMA.[27] The fifth most influential study is by Helms et al. (2020) titled "High risk of thrombosis in patients with severe SARS-COV-2 infection: a multicenter prospective cohort study" published in Intensive Care Medicine.[28] According to the count of co-citations, the studies of Zhou (2020), Huang (2020), Combes (2018), Yang (2020), Barbaro (2020) were determined as the most influential.[18–22] We suggest that clinicians and researchers interested in this subject should read these publications first.

When the keyword analysis was evaluated using the cluster analysis, the topics concerning the use of ECMO in COVID-19 formed clusters in 8 different colors. The most cited keywords were thrombosis, cardiogenic shock, severe acute respiratory syndrome coronavirus 2, coagulopathy, heart failure, ICU, ARDS, risk factors and MIS-C. The use of keywords such as thrombosis and coagulopathy may be due to their major role in COVID-19 patients followed in the ICU. Trend topics may change over time as research on the clinical course and pathogenesis of COVID-19 and the effectiveness of treatment methods (such as favipravir, prone position, tracheosotomy) enhance. According to the analysis to
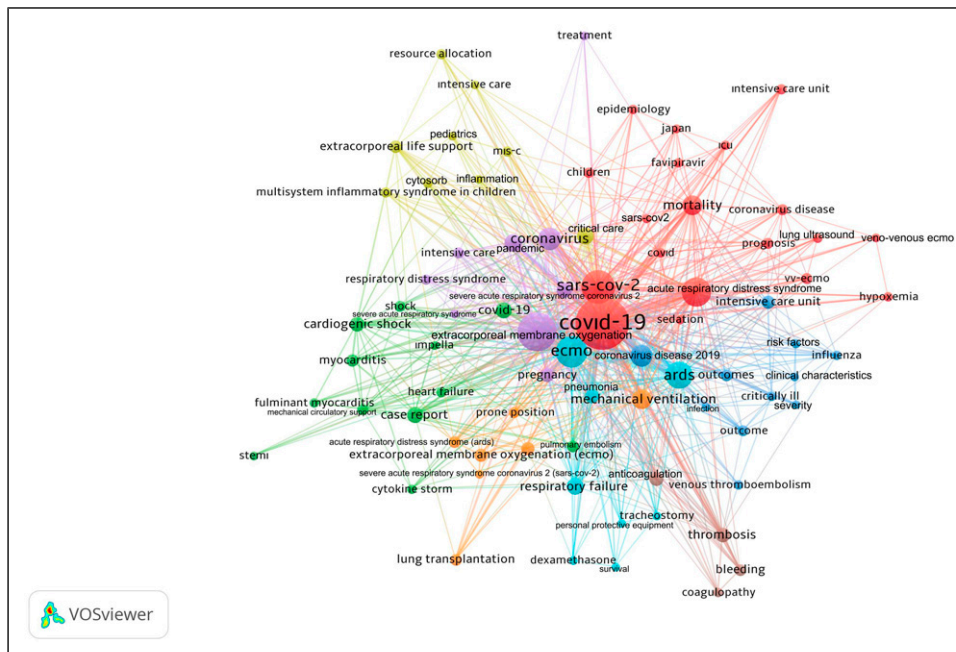
Figure 5. Network visualization map for cluster analysis based on keyword analysis on ECMO in COVID-19. Footnote: Colors indicate clustering. Keywords in the same cluster are of the same color. The size of the circle indicates the number of uses of the keyword. (*Cluster 1:* acute respiratory distress syndrome, children, coronavirus disease, epidemiology, favipiravir, hypoxemia, ICU, intensive care unit, Japan, lung ultrasound, mortality, prognosis, SARS-CoV-2, sedation, VV-ECMO, *Cluster 2:* cardiogenic shock, case report, COVID-19, cytokine storm, fulminant myocarditis, heart failure, impella, mechanical circulatory support, myocarditis, pulmonary embolism, shock, STEMI, *Cluster 3:* clinical characteristics, coronavirus disease 2019, critically ill, infection, influenza, outcome (s), risk factors, severity, venous thromboembolism *Cluster 4:* critical care, cytosorb, extracorporeal life support, inflammation, MIS-C, multisystem inflammatory syndrome in children, pediatrics, resource allocation *Cluster 5:* coronavirus, extracorporeal membrane oxygenation, intensive care, pandemic, pregnancy, respiratory distress syndrome, severe acute respiratory syndrome coronavirus 2, treatment *Cluster 6:* ARDS, dexamethasone, ECMO, personal protective equipment, pneumonia, respiratory failure, survival, tracheostomy *Cluster 7:* acute respiratory distress syndrome (ARDS), coronavirus disease 2019 (COVID-19), extracorporeal membrane oxygenation (ECMO), lung transplantation, mechanical ventilation, prone position, severe acute respiratory syndrome coronavirus 2 (sars-cov-2) *Cluster 8:* anticoagulation, bleeding, coagulopathy, thrombosis).

identify trending topics, the most frequent keywords on the topic in recent months were pediatrics, multisystem inflammatory syndrome in children, prone position, intensive care, veno-venous extracorporeal membrane oxygenation, venous thromboembolism, dexamethasone, thrombosis, anticoagulation, and lung transplantation. These findings suggest that the need for intensive care and ECMO in pediatric patients also increased due to the increase in the number of pediatric patients in the course of the pandemic and the development of MIS-C. Further, it is a normal result that dexamethasone is a trending topic, its use has become widespread after the effectiveness of steroid treatment in COVID-19 has been demonstrated.[29] Various data on the development of COVID-19 in immunosuppressed lung transplant patients and lung transplantation due to COVID-19-related respiratory failure have been published in the literatüre[30,31]. ECMO, which acts as a bridge until transplantation, is frequently used,

especially in patients undergoing lung transplantation for COVID-19. In other words, ECMO is often used not only for treatment, but also during the process of treatment and to save time for the patient while waiting for the natural lungs to heal.

We did not find any bibliometric studies on the use of ECMO in COVID-19 in our review of the literature. This comprehensive study we have done is the first bibliometric research on the subject. We only used the WoS database for literature review, which may be a limitation for our research. We preferred it this way, because citation and co-citation analysis could not be performed in PubMed database. We did not use the Scopus database because journals with low impact factor were also indexed.[9–11] In recent years, WoS has been used more frequently for bibliometric analysis.[9–15]

Since the studies published in the case report category were indexed in the article category in the WoS database, they were also included in our analysis. In the keyword
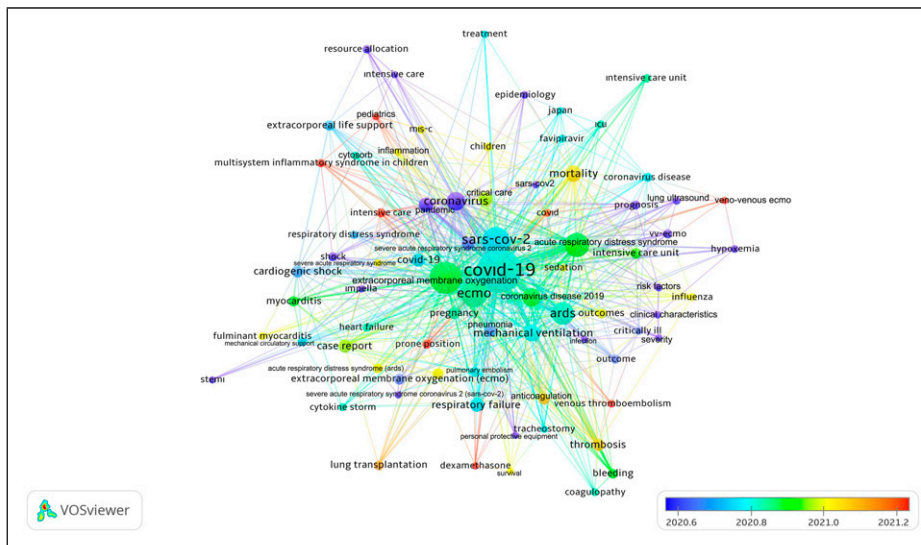
Figure 6. Network visualization map for trends on ECMO in COVID-19. Footnote: In the indicator given in the lower right corner of the figure, the topicality of the article increases from blue to red (blue-green-yellow-red). The size of the circle indicates the number of uses of the keyword.
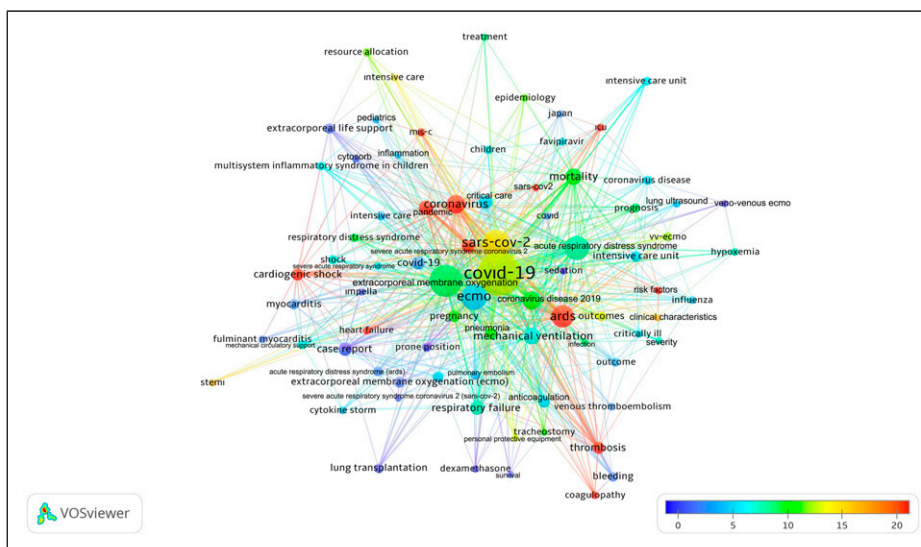

Figure 7. Network visualization map of the most frequently cited topics on ECMO in COVID-19. Footnote: In the indicator given in the lower right corner of the figure, the count of citations received by the topic increases from blue to red (blue-green-yellow-red). The size of the circle indicates the number of uses of the keyword.

analysis, 22 different case reports were determined. Although there are not many, we believe that case reports are also important for the analysis and should be included, which can not be regarded as a limitation.

The count of publications concerning the use of ECMO in COVID-19 does not reflect whole ECMO studies. This study only offers a perspective to researchers on the use of ECMO in COVID-19. Another limitation of the study is that the results are based only on statistical findings from studies in the literature. This study can help physicians find the right journal for publication, provides a holistic view of the summary of scientific output published on this topic in the literature, but does not improve patient management. However, as a result of the detailed analysis of all the articles on this important issue published during the COVID-19 pandemic, we believe that the most influential studies, the most focused topics, global productivity and their

discussion are important statistical information on this subject.

Conclusion

We shared a summary of 758 articles published between 2019–2022 in this comprehensive bibliometric study on the use of ECMO in COVID-19, which is seen more frequently in recent articles. The trending topics in the use of ECMO in COVID-19 studies in recent months are pediatrics, multisystem inflammatory syndrome in children, prone position, intensive care, veno-venous extracorporeal membrane oxygenation, venous thromboembolism, dexamethasone, thrombosis, anticoagulation, and lung transplantation. The fact that most of the studies are from countries in the ELSO Awards of Excellence list indicates that the follow-up of ECMO in certain centers and teams can also be influencing the publications. This article can be a useful source for clinicians, scientists, and students on the global output of the use of ECMO in COVID-19. Although ECMO has been used for respiratory failure for many years, we believe that the use of ECMO due to COVID-19 related respiratory failure and the publications on the subject have increased simultaneously all over the world. When the highly cited publications mentioned in this study are examined, it can help physicians or centers applying ECMO to review their practices in line with who, why and how ECMO is applied and the results obtained. Another contribution is that although there are not enough intensive care specialists today, it can help most physicians who follow COVID-19 patients in intensive care to raise awareness about ECMO and direct patients to the relevant centers at the right time.

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