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Pro-Metrics

ORIGINAL ARTICLE

Scientometric mapping of global publications on pulmonary embolism in Covid-19 research

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ABSTRACT

Objective. The study presents scientometric research on the scientific literature on COVID-19 associated with Pulmonary Embolism indexed in the Web of Science database.

Design/Methodology/Approach. The study analysed 1307 bibliographic records published between 2020 and April 10, 2023. The authors analysed the publication and citation data for the parameters like key participating countries, organisations, authors, journals, and publishers. Collaborative patterns were studied through science mapping tools like VOSviewer and Biblioshiny (R Package).

Results/Discussion. The study analysed 1307 publications, which received 38,930 citations, at the rate of 29.79 Citations Per Paper. The study also presented the publication growth rate (Annual Growth Rate -47.87%), 97.55% collaborated publications, and 21.88% of publications are through international collaboration. 9,523 authors from 87 countries and 2,643 organisations participated in these research publications. The USA (368), Italy (205), and England (135) were the most productive countries. Udice French Research Universities (87), INSERM (72) and Assistance Publique Hopitaux Paris (62) were the top contributing organisations. F.A. Klok of Leiden Univ Med Ctr, Leiden, Netherlands (21) has a highly published author. Thrombosis Research (59), a journal published by Elsevier, is the highly preferred journal to publish the research. Journal of Thrombosis and Haemostasis (2602), published by Wiley, is a highly referred journal among the 22,080 references. Elsevier has published the highest number of 326 research papers on 'Covid 19 and Pulmonary Embolism' publisher among the 115 publishers. The top 5 keywords in terms of frequency of occurrences were: covid-19 (714), pulmonary embolism (405), sars-cov-2 (191), thrombosis (154), and venous thromboembolism (146).

Conclusions. The present study provides a framework to profile the research landscape and exploit the global research on the scientific literature on COVID-19 associated with Pulmonary Embolism, combining the productivity analysis and its impact through citation analysis. A summary of the study throws

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light on the research opportunities for doctors and researchers, along with the implications for various healthcare systems and policymakers.

Keywords: COVID-19; SARS-CoV-2 virus; pulmonary embolism; global publications; scientometrics; thrombosis.

1. INTRODUCTION

Coronavirus disease or COVID-19 is an infectious caused by severe acute respiratory syndrome coronavirus 2 or SARS-CoV-2 virus (Zhu *et al.,* 2020). COVID-19 was first reported in Wuhan, China, in December 2019 and spread worldwide within the shortest period (Liu *et al.,* 2020). The World Health Organization (WHO), on March 11, 2020, declared the novel coronavirus (COVID-19) outbreak a global pandemic (Cucinotta & Vanelli, 2020). According to World Health Organisation (WHO), the COVID-19 infection has been confirmed in more than 76,64,40,796 people and caused the death of more than 69,32,591 people on May 24, 2023. The major outbreak was recorded in Europe (27,62,64,234), Western Pacific (20,34,14,068), and Americas (19,27,18,073) regions, together 87.73% of reported cases (World Health Organisation, 2023).

During the COVID-19 pandemic, a maximum number of people infected experienced respiratory illness, and the mild to moderated infection recovered without requiring major treatment. But some people are affected cardiovascular (CV) system, causing serious illnesses due to infection, including life-threatening Pulmonary Embolism (PE) (Danzi *et al.,* 2020). Up to one-third of COVID-19 patients with pulmonary embolism were at increased risk of critically ill requiring ICU admission (Sakr *et al.,* 2020). COVID-19 pulmonary embolism was the reason for high mortality rates during the COVID-19 pandemic (Tilliridou *et al.,* 2021, Martin *et al.,* 2022, Voci *et al.,* 2022). Thus, in this context, numerous clinical studies and research papers on Covid-19 associated with pulmonary embolism were published in the last three years.

Hence, it is important to study the scientific literature on COVID-19 associated with pulmonary embolism through scientometric ways to identify the stakeholders involved in this research. The main objectives of this study are to identify the productivity and collaboration of significant countries, organisations, authors, and publication sources.

2. LITERATURE REVIEW

Tian *et al.* (2020) conducted a bibliometric analysis of publications on Venous Thromboembolism (VTE) in children between 1988 and 2019. The authors analysed 1,779 publications indexed in the PubMed database. The highest, i.e., 149 publications, were published in 2018. A total of 44.41% of publications were journal articles; the *Thrombosis Research* journal has published the highest number of (34) papers. Fifty-eight countries collaborated in publishing research papers on VTE, and 41.37% of publications were affiliated with the USA.

Further, the authors analysed co-authorship through a visualisation map and found Ulrike NowakGöttl as the most productive author. Highly used keywords were analysed through double clustering of MeSH terms using BICOMB software, and Venous Thromboembolism/Etiology (149) had the highest appearance. Durğun *et al.* (2021) analysed 159 publications on Pulmonary Embolism in the COVID-19 era retrieved from the Web of Science database. Among the total publications, 41.5% were research articles, followed by letters (32.8%) and editorials (17.6%); and 94.97% were in English. One hundred fifty-nine publications have received 1,198 citations at 7.53 per paper and 14 h-index. The authors found only 47.2% of papers were cited, and 52.8% were not cited. Content analysis showed that 71.2% of publications belonged to clinical features. These 159 research papers were published in 88 journals, and *Thrombosis Research* was the most preferred journal. Further, the authors analysed 66 research articles with 143 citations at the rate of 2.17 with an h-index of 7. The study found publications other than research articles performed better than research articles in attracting more citations.

Sedani *et al.* (2021) presented a bibliometric analysis of the top 100 highly cited articles on

Thromboprophylaxis across orthopaedic surgery, indexed on the WoS database. Together these 100 publications have received 21,099 citations. The highly cited paper 'Prevention of Venous Thromboembolism' has received 2802 citations at 215.54 per year, authored by Geerts *et al.* and published in *Chest*. The study used VOSviewer to analyse the data through network mapping to identify the highly published/cited journal and highly used keywords. *Journal of Thrombosis and Haemostasis* (21) was the highly published journal, followed by the *Journal of Bone and Joint Surgery* (11). Among the keywords, "deep vein thrombosis", "low molecular weight heparin", and "prevention" are highly used keywords. Bengt Eriksson was the most prolific author, with the highest number of (16) publications among the top 100, followed by Alexander Turpie with 11 papers. Gupta *et al.* (2021) explored Thrombosis research in India through a bibliometric study using 4026 publication records indexed in the Scopus database between 2000 and 2019. The authors found 1,78,462 global publications on Thrombosis research and a 2.26% contribution from India. The global publications have registered only a 4.18% growth, and India has registered 11.64% growth. Indian publications have received 54,503 citations at the rate of 13.54 per year. Of 4026, 14.13% of publications have international collaboration, and the USA has the most (61) collaborations. The AIIMS, New Delhi (374) was the most productive organisation in India, and K. Ghosh of NIIH-Bombay was the most prolific author with 61 publications. *Indian Heart Journal* was the highly preferred journal among Indian authors.

Naseer *et al.* (2021) studied publications on 'COVID-19 Complications', including Pulmonary Embolism. Two thousand three hundred seventy-five publications were retrieved from the PubMed database published from 2020 to March 20, 2021. Among the significant publications on COVID-19 Complications, 8.55% were on Pulmonary Embolism preceded by Stroke (18.99%) and Pneumonia (65.77%). The highest, i.e., 1712 publications, were recorded in 2020 and 663 in 2021. More than half of the publications on COVID-19 Complications were Journal Articles (54.57%), followed by Case Reports (23.79%). China (343) has published the highest number of publications, and COVID-19 (1,853) was the highly used keyword. Özyalçin and Erol (2021) conducted a bibliometric study of publications on Deep Vein Thrombosis (DVT) indexed in the WoS database. The authors analysed 5,890 journal articles indexed between 1980 and 2020 with 162 h-index and 27.74 citations per paper. The highest, i.e., 235 articles, were published in *Thrombosis and Haemostasis*. The USA was the most productive country, with 30.1% of publications, and McMaster University was the leading institution, with 141 publications. Cardiovascular System Cardiology was a highly productive research area, and 4985 keywords were used in the articles. Deep Vein Thrombosis (1161) was a highly used keyword, followed by Deep Venous Thrombosis (629) and Pulmonary Embolism (390).

Sun *et al.* (2022) analysed publications on Central Venous Catheterization-associated Thrombosis indexed in the WoS-SCIE database. The authors analysed 2,810 publications records indexed till December 31, 2021. A total of 29,920 citations were received by these publications at the rate of 10.65 citations per paper and an h-index of 79. Among the publications under study, 78.93% were journal articles. The study used CiteSpace V software to generate the visualization maps to analyse the data further and found 113 countries have collaborated with the USA (1,015) as the most collaborated country. The study found 482 organisations involved, and McMaster University (56) was the most productive institute. Mauro Pittiruti (26) was the most productive author. Among the 608 journals, the *Journal of Vascular Access* (152) was the most preferred. The study further analysed keyword co-occurrence maps to identify highly used keywords and found Thrombosis (952) was the highly used keyword, followed by Central venous catheter (871) and Complication (853). Duan *et al.* (2022) presented a bibliometric analysis of Thrombosis in Lung Cancer using 378 research papers indexed in the Web of Science database published between 1942 and 2022. The study found a significant upward growth in the number of publications since 2020 and the highest number of citations received only between 2000 and 2022. The researchers from China and the USA have maximum contributions in the number of publications. *Thrombosis Research* was the highly preferred journal among researchers, and the

Journal of Clinical Oncology was highly cited. Y Zhang was the most prolific author with the most published papers, and S Osanto was the highly cited author in the research papers on 'Thrombosis in Lung Cancer'. The study also identified the top 10 highly cited articles; a research paper titled "Malignancies, prothrombotic mutations, and the risk of venous thrombosis", published in 2005, received the highest number of (1259) citations at the rate of 71.94 per year. The study conducted keyword analysis, where "lung cancer", "thrombosis," and "pulmonary embolism" were the most frequently used keywords.

Fan, Xu and Zhao (2023) analysed 5,583 research publications on Pulmonary Embolism published between 2017 and 2021, indexed in the PubMed database. The authors found decreasing trends in the publications, where 1193 papers were published in 2017 and 998 in 2021. Thrombosis Research Journal published the highest number of 130 research papers on Pulmonary Eembolism and F. A. Klok was the most prolific author, with 76 publications to his credit. The authors analysed 52 high-frequency MeSH terms through a co-word analysis visualization map. 'Pulmonary Embolism/Epidemiology' was the highly used Medical Subject Heading (MeSH) term.

Only two bibliometric studies were carried out, covering the publications on COVID-19 associated with pulmonary embolism published till 2021. The remaining is the study on different forms of thrombosis. Since the COVID-19 Pandemic is not over yet, several reports have shown pulmonary embolism (PE) as a cause of sudden death among COVID-19 patients. Several clinical studies and research publications were published during the COVID-19 outbreak. Hence, this study makes a humble effort to undertake a comprehensive scientometrics study to analyse the scientific literature on COVID-19 associated with pulmonary embolism, including recent papers and clinical studies.

3. OBJECTIVES OF THE STUDY

The focal objective of this paper is to analyse the research literature on Covid 19 and Pulmonary Embolism published in Web of Science between 2020 and 2023. The specific objectives of the study are to:

1. study most productive countries, organizations, and authors and their collaborative linkages;
2. determine the highly preferred journals, most referred journals, and most productive publishers;
3. know key subject areas and highly used keywords reflecting the trends of research; and
4. examine the characteristics of highly cited publications.

4. MATERIALS AND METHODS

For this study, the bibliographic data were identified, retrieved, and downloaded using a well-defined search strategy from the WoS Core Collection database shown below. The search was limited to 10-04-2023, covering the 2020-2023 period. The search yielded 1,307 records, later downloaded in the CSV and BibTeX file formats and statistically analysed using MS-Excel and HistCite applications. Further, the data was analysed using Science maps and network visualization tools such as VoSViewer and Biblioshiny App of R Studio. The search strategy used to retrieve the records was:

(TS=("covid 19" OR "2019 novel coronavirus" OR "coronavirus 2019"OR "coronavirus disease 2019" OR "2019-novel CoV" OR "2019 nov" OR covid 2019 or "corona virus 2019" OR ncov-2019 OR ncovid19 OR "nov 2019" OR 2019-ncov OR covid-19 OR "Severe acute respiratory syndrome coronavirus 2" OR "SARS-CoV-2")) AND TS=("pulmonary embolism").

5. ANALYSIS AND RESULTS

5.1. Overall Output

An overall 1307 research publications on Covid 19 and Pulmonary Embolism were indexed in the WoS Core Collection, between 2020 and 2023, with an average annual number of publications of 327. The highest number of publications were published in the year 2021, with 513 papers, followed by 2022 (369), 2020 (353), and the least in the year 2023 (50) till April 10, 2023. These 1307 research publications have received a total of 38,930 citations, at the rate of 29.79 Citations Per Paper (CPP), and the highest, i.e.,

25,729 number of citations received by the publications in the year 2020 at the rate of 72.89 CPP, followed by 2021 (11,911 citations; 22.99 CPP), 2022 (1,267 citations, 3.31 CPP) and least in the year 2023 (23 citations, 0.43 CPP), which clearly showed that the citable year plays an essential role in the research publications. The h-index of overall publications under study is 74. Of the 1307 global literature considered for the study, 1106 (84.62%) are open-access publications and received 37,472 (96.25%) citations together at the rate of 33.88 CPP, which clearly shows that the open-access publications have a higher potentiality to attract a more significant number of citations than the closed-access or subscription-based publications.

Description	Results
Time span	2020:2023
Sources (Journals, Books, etc.)	442
Documents	1307
Annual Growth Rate %	-47.87
Document Average Age	1.91
Average citations per doc	29.79
References	22080
DOCUMENT CONTENTS	
Keywords Plus (ID)	1123
Author's Keywords (DE)	1679
AUTHORS	
Authors	9523
Authors of single-authored docs	32
AUTHORS COLLABORATION	
Single-authored docs	32
Co-Authors per Document	8.77
International co-authorships %	21.88
DOCUMENT TYPES	
Articles	770
Review Articles	255
Letters	128
Meeting Abstracts	97
Editorial Materials	72
Corrections	6
Proceeding Papers	5
Meetings	1
Publication With Expression of Concern	1

Table 1. Main information about data.

A total of 9,523 authors have contributed against 1307 publications under study. Only 32 (2.45%) papers were single-authored, indicating collaborated research trends in Covid 19 and Pulmonary Embolism. The study revealed an average, i.e., 8.77 authors per paper, and found that 21.88% (of 1307) publications have collaborations of authors from two or more countries. Out of 1307 publications under study, 318 (24.33%) research publications have received financial support from 908 funding agencies and organisations, and together such publications have received 15,832 citations, averaging 49.79 citations per year. The articles constituted the most extensive global share (59.91%), followed by Review Articles (19.51%), Letters (9.79%), Meeting Abstracts (7.42%), Editorial Materials (5.51%), others with less than 1%, varying from 0.08 to 0.46%. Of 1307 publications, 98.2% were published in English, followed by Spanish (1.1%), and the remaining 0.7% in other languages such as German, Russian, French, and Hungarian (Table 1).

5.2. Top 10 Most Productive Countries

Authors from 87 countries have participated in research publications on Covid 19 and Pulmonary Embolism. Among the 87 collaborated countries, 55 countries have contributed between 1 and 10 publications each, 23 countries have contributed between 11 and 50 each, three countries have contributed between 51 and 100 publications each, and six countries have contributed between 101 and 368 publications each. The top 10 productive countries have contributed 1300 publications (99.46%) and received more than 100% share in global citations. Among the top 10 countries, the USA was the most significant contributor, with 28.16% of publications, followed by Italy (15.69%), England, and France (10.33% each). The USA has received the highest among the top 10 productive countries, i.e., 10,977 citations, followed by Italy (8,454). However, Peoples R China has achieved the highest, i.e., 123.59 citations per paper, followed by Canada (94.92) and Germany (80.44). All the top 10 productive countries have received higher CPP than the overall CPP. The share of international collaborative papers in the top 10 countries varied from 36.10% to 80.39%, averaging 45.38% (Table 2).

Figure 1 presents the country collaboration map on Covid 19 and Pulmonary Embolism research literature around the world, which is generated using the Biblioshiny R-Package, and Figure 2 shows a collaborative network map of countries involved in the Covid 19 and Pulmonary Embolism research publications, generated using the VOSviewer. The map in Figure 2 presents the collaboration of 81 countries. Among the 87 countries involved in the research, six countries have never collaborated with others in these publications. These 81 countries have been divided into 13 clusters with 823 links and total link strength 2372. Each node represents a country, and its size means its productivity. The lines connecting the nodes show their collaboration. Higher the thickness of the links, the higher the collaboration. Among the top 10 most productive countries, China has not collaborated with the Netherlands and Switzerland. Except for these three, all other countries have collaborated with others listed in the top 10 productive countries.

Countries	TP	% TP	TC	ACPP	h-Index	ICP	%ICP	RCI	T10CL
USA	368	28.16	10,977	29.83	43	135	36.68	1.00	9
Italy	205	15.69	8,454	41.24	34	74	36.10	1.38	9
England	135	10.33	6,780	50.22	34	82	60.74	1.69	9
France	135	10.33	7,811	57.86	34	56	41.48	1.94	9
Spain	121	9.26	4,153	34.32	26	49	40.50	1.15	9
Germany	104	7.96	8,366	80.44	22	61	58.65	2.70	9
Netherlands	70	5.36	5,796	82.8	18	29	41.43	2.78	8
Switzerland	67	5.13	4,039	60.28	20	44	65.67	2.02	8
Canada	51	3.90	4,841	94.92	19	41	80.39	3.19	9
Peoples R. China	44	3.37	5,438	123.59	21	19	43.18	4.15	7

Table 2. Top 10 productive countries. Notes: TP: Total Publications; % TP: Percentage of Total Publications; TC: Total Citations; ACPP: Average Citations per Paper; ICP: International Collaborated Publications; %ICP: Percentage of International Collaborated Publications; RCI: Relative Citation Index; T10CL: Collaboration between top-10 collaborated countries.

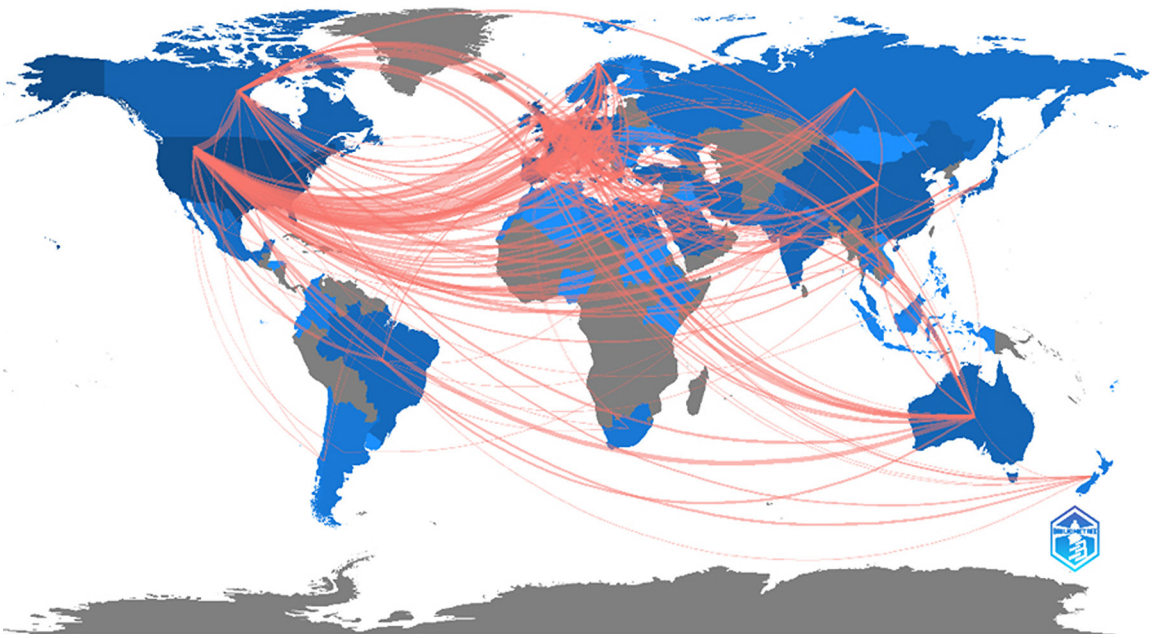

Figure 1. Country collaboration map.

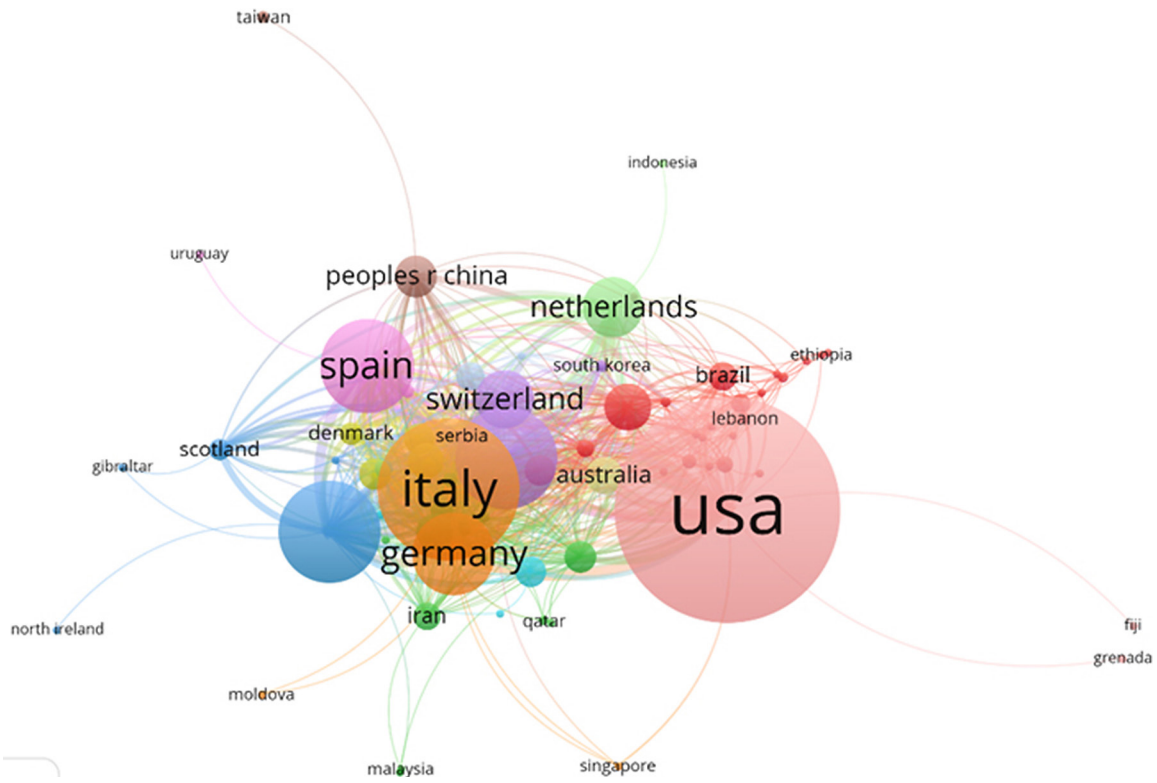

Figure 2. Co-authorship map of highly productive countries.

5.3. Top 10 Subject wise distributions of Publications

The research publications on Covid 19 and Pulmonary Embolism were scattered in 68 Web of Science subject categories. It is observed that the largest share of 20.35% publications was categorised in 'Peripheral Vascular Disease,' followed by Medicine, General & Internal (18.06%), Hematology (17.75%), Cardiac & Cardiovascular Systems (16.91%), Respiratory System (9.87%) and Radiology, Nuclear Medicine & Medical Imaging (9.11%), etc. The subject category 'Peripheral Vascular Disease' has received the highest i.e., 13,113 citations, followed by Hematology (12489) and Medicine, General & Internal (7545) subject categories. However, among the top 10 most productive subject categories. Hematology has achieved the highest (53.83) citations per paper, followed by Peripheral Vascular Disease (49.30) and Critical Care Medicine (40.97). In terms of impact, 'Peripheral Vascular Disease' and 'Hematology' subject categories have achieved the highest h-index of 39 each, followed by 'Cardiac & Cardiovascular Systems' (35) and 'Critical Care Medicine' (26) (Table 3).

Figure 3 presents a network map of all the WoS Subject Categories regarding co-occurrences with each other. All the subject categories are classified into seven clusters, each node represents a subject category, and its size represents research productivity in the subject category. The lines connecting the nodes show their co-occurrences. The higher the thickness of the links, the higher the number of co-occurrences.

5.4. Top 10 Most Productive Organizations

A total of 2,643 Organisations participated in the global research publications on 'Covid 19 and Pulmonary Embolism', and among these organisations, 1,713 organisations have contributed one publications each, 817 organisations have contributed 2-10 publications each, 97 organisations have contributed 11-25 publications each, 11 organisations have contributed 26-50 publications each and five organisations have contributed 56-87 publications each. The top 10 most productive organisations have contributed 509 (38.94%) publications and received 35,573 (91.38%) citations at the rate of 69.89 citations

WoS Subject Categories	TP	% TP	TC	ACPP	h-Index
Peripheral Vascular Disease	266	20.35	13,113	49.30	39
Medicine, General & Internal	236	18.06	7,545	31.97	25
Hematology	232	17.75	12,489	53.83	39
Cardiac & Cardiovascular Systems	221	16.91	7,106	32.15	35
Respiratory System	129	9.87	2,838	22.00	23
Radiology, Nuclear Medicine & Medical Imaging	119	9.11	2,447	20.56	24
Critical Care Medicine	92	7.04	3,769	40.97	26
Surgery	60	4.59	535	8.92	15
Pharmacology Pharmacy	50	3.83	414	8.28	11
Infectious Diseases	49	3.75	486	9.92	12

Table 3. Top 10 Subject wise distributions of Publications. Note: TP: Total Publications; % TP: Percentage of Total Publications; TC: Total Citations; ACPP: Average Citations per Paper.

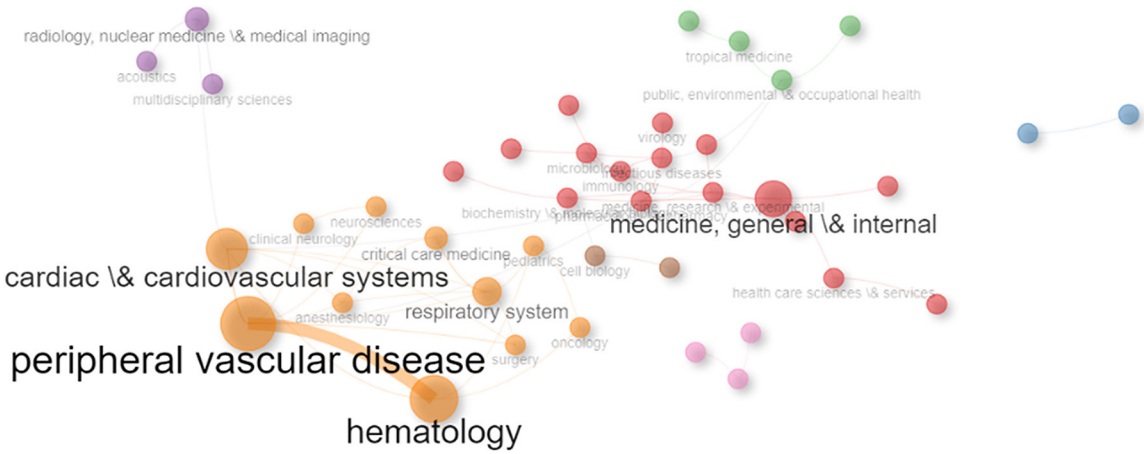

Figure 3. Co-occurrence network of wos subject categories.

per paper, which is almost double the 29.79 CPP of the overall research literature. Further analysis reveals that Udice French Research Universities has contributed the highest, i.e., 87 publications, followed by Institut national de la santé et de la recherche médicale INSERM (72) and Assistance Publique Hopitaux Paris APHP (62). However, Institut national de la santé et de la recherche médicale INSERM has received the highest, i.e. 6,202 citations, followed by Udice French Research Universities (5,646) and Universite Paris Cite (4,567). Among the top 10 productive organisations, Harvard Medical School has achieved 91.48 citations per paper, followed by CIBER-Centro De Investigacion Biomedica En Red (89.63) and Institut national de la santé et de la recherche médicale INSERM (86.14) (Table 4).

Figure 4 presents a co-authorship map of highly productive (top 100) organisations. These 100 organisations have been divided into 3 clusters with 1,664 links and total link strength 4,414. Each node represents an organisation, and its size means its productivity. The lines connecting the nodes show their collaboration. The higher the thickness of the links, the higher the collaboration. Cluster 1 in red has 52 organisations, Cluster 2 in Green has 34 organisations, and Cluster 3 in Blue has 14 organisations based on their collaborations. Figure 5 presents a citation based network map of the top 100 most productive organisations. These top 100 productive organisations are divided into 5 clusters with 4,029 links and 19,429 link strengths based on the shared citations among the organisations.

Name of the Organisation	TP	% TP	TC	ACPP	h-Index
Udice French Research Universities	87	6.66	5,646	64.90	27
Institut National de la Santé et de la Recherche Médicale INSERM	72	5.51	6,202	86.14	27
Assistance Publique Hopitaux Paris APHP	62	4.74	4,534	73.13	21
Universite Paris Cite	59	4.51	4,567	77.41	22
Harvard University	56	4.29	4,054	72.39	21
Harvard Medical School	40	3.06	3,659	91.48	19
University of London	39	2.98	1,860	47.69	16
CIBER-Centro De Investigacion Biomedica En Red	32	2.45	2,868	89.63	15
University of Barcelona	31	2.37	551	17.77	11
University of Milan	31	2.37	1,632	52.65	14

Table 4. Top 10 Most Productive Organizations. Note: TP: Total Publications; % TP: Percentage of Total Publications; TC: Total Citations; ACPP: Average Citations per Paper.

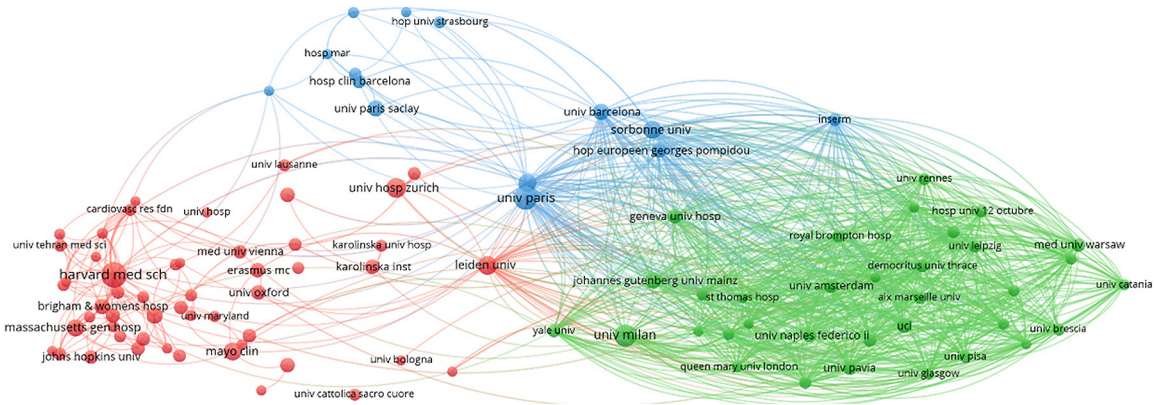

Figure 4. Co-authorship map of highly productive organisations.

5.5. Top 10 Most Prolific Authors

Overall, 9,523 authors are associated with publishing 1,307 global research literature on 'Covid 19 and Pulmonary Embolism', and among these authors, 8,018 authors have published one paper each, followed by 1,458 authors have published 2-5 papers each, 41 authors have published 6-10 papers each, and 6 authors have published 11-21 papers each. Together top 10 authors have published 122 (9.33%) research papers and received 21,589 (55.46%) citations at the rate of 176.96 per paper. Among the top 10 most productive authors, F. A. Klok of Leiden Univ Med Ctr, Leiden, Netherlands, has published the highest (21) papers, followed by Stefano Barco of University Hospital Zurich, Switzerland (16) and David Jimenez of Univ Alcala, Madrid, Spain (13). Among the most productive authors, F. A. Klok has received the highest, i.e., 4,124 citations, followed by Menno V. Huisman of Leiden Univ Med Ctr, Leiden, Netherlands (3,802) and David Jimenez of Univ Alcala, Madrid, Spain (2,529). Menno V. Huisman of Leiden Univ Med Ctr, Leiden, Netherlands, has achieved the highest, i.e., 422.44 citations per paper, followed by Manuel Monreal of Univ Catolica Murcia, Murcia, Spain (209.5) and F.A. Klok of Leiden Univ Med Ctr, Leiden, Netherlands (196.38). Among the top 10 most productive authors, two belong to the Univ Hosp Zurich, Zurich, Switzerland, Leiden Univ Med Ctr, Leiden, Netherlands, and the Netherlands, Spain, Switzerland, and the USA, respectively (Table 5).

Figure 6 presents a co-authorship map of highly productive top 100 authors with at least 5 publications each. Out of the top 100, only 87 authors have connections between them, and connected authors have been divided into 8 clusters with 475 links and total link strength

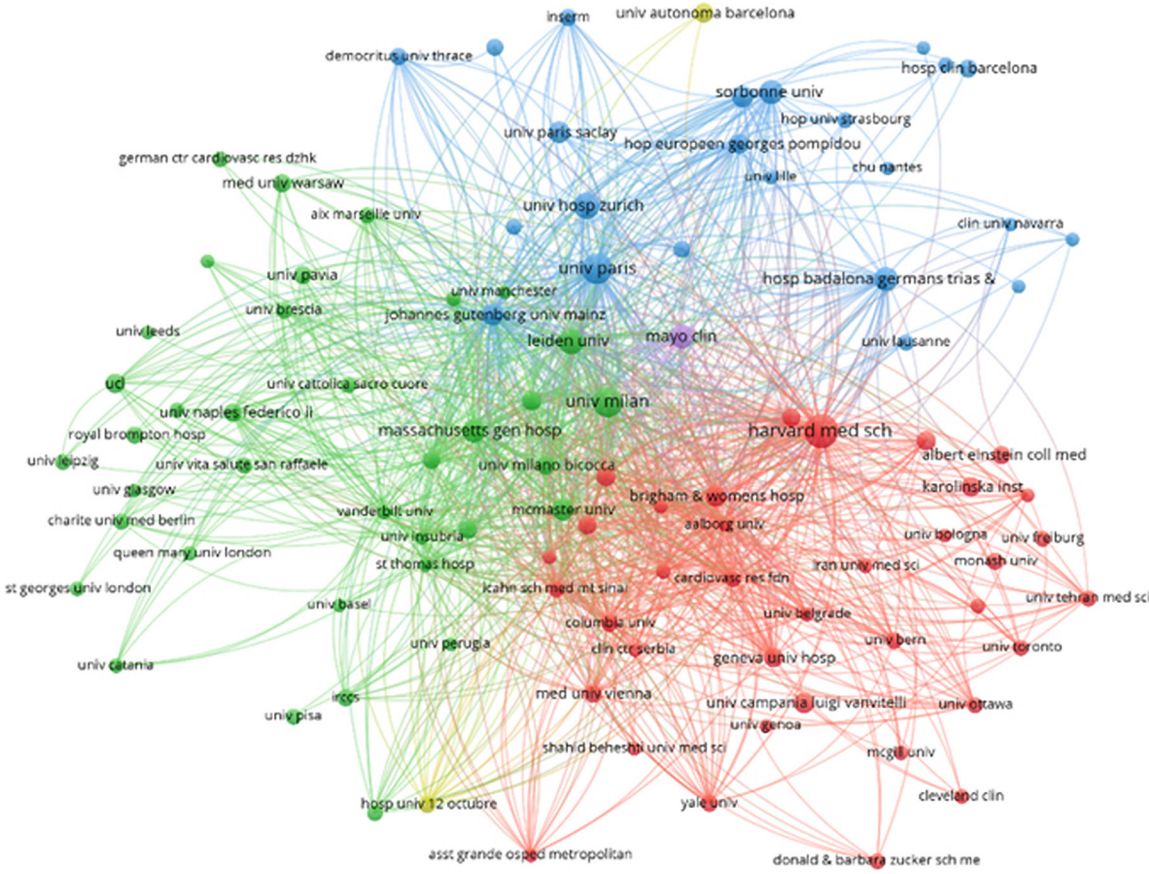

Figure 5. Co-citation map of most productive organisations.

of 1313. Each node represents an author, and the node size represents the number of authors' productivity. The lines connecting the nodes show collaboration between the authors; the higher the links' thickness, the higher the authors' collaboration. Figure 7 presents the citation-based network map of the top 10 most productive authors. These productive authors are divided into 2 clusters with 45 links and 564 total link strengths based on the shared citations among the authors. All ten authors were connected through citations.

Authors	Affiliation	TP	%TP	TC	ACPP	h-Index
F. A. Klok	Leiden Univ Med Ctr, Leiden, Netherlands	21	1.607	4,124	196.38	9
Stefano Barco	Univ Hosp Zurich, Zurich, Switzerland	16	1.224	1,422	88.88	6
David Jimenez	Univ Alcala, Madrid, Spain	13	0.995	2,529	194.54	7
Behnood Bikdeli	Harvard Med Sch, Boston, USA	12	0.918	2,086	173.83	5
Olivier Sanchez	INSERM, Paris, France	11	0.842	354	32.18	6
Alex C. Spyropoulos	Donald & Barbara Zucker Sch Med Hofstra Northwell, Manhasset, USA	11	0.842	1,943	176.64	7
Stavros, V. Konstantinides	Democritus Univ Thrace, Thrace, Greece	10	0.765	1,925	192.5	7
Manuel Monreal	Univ Catolica Murcia, Murcia, Spain	10	0.765	2,095	209.5	6
Menno V. Huisman	Leiden Univ Med Ctr, Leiden, Netherlands	9	0.689	3,802	422.44	6
Nils Kucher	Univ Hosp Zurich, Zurich, Switzerland	9	0.689	1,309	145.44	4

Table 5. Top 10 most prolific authors. Note: TP: Total Publications; % TP: Percentage of Total Publications; TC: Total Citations; ACPP: Average Citations per Paper.

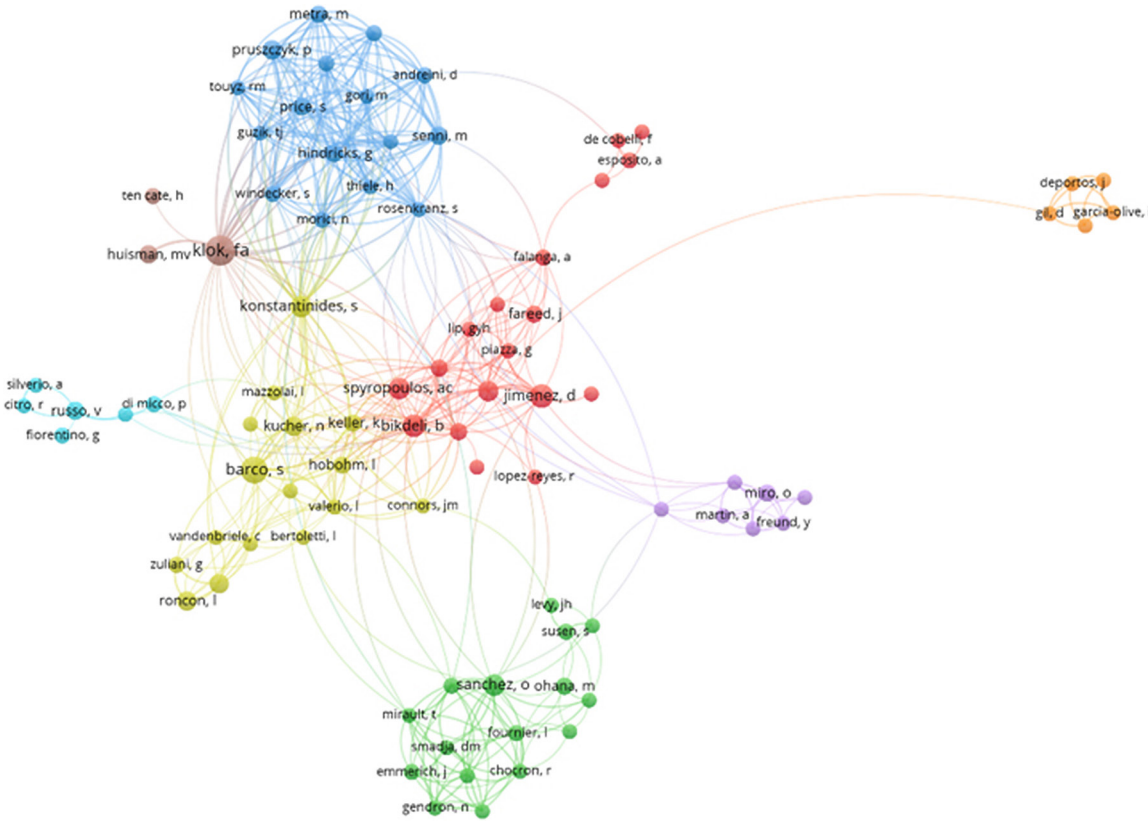

Figure 6. Co-authorship map of highly productive authors.

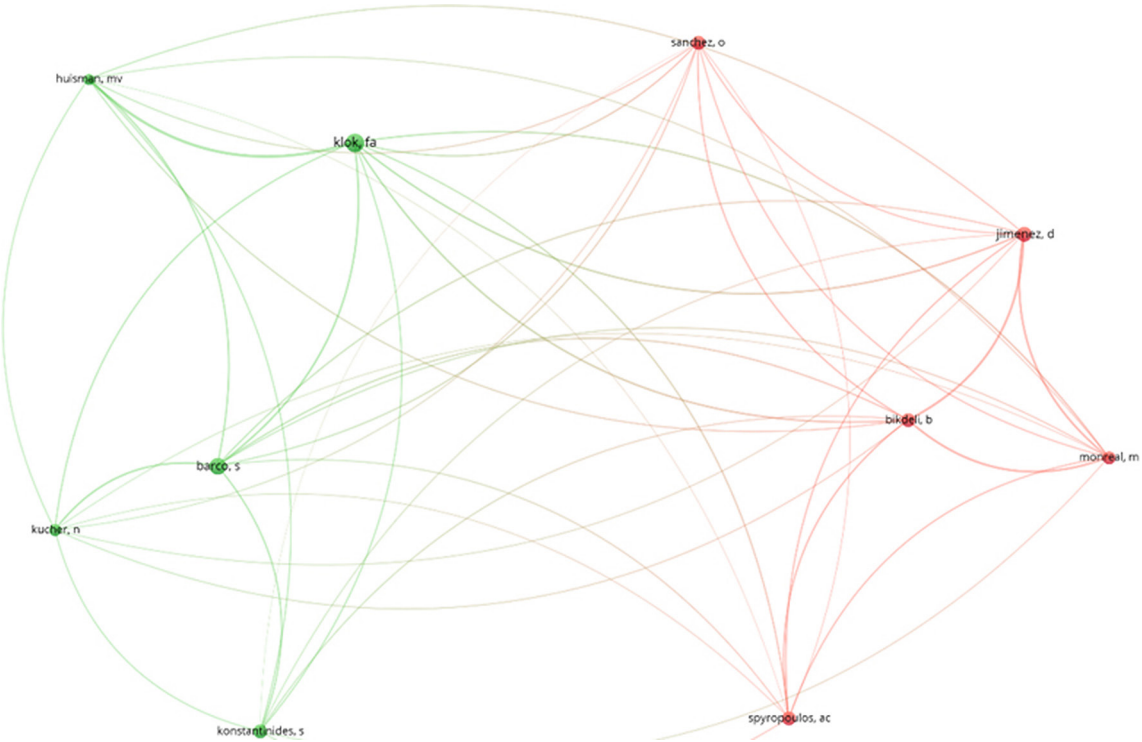

Figure 7. Co-citation map of most productive top 10 authors.

5.6. Top 10 Highly preferred journals

All the 1307 research publications on 'Covid 19 and Pulmonary Embolism' were published across 442 journals, where 234 journals have published one research paper each, 163 journals have published 2-5 papers each, 26 journals have published 6-10 papers each, 15 journals have published 11-25 papers each and 4 journals have published 26-59 papers each. The top 10 most productive journals have published 277 (21.19%) research papers and received 9,948 (25.55%) citations at 35.91 per paper. Among the top 10 most productive journals, 'Thrombosis Research' has published the highest, i.e., 59 research papers, followed by the *Journal of Thrombosis and Thrombolysis* (38) and the *Journal of Clinical Medicine* (33). *Thrombosis Research* was the journal which has received the highest, i.e., 6,204 citations at the rate of 105.15 citations per paper, followed by *Chest* (36.77) and *Research and Practice in Thrombosis and Haemostasis* (24.30). It is evident from the data that the journal *Thrombosis Research* has recorded the maximum (19) h-index, followed by the *Journal of Thrombosis and Thrombolysis* (15) and *Clinical and Applied Thrombosis Hemostasis* (10). Among the top 10 authors, 9 journals have "Impact Factor," and European Respiratory Journal received the highest (33.795) impact factor, followed by *Thrombosis Research* (10.407) and *Chest* (10.262) (Table 6).

Figure 8 presents a citation networking map of the top 100 journals with a minimum of three publications each, and these 100 journals are divided into 13 clusters with 1277 links and total link strength of 3497. Each node represents a journal, and the node size represents several connections through citations in the journal. The lines connecting the nodes show the citation connection between the journals. The higher the thickness of the links, the higher the number of citation connections of journals.

Publication Title	Publisher	IF	TP	%TP	TC	ACPP	h-Index
Thrombosis Research	Elsevier	10.407	59	4.514	6,204	105.15	19
Journal of Thrombosis and Thrombolysis	Wiley	5.221	38	2.907	768	20.21	15
Journal of Clinical Medicine	MDPI	4.964	33	2.525	196	5.94	6
Clinical and Applied Thrombosis Hemostasis	Sage	3.512	26	1.989	483	18.58	10
Chest	American College of Chest Physicians	10.262	22	1.683	809	36.77	7
European Respiratory Journal	European Respiratory Society	33.795	22	1.683	387	17.59	6
Journal of Vascular Surgery Venous and Lymphatic Disorders	Elsevier	4.86	20	1.53	265	13.25	9
Research and Practice in Thrombosis and Haemostasis	Elsevier	NA	20	1.53	486	24.30	9
PLOS One	PLOS	3.752	19	1.454	201	10.58	8
Thrombosis Journal	Springer	5.509	18	1.377	149	8.28	7

Table 6. Top 10 Highly preferred journals. Note: IF: Impact Factor; TP: Total Publications; % TP: Percentage of Total Publications; TC: Total Citations; ACPP: Average Citations per Paper.

5.7. Top 10 Highly Referred Journals

All of the 1,307 research papers on 'Covid 19 and Pulmonary Embolism' were published, referring to the 22,080 references together. Among the top 10 highly referred journals, the *Journal of Thrombosis and Haemostasis* has been referred 2,602 times, followed by *Thrombosis Research* (1,951) and the *New England Journal of Medicine* (1,825). Among the top 10 highly referred journals, *Lancet* was the high Impact Factored journal with 202.731 IF, followed by the *New England Journal of Medicine* (176.079) and *Journal of the American Medical Association* (157.335) (Table 7).

Figure 9 presents a co-citation analysis of the top 100 references divided into 5 clusters with 4804 links and total link strength of

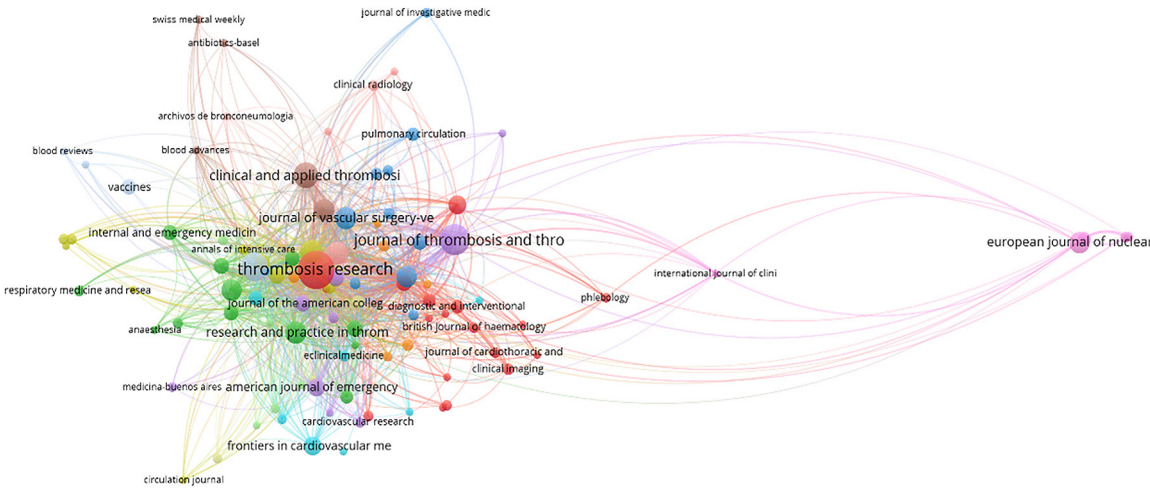

Figure 8. Top 100 journals citation network.

531352. Each node represents a journal, and the node size represents the number of co-citations of each journal. The lines connecting the nodes show the citation connection between the journals referred, which means the higher the thickness of the links, the higher the number of citation connections of journals referred.

Sources	Publisher	Impact Factor	No. of References	% of 22080 References
Journal of Thrombosis and Haemostasis	Wiley	16.036	2602	11.78
Thrombosis Research	Elsevier	10.407	1951	8.84
New England Journal of Medicine	Massachusetts Medical Society	176.079	1825	8.27
Lancet	Elsevier	202.731	1209	5.48
JAMA-Journal of the American Medical Association	American Medical Association	157.335	1012	4.58
Circulation	Lippincott Williams & Wilkins	39.918	906	4.10
Radiology	Radiological Society of North America	29.146	901	4.08
European Heart Journal	Oxford University Press	35.855	763	3.46
Thrombosis and Haemostasis	Thieme Medical Publishers	6.681	720	3.26
Journal of the American College of Cardiology	Elsevier	27.206	695	3.15

Table 7. Top 10 highly referred journals.

5.8. Top 10 Most Productive Publishers

The published papers (1,307) on 'Covid 19 and Pulmonary Embolism' appeared in the 442 journals published by 115 publishers. Elsevier has published the highest among the publishers, i.e., 326 articles, followed by Springer Nature (189) and MDPI (106). Ranking according to the citations received, publications by Elsevier has received the highest, i.e., 18,742 citations, followed by papers published in Springer Nature (3,725) and Wiley (1,980). According to impact by citations per paper, Elsevier has achieved the highest (57.49) CPP, followed by Oxford University Press (41.26) and Lippincott Williams & Wilkins (28.83). The highest h-index has been achieved by Elsevier (46), Springer Nature (30), and Wiley (21). The top 10 most productive publishers have contributed 984 (75.29%) papers and have received 31,123 (79.95%) citations at the rate of 31.63 citations per paper (Table 8).

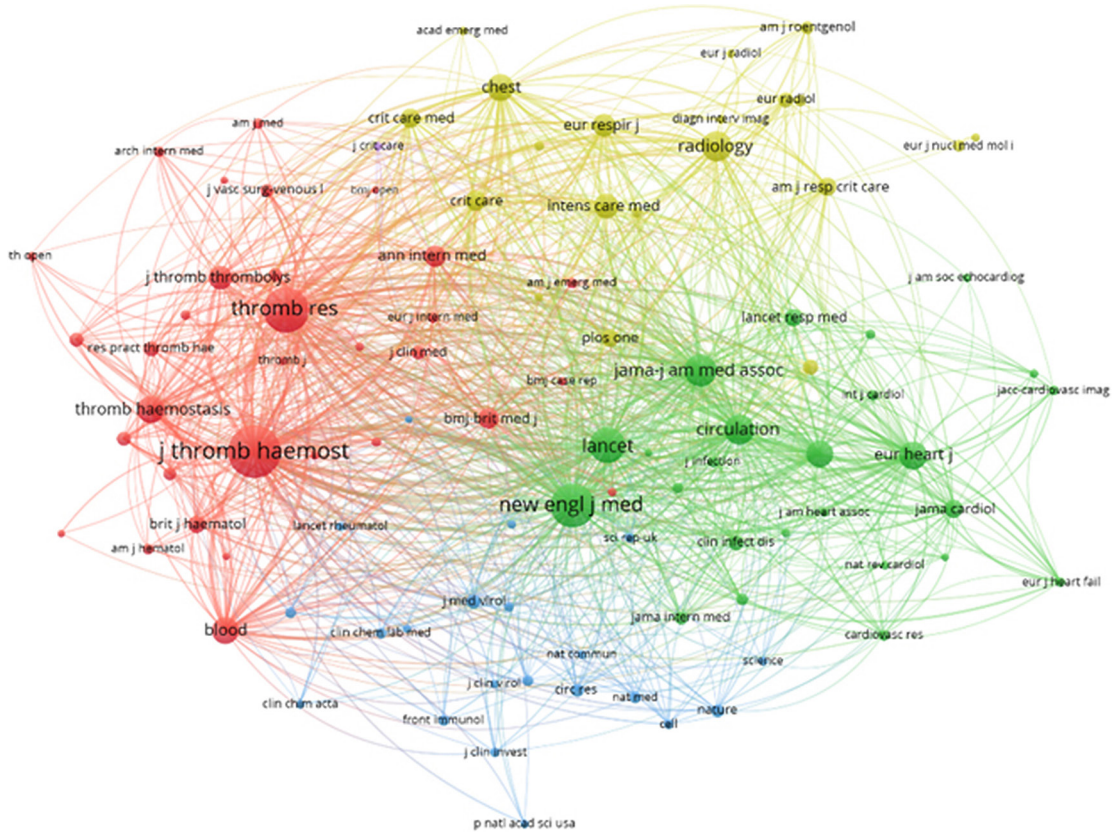

Figure 9. Co-citation analysis of top 100 references.

Publishers	TP	% TP	TC	ACPP	h-Index
Elsevier	326	24.943	18,742	57.49	46
Springer Nature	189	14.461	3,725	19.71	30
MDPI	106	8.11	756	7.13	14
Wiley	92	7.039	1,980	21.52	21
Lippincott Williams & Wilkins	65	4.973	1,874	28.83	15
Sage	64	4.897	781	12.20	14
Frontiers Media Sa	46	3.52	351	7.63	12
Oxford Univ Press	42	3.213	1,733	41.26	13
BMJ Publishing Group	28	2.142	789	28.18	8
European Respiratory Soc Journals Ltd	26	1.989	392	15.08	6

Table 8. Top 10 most productive publishers. Note: TP: Total Publications; % TP: Percentage of Total Publications; TC: Total Citations; ACPP: Average Citations per Paper.

5.9. Top 25 Significant Keywords

The majority of the authors have used 1,679 different keywords assigned by the authors, and Web of Science has also added 1,123 additional keywords. However, only 1,679 'Author Keywords' have been analysed and presented in Table 9. These keywords analysis supports identifying the most relevant content covered in the research papers and helps other researchers to find the most relevant content in the literature under study. Hence, the authors identified the top 25 highly used keywords in the literature under investigation. The most significant keywords used were covid-19 (714), pulmonary embolism (405), sars-cov-2 (191), thrombosis (154), and venous thromboembolism (146).

Figure 10 presents the keyword co-occurrence map of the highly used top 25 keywords, divided into 4 clusters with 213 links and total link strength 2,683. Each circle represents a keyword, and the circle size represents the frequency of keyword appearance in the literature under study. The links between the keywords show the co-occurrence of keywords in the literature, which means the higher the thickness of the links, the higher the number of co-occurrence of keywords.

Words	Occurrences	Total Link Strength
covid-19	714	1286
pulmonary embolism	405	902
sars-cov-2	191	456
thrombosis	154	391
venous thromboembolism	146	418
d-dimer	81	223
thromboembolism	79	114
coronavirus	70	168
anticoagulation	62	182
deep vein thrombosis	77	251
embolism	18	61
coagulopathy	43	136
mortality	39	74
heparin	33	92
coronavirus disease 2019	33	51
pneumonia	26	52
thromboprophylaxis	26	84
anticoagulants	24	58
coagulation	22	67
computed tomography	24	43
stroke	21	66
deep venous thrombosis	28	85
inflammation	20	56
acute respiratory distress syndrome	24	40
disseminated intravascular coagulation	18	61

Table 9. Top 25 Significant Keywords.

5.10. Top 10 Highly Cited Research Papers

Table 10 depicts the top ten highly cited publications on 'Covid 19 and Pulmonary Embolism'. Out of the 1,307 research publications, six publications have received more than 1000 citations, followed by seven publications with citations between 501 and 1000 each, 49 publications with citations between 101 and 500, 345 publications with citations between 11 and 100, and 596 publications with citations between 1 and 10. Together top 10 highly cited publications have received 14,378 (36.93%) citations. A journal article entitled "Incidence of thrombotic complications in critically ill ICU patients with COVID-19", authored by Klok, F.A. *et al.,* published in the journal *"Thrombosis Research"* in the year 2020 received the highest number of (3,463) citations. Among the top 10 highly cited publications, two papers were published in the *Journal of Thrombosis and Haemostasis* and *Thrombosis Research*. Among the top 10 highly

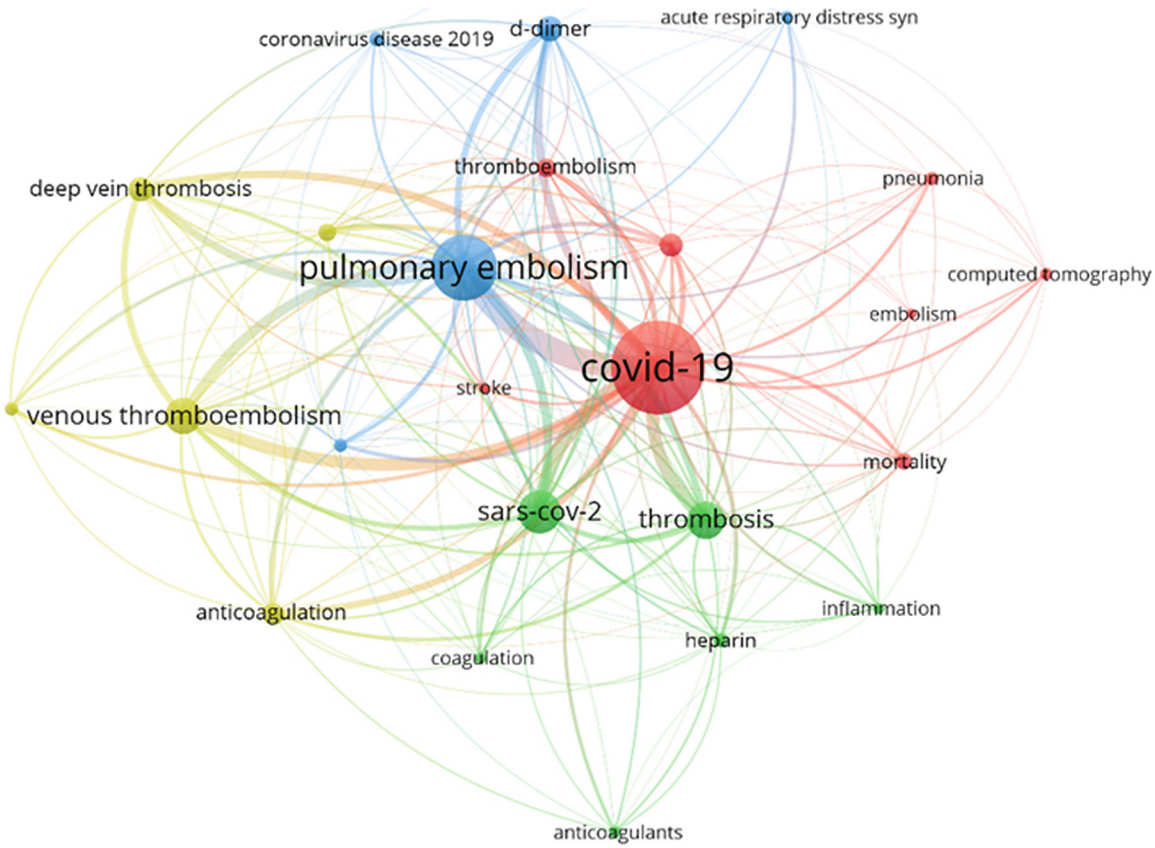

Figure 10. Keyword co-occurrence map.

cited publications, eight papers were published in 2020, and two were during 2021. However, no publication published between 2022 and 2023 was found in the top 10 highly cited publications.

Figure 11 presents the bibliographic coupling network map of highly cited papers. Bibliographic coupling occurs when two works reference a common third work in their bibliographies. The bibliographic coupling map shows that only eight highly cited papers are bibliographically coupled, and the remaining two papers of the highly cited publications are not connected. Figure 12 presents a co-citation analysis of top-10 highly cited publications, and it is also noticed that only six of these publications have connected through their citation. The other four are not cited together.

6. SUMMARY AND CONCLUSION

The Covid-19 outbreak was a health emergency that threatened the health system of various countries. Pulmonary Embolism (PE) has been described in coronavirus disease 2019 (COVID-19) critically ill patients (Ameri, 2021). Thus, numerous studies have been published on Pulmonary Embolism in patients with COVID-19, and these papers provide various solutions to expand the knowledge and possibly inform clinical practice. The present study analysed 1307 research studies indexed in the WoS database during 2020-2023, and 59.91% of publications are journal articles. These 1307 global publications were published by 9,523 authors with a ratio of 7.28 authors per paper and received 38,930 citations at 29.79 citations per paper. The study found a multi-authorship trend in Pulmonary Embolism research, with 97.55% paper through collaborated research. Authors from 87 countries have collaborated in the research literature analysed; the highest, i.e., 368 authors, belong to the USA. Also, the USA has collaborated with other countries in more than 135 publications.

Rank	Author	Title	Year	Journal details	Total Citations (TC)	TC per Year
1	Klok, F. A. *et al.*	Incidence of thrombotic complications in critically ill ICU patients with COVID-19	2020	Thrombosis Research. V.191, pp.145-147	3463	865.75
2	Huang, C. L. *et al.*	6-month consequences of COVID-19 in patients discharged from hospital: a cohort study	2021	Lancet. V.397(10270), pp.220-232	1920	640
3	Bikdeli, B. *et al.*	COVID-19 and Thrombotic or Thromboembolic Disease: Implications for Prevention, Antithrombotic Therapy, and Follow	2020	Journal of the American College of Cardiology. V.75(23), pp.2950-2973	1756	439
4	Wichmann, D. *et al.*	Autopsy Findings and Venous Thromboembolism in Patients With COVID-19	2020	Annals of Internal Medicine. V.173(4), pp.268+	1514	378.5
5	Greinacher, A. *et al.*	Thrombotic Thrombocytopenia after ChAdOx1 nCov-19 Vaccination	2021	New England Journal of Medicine. V.384(22), pp.2092-2101	1274	424.67
6	Lodigiani, C. *et al.*	Venous and arterial thromboembolic complications in COVID-19 patients admitted to an academic hospital in Milan, Italy	2020	Thrombosis Research. V.191, pp.9-14	1268	317
7	Middeldorp, S. *et al.*	Incidence of venous thromboembolism in hospitalized patients with COVID-19	2020	Journal of Thrombosis and Haemostasis. V.18(8), pp.1995-2002	935	233.75
8	Guzik, T. J. *et al.*	COVID-19 and the cardiovascular system: implications for risk assessment, diagnosis, and treatment options	2020	Cardiovascular Research. V.116(10), pp.1666-1687	763	190.75
9	Menter, T. *et al.*	Postmortem examination of COVID-19 patients reveals diffuse alveolar damage with severe capillary congestion and variegated findings in lungs and other organs suggesting vascular dysfunction	2020	Histopathology. V.77(2), pp.198-209	743	185.75
10	Llitjos, J. F. *et al.*	High incidence of venous thromboembolic events in anticoagulated severe COVID-19 patients	2020	Journal of Thrombosis and Haemostasis. V.18(7), 2020 pp.1743-1746	742	185.5

Table 10. Top 10 highly cited research papers.

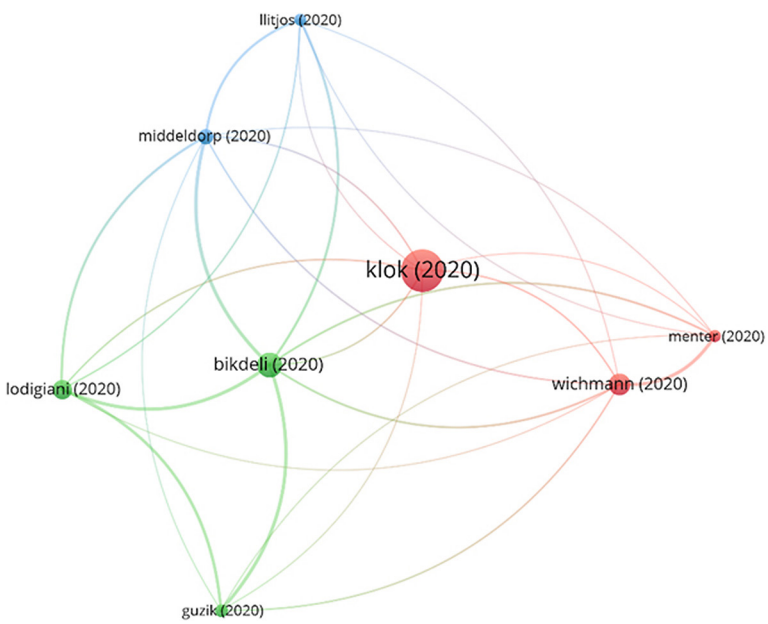

Figure 11. Bibliographic coupling network map of highly cited papers.

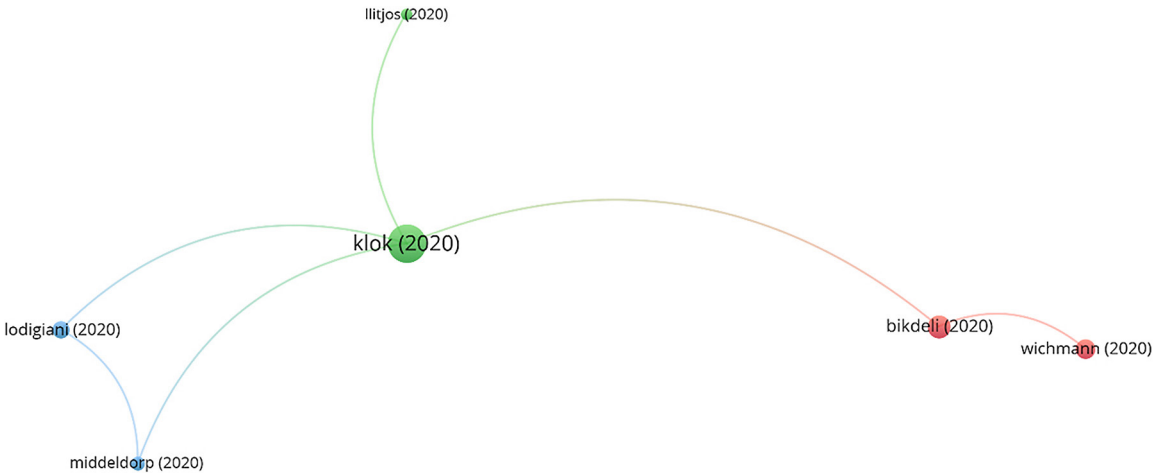

Figure 12. Co-citation analysis of top-10 highly cited publications.

A maximum number of research papers were published in the Peripheral Vascular Disease (266) subject area, and the Udice French Research Universities (87) was the most productive organisation. F. A. Klok of Leiden Univ Med Ctr, Leiden, Netherlands, has published the highest, i.e., 21 research papers, and *Thrombosis Research,* published by Elsevier was the most preferred journal among the researchers. As per publications according to the publishers, Elsevier (326) has published a large number of research papers. Highly used keywords in the research are covid-19 (714), pulmonary embolism (405), and sars-cov-2 (191). The present study analysed the global publications on pulmonary embolism in COVID-19 between 2020 and 2023. It helps doctors and researchers identify the major research evidence and its impact on the research community, along with the health care systems and policymakers for evidence-based policymaking.

Contribution statement

Conceptualization: B. M. Gupta, Ramesh Timanaykar, and Gururaj S. Hadagali

Data Curation and visualization: Iranna M. Shettar

Investigation, methodology, writing- original draft and project administration: Gururaj S. Hadagali, Iranna M. Shettar and Ramesh Timanaykar

Writing and editing the manuscript: Iranna M. Shettar, Gururaj S. Hadagali, and B. M. Gupta

Conflict of Interest

The authors declare that there is no Conflict of Interest.

Statement of data consent

The data generated during the development of this study has been included in the manuscript.

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