

Use of Convalescent Plasma Therapy for COVID-19: A Scientometric Assessment of Global Publications during 2020-21

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ABSTRACT

The study evaluates the global research output (820 records) on "Use of Convalescent Plasma Therapy for COVID-19" on metrics with the aim to understand the current status of research at the global, national, institutional, and individual author level. The study is based on publications and citations data sourced from the Scopus database during 2020-21. The publications and citations data was statistically analyzed on various metrics such as document type, country of publication, collaboration patterns, author affiliation, journal name, and citation patterns. The USA, China and India lead the world ranking of 15 most productive countries in the subject. China, U.K. and Netherlands lead in the ranking of most cited countries. In addition, the study maps key productive institutions, key authors, key source journals, as well as most significant keywords in the subject to visually present their inter-relationships using Biblioshiny and VOSviewer software. This results and findings from the study describe the progress made by the world in this hot area of global interest.

Key words: Convalescent plasma, Serum therapy, Plasma therapy, COVID-19, Scientometric, Bibliometric.

INTRODUCTION

Since December 2019, a pneumonia outbreak associated with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) had caused a worldwide epidemic. World Health Organization (WHO) named this virus as coronavirus disease 2019 (COVID-19). It spread rapidly worldwide with a high rate of transmission and substantial mortality. COVID-19 symptoms range from mild, self-limited respiratory disease to severe progressive pneumonia, multiple organ failure, and even death. WHO declared it as a pandemic on March 11, 2020. As of February 2021, a total 103,631,793 confirmed cases and 2251613 deaths had been reported in 223 countries.¹

Considering that there has been no proven therapy in terms of effective vaccine (though it is now available) and specific antiviral medicine, it was necessary and urgent on the part of scientists and doctors to look for an alternative strategy or option for COVID-19 treatment, especially for the benefit of patients with sever symptoms. Ongoing research in this area has resulted a multiple studies on the use of convalescent plasma for COVID-19 to treat severely or critically ill COVID-19 patients, without unexpected or serious adverse events.² Convalescent plasma (CP) therapy (or passive immunization or serum therapy), a classic adaptive immunotherapy, was born from the intuition of Behring and Kisato in the late 19th century. It was widely used for the treatment of bacterial infections until the discovery of antibiotics, as well

as during the viral pandemics of the 20th century and in the beginning of the 21st century. It still has clinical applications (e.g., tetanus prevention). The use of convalescent plasma involves transfusing plasma collected from patients who have already recovered from an illness, in an attempt to transfer neutralizing antibodies and confer passive immunity. The potential efficacy of convalescent plasma was first described during the Spanish influenza pandemic of the early 1900s Since then, convalescent plasma has been used to treat a wide range of viral infections, including measles, parvovirus B19, H1N1, Ebola and some coronaviruses. Among the many coronaviruses that are only mildly pathogenic to humans, there are three that have caused notably severe clinical manifestations and have been treated with convalescent plasma: i) severe acute respiratory syndrome coronavirus (SARS-CoV), ii) Middle East respiratory syndrome coronavirus (MERS-CoV) and iii) severe acute respiratory infections (SAR) viruses.³ Virus neutralization by antibodies is the principle behind the functioning of plasma of patients recovered from SARS-CoV-2; high-titer-specific antibodies bind to SARS-CoV-2 neutralizing the viral particles, blocking access to cells, and activating potent effect or mechanisms, such as complement activation and phagocytosis.⁴

Recently, in 2017, the WHO Blood Regulators Network (BRN) published a position paper,

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recommending convalescent plasma as the first-choice treatment to be tested in the absence of authorized drugs; however, this strategy has not been followed. In the current epidemic, the principle of passive immunization through convalescent plasma has been applied in several circumstances and particularly in patients with serious complications. Also, the FDA of USA has proposed plasma treatment in order to face the increasingly complex situation and manage patients with serious or immediately life-threatening COVID-19 disease. Several studies and clinical programs are still ongoing and more extensive studies are now in the pipeline to provide a robust evidence for or against the use of convalescent plasma. Worldwide there are over 60 clinical trials actively recruiting COVID-19 patients to study the effect of convalescent plasma.⁵ Given the ongoing trends in “Use of Convalescent Plasma Therapy for COVID-19” it is considered worthwhile that a bibliometric study be undertaken to understand and describe the current state of research in the subject based on global literature published till date.

Literature Review

Till date, quite a few studies have been undertaken to assess and describe the state of global research in COVID-19 literature using bibliometric methods. A review of such studies is described here. Zyoud and Al-Jabi⁶ performed a bibliometric analysis to track the current hotspots and identify future directions in COVID-19 (19,044 publications). Research studies related to COVID-19 were obtained from the Scopus database during the early stage of the outbreak. The data was analyzed by using well-established bibliometric indices such as document type, country, collaboration patterns, affiliation, journal name, and citation patterns. Biblioshiny and VOSviewer were used to map and determine hot topics in this field. The most discussed topics of research in COVID-19 include “clinical features studies”, “pathological findings and therapeutic design”, “care facilities preparation and infection control”, and “maternal, perinatal and neonatal outcomes”. Philip Shapira⁷ undertook a bibliometric study to analyze COVID-19 related scientific publications through to October of 2020 and described broad trends, fields, countries, and organizations in the subject. Two different databases were used for sourcing data: PubMed and the Web of Science. Yue Gong *et al.*⁸ analysed the global literature related to COVID-19 using bibliometric methods, citation analysis, and knowledge mapping methods. Studies reported temporal patterns, main countries affected, and core subjects. The status and trends in COVID-19 research were explored from January 2020 to March 2020 to reveal the conceptual knowledge map in SARS-CoV-2. The results provide a reference point for the current and future coronavirus research studies for policymaking worldwide. Lou, Tian, Niu, Kang, Lian, Zhang and Zhang⁹ analysed the publications about COVID-19 to summarize the research hotspots and make a review, to provide a reference point for researchers in the world. The authors searched PubMed using the keywords “COVID-19” from inception to March 1, 2020. They identified and analyzed the data which included title, corresponding author, language, publication time, publication type, research focus. It is evident from this literature review that not even a single bibliometric study has appeared so far on the topic of ‘application of convalescent plasma therapy to COVID-19 patients’. Given this context, it was decided to undertake a bibliometric study in the proposed subject.

Objectives

The purpose of this study is to analyze and evaluate the literature on “Use of Convalescent Plasma Therapy for COVID-19” on bibliometric indicators as a way to understand the status of global research in the subject. The data for the study was sourced from the Scopus database covering the period 2020-2021. The study attempt to describe the global research on a series of metrics such as (i) publication output count, type and source, (ii) annual growth trends, (iii) citation trends, (iv) identify

key countries, organizations, individual authors, (v) highlight most significant keywords, most sought after subject areas of interest, (vi) research collaborative linkages, (vii) most preferred source journals, and (viii) characterize bibliographic features of highly cited papers on this topic.

METHODOLOGY

A well-defined search strategy was used to retrieve and download publications data from the Scopus database. The search for global literature published on “Use of Convalescent Plasma Therapy for COVID-19” was conducted on 21.1.2021 with no publication date limitations. Key search terms were clubbed into two sets: (i) “COVID 19” OR “2019 novel coronavirus” OR “coronavirus 2019” OR “coronavirus disease 2019” OR “2019-novel CoV” OR “2019 ncov” OR “covid 2019” OR “covid19” OR “corona virus 2019” OR “ncov-2019” OR “ncov2019” OR “nCoV 2019” OR “2019-ncov” OR “covid-19” OR “Severe acute respiratory syndrome coronavirus 2” OR “SARS-CoV-2” and (ii) “plasma therapy*” or “Convalescent plasma”. These two set of keywords were tagged to “Keyword” and “Article Title” tags as described below. The database search resulted 820 records as global output. All types of documents were included in the search output. The global output was subsequently analyzed for publication trends by author, affiliation, journal, country of publication, top-cited countries, top-cited documents, country-wise research collaboration and by keywords. ((TITLE (“COVID 19” OR “2019 novel coronavirus” OR “coronavirus 2019” OR “coronavirus disease 2019” OR “2019-novel CoV” OR “2019 ncov” OR covid 2019 OR covid19 OR “corona virus 2019” OR ncov-2019 OR ncov2019 OR “nCoV 2019” OR 2019-ncov OR covid-19 OR “Severe acute respiratory syndrome coronavirus 2” OR “SARS-CoV-2”) OR (KEY (“COVID 19” OR “2019 novel coronavirus” OR “coronavirus 2019” OR “coronavirus disease 2019” OR “2019-novel CoV” OR “2019 ncov” OR covid 2019 OR covid19 OR “corona virus 2019” OR ncov-2019 OR ncov2019 OR “nCoV 2019” OR 2019-ncov OR covid-19 OR “Severe acute respiratory syndrome coronavirus 2” OR “SARS-CoV-2”) and KEY (Plasma Therapy* or Convalescent plasma))).

ANALYSIS AND RESULTS

The search on theme “Use of Convalescent Plasma Therapy for COVID-19” in Scopus database resulted in a total of 820 (2020=790; 2021=30) publications. The global publications (820) received 10641 citations, averaging to 12.98 citations per paper. Of the 820 publications, 170 (20.73%) resulted from research projects funded by 100+ funding agencies, received 4316 citations, averaging to 25.39 citations per paper. The major funding agencies supporting research projects are: National Institute of Health, USA (39 publications), National Natural Science Foundation of China (31 papers), National Institute of Allergy and Infectious Diseases (11 papers), Canadian Institute of Health Research, National Cancer Institute, National Heart, Lung and Blood Institute, USA and National Key Research and Development Program of China (7 papers each), etc.. Of the total output, articles and reviews account for the largest publications share (34.61% and 34.27%), followed by letters (12.07%), notes (6.83%) and the rest by others. English was the dominant publishing language (with 797 publications), followed by Chinese (6), Russian (5), French (3), Czech, Hungarian and Spanish (2 each) and 3 other languages with 1 each.

Top 15 Most Productive Countries

In all, 90 countries participated in global research on “Use of Convalescent Plasma Therapy for COVID-19” but the distribution of productivity by country of origin is highly skewed. For instance, 56 countries contributed 1-5 papers each, 15 countries 6-10 papers each, 8 countries 11-20 papers

each, 6 countries 21-50 papers each, 2 countries 51-100 papers each and 3 countries 104-286 papers each. The USA, China and India lead in global ranking with most publication share of 34.88%, 15.98% and 12.68% respectively, followed by 12 other countries which together accounted for a 36.46% global share. In terms of research citations performance only three countries - China (39.78 and 3.06), U.K. (23.64 and 1.82) and Netherlands (20.69 and 1.59) performed above the world average (14.33 CPP and 1.10 RCI) (Table 1).

A networks map of top 15 most productive countries, generated using VOSviewer software tool. Figure 1, visually presents their comparative productivity and their interrelations for collaborative research in the subject. The United States dominates in research productivity as well as in international collaboration, followed by China and India. The size of the circle of a country is proportional to its productivity. The thickness of links between countries represents the strength of their collaborative contributions to the research topic. Network visualization of countries is grouped into four clusters. Cluster 1 and 2, in red and green colour, and they represent 6 countries each - (the United States, China, India, Canada, Saudi Arabia and South Africa) and (Italy, the United Kingdom, France, Turkey, Germany and Netherlands), followed by clusters 3 illustrated in blue colour with 2 countries (Iran and Australia) and the last cluster in yellow colour comprises 1 country (Brazil).

Collaborative Linkages among Top 15 Countries

The country-wise collaboration links between countries are depicted in Figure 2. The size of the node is proportional to the collaborative activity of the country. The biblioshiny app web interface divides the most productive 15 countries grouped into 3 clusters. Cluster 1 orange colour represents the USA, India, and China are the biggest nodes and followed by the United Kingdom and Italy belong to the blue colour cluster 2 and Turkey belong to the red cluster 3 respectively. A line between the two countries indicates their collaborative linkages in research. The thickness of lines connecting the countries indicates the degree of their co-authorship in publications. When the two countries connected by

one line, it indicates that they collaborated to publish a single paper. The USA, U.K. and Italy collaborated with 13-14 countries and top the list with most collaborative linkages (131, 78 and 48). The bottom three countries (Turkey, France and Iran) collaborated with 6-11 countries but rank at the bottom with least number of collaborative linkages (6, 22 and 26). Of the collaborative linkages at the country-country level, USA-China, registered the highest number of collaborative linkages (20), followed by USA-U.K (16 linkages), USA-India (15 linkages), U.S.A-Canada (13 linkages), USA-Italy (12 linkages), USA-Iran, USA-Brazil and Italy-U.K.(9 linkages each), USA-Saudi Arabia, USA-Australia, USA-Netherlands, China-Canada, India-Saudi Arabia, U.K.-Canada and U.K.-Australia (8 linkages each), etc. (Table 2).

Subject-Wise Distribution of Research Output

The Scopus database organized global research output on “Use of Convalescent Plasma Therapy for COVID-19” under four broad disciplines (Table 3). Medicine accounts for a 81.83% share of publications, followed by Immunology and Microbiology (18.41%), Pharmacology, Toxicology and Pharmaceutics (14.39%) and Biochemistry, Genetics and Molecular Biology (16.71%). In terms of discipline-wise research performance on citations, Immunology and Microbiology registered the

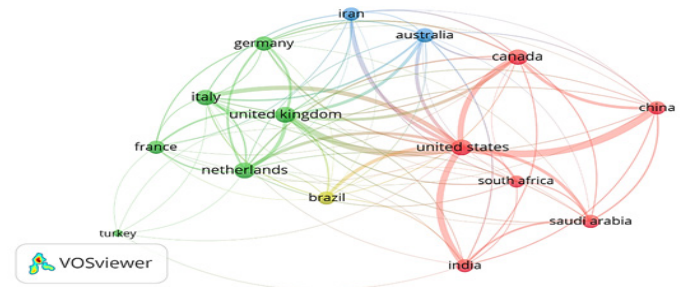


Figure 1: Networks Map of 15 Most Productive Countries.

Table 1: Top 15 Most Productive Countries Global Publication Output and Share in Research on “Use of Convalescent Plasma Therapy for COVID-19.”

S.No	Name of the Country	TP	TC	CPP	%TP	HI	ICP	%ICP	RCI	TCL
1	USA	286	2813	9.84	34.88	26	96	33.57	0.76	208
2	China	131	5211	39.78	15.98	27	38	29.01	3.06	88
3	India	104	1046	10.06	12.68	12	32	30.77	0.77	79
4	Italy	57	349	6.12	6.95	11	26	45.61	0.47	78
5	U.K.	53	1253	23.64	6.46	11	40	75.47	1.82	135
6	Canada	39	223	5.72	4.76	8	28	71.79	0.44	79
7	Iran	35	281	8.03	4.27	7	18	51.43	0.62	46
8	Saudi Arabia	29	153	5.28	3.54	6	20	68.97	0.41	57
9	Australia	25	352	14.08	3.05	6	19	76.00	1.08	62
10	France	25	256	10.24	3.05	8	13	52.00	0.79	47
11	Turkey	24	68	2.83	2.93	4	5	20.83	0.22	12
12	Brazil	18	56	3.11	2.20	5	11	61.11	0.24	51
13	Germany	18	97	5.39	2.20	4	13	72.22	0.42	50
14	Netherlands	16	331	20.69	1.95	6	15	93.75	1.59	77
15	South Africa	15	49	3.27	1.83	3	9	60.00	0.25	43
	Total of 15 countries	875	12538	14.33	106.71	9.6	383	43.77	1.10	1112
	Global total	820	10641	12.98	100.00					

TP - Total Publications, TC - Total Citations, CPP - Citations per Paper, HI - Hersh Index, ICP - International Collaborative Publications, RCI - Relative Citations Index, TCL - Total Collaborative Linkages

highest rate of citations per paper (19.42 CPP) and it was the least for Pharmacology, Toxicology and Pharmaceutics (4.50 CPP) (Table 3).

Sub-Field-Wise Distribution of Global Output.

On further classification of global output on “Use of Convalescent Plasma Therapy for COVID-19” under topical areas, it was found that ‘clinical studies’ accounted for most share (47.44%) of publications, followed by ‘treatment outcome’ (12.20%), ‘complications’ (12.07%), pathophysiology (8.29%), epidemiology (5.37%) and genetics (5.0%). In terms research performance on citations, ‘genetics’ sub-area registered the highest citations per paper 43.71 citations per paper, followed by pathophysiology (24.22), treatment outcome (21.60), clinical studies (17.39), complications (14.89) and epidemiology (10.43) (Table 4).

Significant Keywords

The keyword co-occurrence in research publications serves as a secondary support to get an insight into main topics and research trends in the “use of convalescent plasma therapy for COVID-19”. Figure 3 (A&B) were generated through VOSviewer software and Biblioshiny app web interface application. Figure 3A is a networks map of keyword co-occurrences at a glance. Figure 3B presents textual data about keywords in a simple way. The keywords are listed in Table 5 in the decreasing order of the frequency of their occurrence in the literature. The most

significant keywords such as Coronavirus Disease, Convalescent Plasma, Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), Pandemic, Coronavirus Infection, Viral Pneumonia appear in circles. The circle size and font size in Figure 3A is proportional to the frequency of occurrence of a keyword. The links between the keywords show that these keywords co-occur in the literature.

On classifying global research publications on the theme “Use of Convalescent Plasma Therapy for COVID-19” under different patient

Table 3: Subject-Wise Breakup of Global Publications on “Use of Convalescent Plasma Therapy for COVID-19” Research.

S.No.	Subject	TP	%TP	TC	CPP
1	Medicine	671	81.83	9094	13.55
2	Immunology and Microbiology	151	18.41	2933	19.42
3	Pharmacology, Toxicology and Pharmaceutics	118	14.39	531	4.50
4	Biochemistry, Genetics and Molecular Biology	137	16.71	1175	8.58
	Global Total	820	100.00	10641	12.98

*TP=Total publications; TC=Total citations; CPP=Citations per paper



Figure 2: Research Collaboration Networks Map of Top 15 Countries.

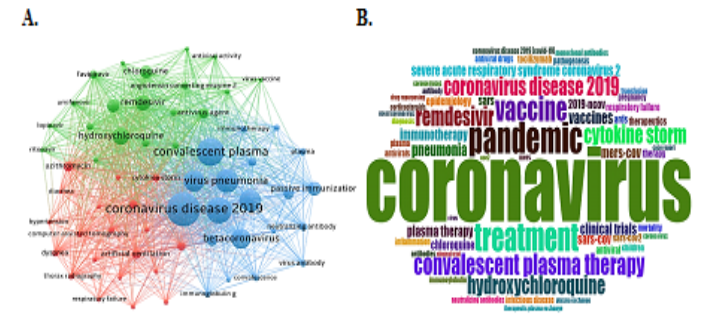


Figure 3: (A) The top 60 Keyword co-occurrence and (B) Word Cloud Keyword co-occurrence.

Table 2: Collaborative Linkages among top 15 countries in Research on “Use of Convalescent Plasma Therapy for COVID-19.”

S.No	Country Name	Number of Collaborative linkages with other countries	TCL(NOC)
1	USA	2(20), 3(15), 4(12), 5(16), 6(13), 7(9), 8(8), 9(8), 10(1), 11(1), 12(9), 13(4), 14(8), 15(5)	131(14)
2	China	1(20), 3(3), 4(2), 5(2), 6(8), 8(4), 9(2), 10(1), 13(1), 14(2)	45(10)
3	India	1(15), 2(3), 4(1), 5(2), 6(3), 8(8), 9(3)11(1), 12(2), 14(1), 15(2)	41(11)
4	Italy	1(12), 2(2), 3(1), 5(9), 6(3), 7(3), 8(1), 9(5), 10(2), 11(1), 12(3), 13(2), 14(4)	48(13)
5	U.K.	1(16), 2(2), 3(2), 4(9), 6(8), 7(3), 8(2), 9(8), 10(5), 11(1), 12(4), 13(6), 14(9), 15(3)	78(14)
6	Canada	1(13), 2(8), 3(3), 4(3), 5(8), 7(3), 8(3), 9(4), 10(1), 13(4), 15(1)	51(11)
7	Iran	1(9), 2(1), 4(3), 5(3), 6(3), 9(2), 10(2), 12(1), 13(1), 14(1)	26(10)
8	Saudi Arabia	1(8), 2(4), 3(5), 4(1), 5(2), 6(3), 9(1), 10(1), 13(1), 14(2), 15(3)	31(11)
9	Australia	1(8), 2(2), 3(3), 4(5), 5(8), 6(4), 7(2), 8(1), 12(2), 13(3), 14(2), 15(1)	40(12)
10	France	1(1), 2(1), 4(2), 5(5), 6(1), 7(2), 8(1), 11(1), 12(1), 13(3), 14(4)	22(11)
11	Turkey	1(1), 3(1), 4(1), 5(1), 10(1), 14(1)	6(6)
12	Brazil	1(9), 3(2), 4(3), 5(4), 6(2), 7(1), 9(2), 10(1), 13(1), 14(1), 15(1)	27(11)
13	Germany	1(4), 2(1), 4(2), 5(6), 6(4), 8(1), 9(3), 10(1), 12(1), 14(5)	28(10)
14	Netherlands	1(8), 2(2), 3(1), 4(4), 5(9), 6(4), 8(2), 9(2), 10(4), 11(1), 12(2), 13(5), 15(2)	46(13)
15	South Africa	1(5), 3(2), 5(3), 6(2), 8(1), 12(1), 13(1), 14(2)	17(8)

TCL=Total collaborative linkages; NOC=Number of countries

Table 4: Sub-field wise break-up of publications on “Use of Convalescent Plasma Therapy for COVID-19” Research.

S.No	Sub-field	TP	TC	CPP	% TP
1	Clinical Studies	389	6763	17.39	47.44
2	Epidemiology	44	459	10.43	5.37
3	Genetics	41	1792	43.71	5.00
4	Pathophysiology	68	1647	24.22	8.29
5	Treatment Outcome	100	2160	21.60	12.20
6	Complications	99	1474	14.89	12.07
		820	10641	12.98	

*TP=Total publications; TC=Total citations; CPP=Citations per paper

population groups, it was found that studies on adults patient group account for the largest publication share (22.56%), followed by middle aged (18.85%), aged (15.49%), child (3.66%) and adolescents (3.05%). In terms of research performance measured on citations, aged patients group studies registered the highest citations per paper (25.57), followed by middle aged group (24.22), adult group (19.97), adolescents (19.08) and child (15.10) (Table 6).

Most Productive Global Organizations

In all, 457 organizations were found to have participated unevenly in global research on “Use of Convalescent Plasma Therapy in COVID-19 Patents”. The productivity of top 25 most productive organizations varied from 8 to 21 publications per organization whereas the global average productivity of all organizations was just 1.79 per organization. Secondly, the organization-wise distribution of global research output is highly skewed. For instance, the top 25 organizations together contributed

Table 5: Significant Keywords Appearing in Global Publications in Research on “Use of Convalescent Plasma Therapy for COVID-19.”

S.No	Name of the Keyword	Frequency	S.No	Name of the Keyword	Frequency
1	Coronavirus Disease 2019	706	31	Virus Transmission	94
2	Convalescent Plasma	546	32	Immunotherapy	87
3	Severe Acute Respiratory Syndrome Coronavirus 2(SARS-CoV-2)	526	33	Computer Assisted Tomography	86
4	Pandemic	507	34	Immunoglobulin G	82
5	Coronavirus Infection	411	35	Methylprednisolone	81
6	Virus Pneumonia	405	36	Thorax Radiography	80
7	Beta coronavirus	362	37	Randomized Control Trials	87
8	Passive Immunization	324	38	Umifenovir	77
9	Hydroxychloroquine	298	39	Convalescence	74
10	Remdesivir	268	40	Virus Replication	69
11	Lopinavir Plus Ritonavir	209	41	Dexamethasone	68
12	Choloroquine	194	42	Extracorporeal Oxygenation	65
13	Antivirus Agents	167	43	Oxygen Therapy	65
14	Immunology	160	44	Oseltamivir	64
15	Plasma Transfusion	160	45	Plasma Exchange	64
16	Azithromycin	156	46	Lopainavir	58
17	Artificial Ventilation	135	47	Respiratory Failure	58
18	Neutralizing antibody	124	48	Convalescent Plasma Therapy	57
19	Favipiravir	123	49	Anti-Viral Activity	56
20	Adult Respiratory Distress Syndrome	120	50	Enzyme Linked Immunosorben Assay	56
21	Immunoglobulin	119	51	Ritonavir	56
22	Virology	116	52	Multiple Organ Failure	55
23	Corticosteroid	114	53	Hypertension	53
24	Ribavirin	106	54	Throat Culture	53
25	Cytokino Storm	99	55	Virus Vaccine	53
26	Dyspnea	98	56	Lymphocytopenia	52
27	Plasma	98	57	Reverse Transcription Polymerase Chain Reaction	52
28	Angiotensing Converting Enzyme 2	97	58	SARS-CoV-2 Vaccine	52
29	Virus Antibody	96	59	Sarilumab	52
30	Anti-Viral Therapy	95	60	Diarrhea	51

a 34.15% (280) global publications share. Besides, 404 out of 457 organizations published 1-5 papers each, 46 organizations 6-10 papers each and 7 organizations 11-21 papers each. Of the 25 organizations, 9 were from the USA, 5 from China, 2 each from Canada, Iran and South Africa and 1 each from France, India, Saudi Arabia, Singapore and South Africa.

The publications profile of top 25 most productive organizations is shown in Table 7. Six (shaded in green colour) out of top 25 organizations contributed above the group-25 average productivity (11.2), and four (shaded in yellow colour) registered their research performance (measured on metrics such as ‘citations per paper’ and ‘relative citation index’) above the group-25 average (28.45 CPP and 2.19 RCI).

Table 6: Distribution by Patient Population Age Groups in “Use of Convalescent Plasma Therapy for COVID-19.”

S.No	Population Group	TP	TC	CPP	%TP
1	Adults	185	3695	19.97	22.56
2	Middle Aged	130	3149	24.22	15.85
3	Aged	127	3248	25.57	15.49
4	Child	30	453	15.10	3.66
5	Adolescents	25	477	19.08	3.05
	Global output	820	10641	12.98	100.00

*TP=Total publications; TC=Total citations; CPP=Citations per paper

Collaboration among top 25 organizations

The research collaboration network map (Figure 4) depicts top 25 organizations in 6 clusters. The Biblioshiny app was used to analyse the distribution and collaboration of top institutes in the field of “Use of Convalescent Plasma Therapy for COVID-19”. The box size and font size of each node is proportional to its publication output in the field. The bigger the font and box size of the node, the higher its output. The top five institutes with most publications output include Icahn School of Medicine at Mount Sinai, New York, USA, Huazhong University of Science and Technology, China, Chinese Academy of Medical Sciences - Peking Union Medical College, China, Johns Hopkins Bloomberg School of Public Health, USA, Tongji Medical College, China, and University of Oxford, U.K. (Table 7). The thickness of the lines joining

Table 7: Scientometric profile of top 20 most productive organizations in research on “Use of Convalescent Plasma Therapy for COVID-19.”

S.No	Name of the Organization	TP	TC	CPP	HI	ICP	ICP (%)	RCI	TCL
1	Icahn School of Medicine at Mount Sinai, New York, USA	21	95	4.52	4	4	19.05	0.35	80
2	Huazhong University of Science and Technology, China	18	1117	62.06	6	9	50.00	4.78	181
3	Peking Union Medical College, Chinese Academy of Medical Sciences, China	18	449	24.94	6	9	50.00	1.92	151
4	Johns Hopkins Bloomberg School of Public Health, USA	18	319	17.72	5	1	5.56	1.37	186
5	Tongji Medical College, China	17	1116	65.65	7	3	17.65	5.06	175
6	University of Oxford, U.K.	15	67	4.47	6	11	73.33	0.34	188
7	Harvard Medical School, USA	11	26	21.45	5	5	45.45	1.65	118
8	Weill Medical College, Cornell University, USA	11	170	15.45	6	3	27.27	1.19	108
9	NHS Blood and Transplant, U.K.	11	38	3.45	4	7	63.64	0.27	123
10	Johns Hopkins School of Medicine, USA	10	196	19.60	4	3	30.00	1.51	180
11	All India Institute of Medical Sciences, New Delhi, India	10	19	1.90	3	3	30.00	0.15	83
12	King Saud University, Saudi Arabia	10	22	2.20	3	6	60.00	0.17	54
13	INSERM, France	9	114	12.67	3	4	44.44	0.98	79
14	National University of Singapore	9	1786	198.44	7	7	77.78	15.29	101
15	Tehran University of Medical Sciences, Iran	9	95	10.56	3	5	55.56	0.81	51
16	Massachusetts General Hospital, USA	9	119	13.22	6	5	55.56	1.02	68
17	McMaster University, Canada	9	118	13.11	4	6	66.67	1.01	136
18	Zhongnan Hospital of Wuhan University, China	9	147	16.33	4	4	44.44	1.26	131
19	University of Cape Town, South Africa	8	10	1.25	2	4	50.00	0.10	71
20	Mayo Clinic, USA	8	134	16.75	4	2	25.00	1.29	54
21	University of Pennsylvania, USA	8	213	26.63	5	4	50.00	2.05	74
22	Shahid Beheshti University of Medical Sciences, Iran	8	28	3.50	2	5	62.50	0.27	41
23	Renmin Hospital of Wuhan, China	8	1138	142.25	5	4	50.00	10.96	113
24	Emory University School of Medicine, USA	8	150	18.75	4	2	25.00	1.44	17
25	University of British Columbia, Canada	8	71	8.88	3	4	50.00	0.68	62
	Total of 25 organizations	280	7967	28.45	4.44	120	42.86	2.19	2625
	Global total	820	10641	12.98					
	Share of top 25 organizations in global total	34.15	74.87						

*TP=Total publications; TC=Total citations; CPP=Citations per paper; HI = Herch Index; International Collaborative Papers: RCI = Relative Citation Index

the two organizations depict the degree of collaboration between. The thicker the lines, the greater is the number of linkages between them. The top three organizations Huazhong University of Science and Technology, China, Tongji Medical College, China and Peking Union Medical College, China account for the most collaborative linkages (35, 30 and 21). Whereas organizations like INSERM, France, Shahid Beheshti University of Medical Sciences, Iran and Tehran University of

Medical Sciences, Iran for the least number of collaborative linkages (1, 1 and 2). (Table 8)

Most Productive Authors

In all, 570 authors were found to have unevenly participated in global in research on “Use of Convalescent Plasma Therapy for COVID-19”. The research productivity of top 25 most productive authors varied from 3 to 5 publications per author whereas global average productivity of all authors was 1.43 per author. Author-wise distribution of global research output is skewed. For example, top 25 authors together they contributed a 12.32% (101) global publications share and 10.06% (1070) global citations share. Besides, 410 authors out of 570 published 1 papers each, 94 authors 2 papers each, 45 authors 3 papers each, 14 authors 4 papers each and 7 authors 5 papers each. The detailed scientometric profile of top 25 most productive authors is presented in Table 9.

Of the top 25 authors, 10 were from USA, 3 from Turkey, 2 each from China, Greece, Iran and Italy, and 1 each from Belgium, Canada, India and U.K. On further analysis, it was observed that six authors have made contribution above the group-25 average productivity (4.04): M.A. Erkert, Turkey, H. Harvala, U.K., M.J. Joyner, USA, F. Kramme, USA and Z. Liu, China (5 papers each); and Six authors have registered citation per paper and relative citation index higher than the group average (10.59 and 0.82): Y. Wu, China (57.75 and 4.45), Z. Liu, China (47.2 and

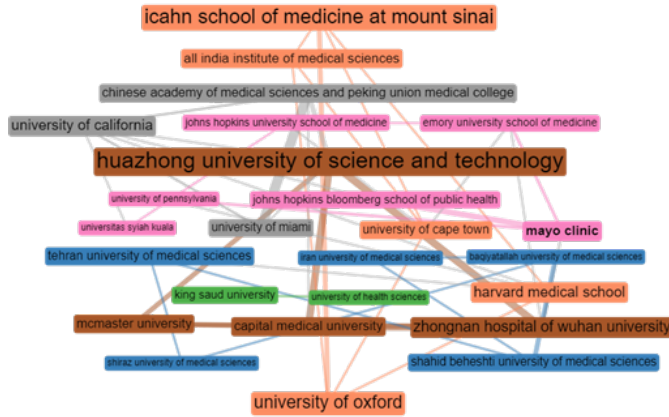


Figure 4: Collaboration Network Map of Top 25 Organizations.

Table 8: Collaborative Linkages among Top 25 Organizations in research on “Use of Convalescent Plasma Therapy in COVID-19 Patents.”

S.No	Name of Organization	Number of Collaborative Linkages with Different Organizations	TCL (NO)
1	Icahn School of Medicine at Mount Sinai, New York, USA	6(2), 7(1), 11(1), 19(1), 16(1), 14(1)	7(6)
2	Huazhong University of Science and Technology, China	3(6), 5(17), 17(2), 18(4), 23(6)	35(5)
3	Peking Union Medical College, Chinese Academy of Medical Sciences, China	2(6), 5(6), 17(2), 18(3), 23(4)	21(5)
4	John Hopkins Bloomberg School of Public Health, USA	10(1), 20(3)	4(2)
5	Tongji Medical College, China	2(17), 7(1), 17(2), 18(4), 23(6)	30(5)
6	University of Oxford, U.K.	1(2), 7(1), 9(9), 10(1), 11(1), 14(1), 19(2), 25(1)	18(8)
7	Harvard Medical School, USA	1(1), 2(1), 5(1), 6(1), 10(1), 14(1), 15(1), 16(3), 18(1), 21(1), 23(1)	13(11)
8	Sanford Weill Medical College, Cornell University, USA	20(1), 21(3)	4(2)
9	NHS Blood and Transplant, U.K.	6(9), 10(1), 13(1), 19(1), 22(1), 24(1), 25(1)	15(7)
10	John Hopkins School of Medicine, USA	6(1), 7(1), 19(1), 24(1), 25(1)	5(5)
11	All India Institute of Medical Sciences, New Delhi, India	1(1), 6(1), 19(1)	3(3)
12	King Saud University, Saudi Arabia	Nil	0
13	INSERM, France	9(1)	1(1)
14	National University of Singapore	1(1), 2(1), 6(1), 18(2), 19(1), 24(1)	7(6)
15	Tehran University of Medical Sciences, Iran	16(1), 22(1)	2(2)
16	Massachusetts General Hospital, USA	6(2), 7(3), 8(1) 9(2)	8(4)
17	McMasters University, Canada	2(2), 3(2), 5(2), 23(2), 25(1)	9(5)
18	Zhongnan Hospital of Wuhan University, China	2(4), 5(4), 7(1), 14(2), 23(4), 24(1)	17(6)
19	University of Cape Town, South Africa	1(1), 6(2), 9(1), 11(1), 14(1)	6(5)
20	Mayo Clinic, USA	4(3), 14(1), 16(1), 21(1), 24(1)	7(5)
21	University of Pennsylvania, USA	6(1), 7(1), 8(3)	5(3)
22	Shahid Beheshti University of Medical Sciences, Iran	9(1)	1(1)
23	Renmin Hospital of Wuhan, China	2(6), 3(4), 18(4)	14(3)
24	Emory University, School of Medicine, USA	6(1), 9(1), 14(1), 18(1), 19(1), 25(1)	6(6)
25	University of British Columbia, Canada	6(1), 9(1), 10(1) 17(1), 24(1)	5(5)

TCL=Total Collaborative Linkages, NO=Number of Organizations

Table 9: Scientometric profile of top 25 Most Productive authors in research on “Use of Convalescent Plasma Therapy for COVID-19.”

S.No	Name of the Organization	Affiliation	TP	TC	CPP	HI	ICP	ICP (%)	RCI	TCL
1	M.A. Erkurt	Inonu University, Turgut Ozal Medical Center, Malatya, Turkey	5	15	3.00	3	2	40.00	0.23	38
2	H. Harvala	NHS Blood and Transfusion, U.K.	5	2	0.40	1	3	60.00	0.03	84
3	M.J. Joyner	Mayp Clinic, USA	5	107	21.4	3	0	0.00	1.65	62
4	F. Krammer	ICAHN School of Medicine at Mount Sinai, USA	5	57	11.4	2	0	0.00	0.88	92
5	Z. Liu	Peking Union Medical College, CAMS, China	5	236	47.2	4	4	80.00	3.64	63
6	B.H. Shaz	New York Blood Center, USA	5	6	1.20	1	0	0.00	0.09	58
7	J.A. Aberg	ICAHN School of Medicine at Mount Sinai, USA	4	3	0.75	1	0	0.00	0.06	58
8	E.M. Bloch	John Hopkins School of Medicine, USA	4	13	3.25	2	1	25.00	0.25	19
9	P. Begin	University of Montreal, Canada	4	25	6.25	3	2	50.00	0.48	43
10	A.C. Cardevall	John Hopkins, Bloomberg School of Public Health, USA	4	106	26.5	3	0	0.00	2.04	46
11	M.S. Dal	Ankara Oncology Education and Research Hospital, Ankara, Turkey	4	10	2.5	2	2	50.00	0.19	46
12	K. Dhama	Indian Veterinary Research Institute, Bareilly, India	4	39	9.75	2	3	75.00	0.75	23
13	M. Franchino	Azienda Ospedaliera Carlo Poma, Italy	4	16	4.00	3	0	0.00	0.31	20
14	S. Korkmaz	Ankara Oncology Education and Research Hospital, Turkey	4	10	2.50	2	2	50.00	0.19	43
15	S.T.H. Liu	ICAHN School of Medicine at Mount Sinai, USA	4	3	0.75	1	0	0.00	0.06	80
16	I. Ntanasis-Stathopoulos	National Kapodistrian University of Athens, Greece	4	25	6.25	2	3	75.00	0.48	46
17	F. Rahman	ICAHN School of Medicine at Mount Sinai, USA	4	3	0.75	1	0	0.00	0.06	95
18	N. Razaee	Tehran University of Medical Sciences, Iran	4	91	22.75	3	1	25.00	1.75	7
19	E. Terpos	National Kapodistrian University of Athens, Greece	4	25	6.25	2	3	75.00	0.48	68
20	Y. Wu	Key Lab of Transfusion Adverse Reactions, China	4	231	57.75	4	4	100.00	4.45	75
21	H. Abolghasemi	Baqiyatallah University of Medical Sciences, Iran	3	18	6.00	2	1	33.33	0.46	36
22	A. Abrams-Downey	ICAHN School of Medicine at Mount Sinai, USA	3	4	1.33	2	0	0.00	0.10	76
23	R. Attou	Centre Hospitalier University Brugmann, Brussels, Belgium	3	2	0.67	1	1	33.33	0.05	18
24	I. Baine	ICAHN School of Medicine at Mount Sinai, USA	3	5	1.67	2	2	66.67	0.13	80
25	F. Baldanti	Univ. degli studi di Pavia, Italy	3	18	6.00	3	1	33.33	0.46	21
		Total of 25 authors	101	1070	10.59	2.2	35	34.65	0.82	1297
		Global output	820	10641	12.98					
		Share of 25 authors in global output	12.32	10.06						

*TP=Total publications; TC=Total citations; CPP=Citations per paper; HI = Herch Index; International Collaborative Papers: RCI = Relative Citation Index

3.64), A.C. Cardevall, USA (26.5 and 2.04), N. Razaei, Iran (22.75 and 1.75), M.J. Joyner, USA (21.4 AND 1.65) and F. Krammer, USA (11.4 and 0.88).

Collaborative Linkages among Top authors

The networks collaboration map of top 16 authors (Figure 5) depicts authors in 12 clusters. Of these, 6 clusters have the most publications. Cluster 1 in red colour is formed by authors such as Aberg J.A., Abrams-Downey A., Baine I., Krammer F., Liu S.T.H. and Rahman F. Cluster 2 in green colour includes authors such as Bloch E.M., Casadevall A., Joyner M.J. and Shaz B.H. Clusters 4, 5 and 6 in yellow, purple and turquoise colors have two authors each. Clusters 7 to 12 have one author each. The thickness of lines between authors depict the degree of their collaboration in research. The top three authors with largest collaborative linkages (18, 15 and 14) are A.Aberg, F.Rahman and S.T.H.Liu. The authors with least collaborative linkages (1, 2, 14) are A.C.Casdevalli, M.Franchino and E.M.Bloch. Individual-individual author collaborations are by Z.Liu - Y.Wu, J.A.Aberg - M.S. Dal, J.A.Aberg - S.T.H.Liu, and J.A.Aberg -F.Rahman (4 linkages each) (Table 10).

4.6 Medium of Research Communication

All of the research publications on “Use of Convalescent Plasma Therapy for COVID-19”, have appeared in journal medium. Of the total 470 journals which reported 820 articles, 331 published 1 paper each, 80 published 2 papers each, 47 published 3-5 papers each, 13 published 6-10 papers each, and 6 published 11-29 papers each.

A co-citation networks map of top 25 most productive journals (Figure 6) depicts journals in 11 clusters. In the map, two or more journals that cover closely related topics are placed close to one another, and those covering fundamentally different topics are located far from each other. The circle size and font size of a journal node is proportional to the frequency of its co-citations. Cluster 1 in red colour has 5 journals i.e. (a-JAMA-Journal of the American Medical Association, b-Frontiers in Pharmacology, c-International Journal of Infectious Diseases, d-Journal of Infectious Diseases and e-Mayo Clinic Proceedings), Cluster 2 in green colour has 4 journals (a-Journal of Medical Virology, b-Frontiers in Medicine, c-European Journal of Pharmacology and d-Military Medical Research) and Clusters 3, 4 and 5 are in blue, yellow and purple colour with 3 journals each.

The top 25 most productive journals published 4 to 29 papers each. Together these 25 journals accounted for a 26.59% share. The top 5 most productive journals are *Transfusion and Apheresis Science* (29 papers), *Transfusion* (21 papers), *JAMA-Journal of the American Medical Association* (15 papers), *Journal of Medical Virology* (13 papers) and *Frontiers in Immunology* (11 papers). The top 5 most impactful journals in terms of citations per paper registered are: *Military Medical Research* (211.4), *Nature Reviews Immunology* (132.0), *Journal of Medical Virology*

(60.08), *JAMA-Journal of the American Medical Association* (42.2 and *Critical Care* (16.83) (Table 11).

Highly Cited Papers

Of the total output in the research on “Use of Convalescent Plasma Therapy for COVID-19” (820 publications), only 16 publications (1.95% share)

Table 10: Collaborative Linkages among Top 25 authors in research on “Use of Convalescent Plasma Therapy for COVID-19.”

S.No	Name of the Author	Number of collaborative linkages with other authors	TCL(NOA)
1	M.A. Erkurt	11(4), 14(4)	8(2)
2	H. Harvala	Nil	Nil
3	M.J. Joyner	Nil	Nil
4	F. Krammer	6(1), 7(2), 15(2), 17(2), 22(2), 24(3)	12(6)
5	Z. Liu	20(4)	4(1)
6	B.H. Shaz	4(1), 8(1), 17(1), 22(2), 24(1)	6(5)
7	J.A. Aberg	4(2), 11(4), 15(4), 17(4), 22(2), 24(2)	18(6)
8	E.M. Bloch	6(1), 10(1)	2(2)
9	P. Begin	Nil	Nil
10	A.C. Casdevalli	8(1)	1(1)
11	M.S. Dal	1(4), 14(4)	8(2)
12	K. Dhama	Nil	Nil
13	M. Franchino	15(2)	2(1)
14	S. Korkmaz	1(4), 11(4)	8(2)
15	S.T.H. Liu	4(2), 7(4), 17(4), 22(2), 24(2)	14(5)
16	I. Ntanasis-Stathopoulos	19(4)	4(1)
17	F. Rahman	4(2),6(1), 7(4), 15(4), 22(2), 24(2)	15(6)
18	N. Razaei	Nil	Nil
19	E. Terpos	16(4)	4(1)
20	Y. Wu	5(4)	4(1)
21	H. Abolghasemi	Nil	Nil
22	A. Abrams-Downey	4(2), 6(2), 7(2), 17(2), 25(2)	10(5)
23	R. Attou	Nil	Nil
24	I. Baine	4(3), 7(2), 15(2), 17(2), 22(2)	11(5)
25	F. Baldanti	13(2)	2(1)

TCL=Total Collaborative Linkages, NOA=Number of Authors

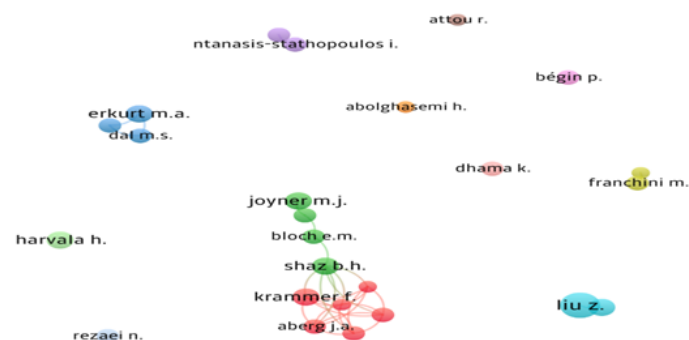


Figure 5: Collaborative Networks map of Top 16 Authors.

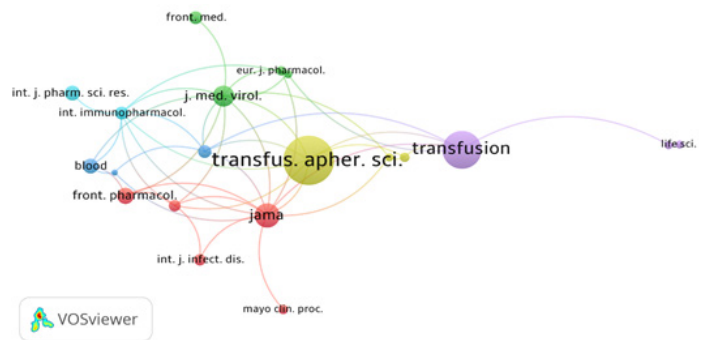


Figure 6: Co-citations Networks Map of Top 25 most productive journals.

accumulated high citations, 101 to 977 citations per paper since their publication during 2020-21, and averaging their performance to 394.81 citations per paper (cumulative total 6317 citations). The distribution of 16 highly cited papers is skewed: 6 papers received citations in the range 101-200 per paper, 5 papers were in the citation range 201-400, 4 papers in the citations range 401-607 and 1 paper received a high of 977 citations. Of the 16 highly cited papers, 7 were published as articles, 8 as review papers and 1 as a note. Of the 16 highly cited papers, 4 were contributed by one single organization per paper (as non-collaborative papers) and the remaining 12 resulted by two or multiple organizations per paper (9 appeared as national collaborative and 3 as international collaborative papers). The 16 highly cited papers involved 156 authors from 83 organizations. Tongji Medical College, China contributed 3 highly cited papers, the largest number of papers, followed by National University of Singapore, Renmin Hospital of Wuhan University (2 papers

each), etc. These 16 highly cited papers appeared across 11 journals, of which 3 papers appeared in Journal of Medical Virology, 2 papers each appeared in International Journal of Microbial Agents and Journal of the JAMA-Journal of the American Medical Association and 1 paper each in Clinical Immunology, Indian Journal of Pediatrics, Journal of Korean Medical Science, Journal of Microbial Immunology and Infection, The Journal of Infectious Diseases, Military Medical Research, Nature Review Immunology, Proceedings of the NSA of USA and Translational Pediatrics.

SUMMARY AND CONCLUSION

This study evaluates global research on “Use of Convalescent Plasma Therapy for COVID-19 with the aim to describe research productivity, performance, and bibliometric mapping in the subject on bibliometric indicators. The data for the study was sourced from Scopus database covering the period 2020-2021. The global research on “Use of Convalescent Plasma Therapy for COVID-19 comprised a total of 820 publications, and these were contributed by 570 authors from 457 research organizations spread across 90 countries. The average research productivity in the subject was 1.43 per contributing author, and 1.79 per research organization. The global research output (820 publications) received a total of 10641 citations since publication. The average performance in the subject was 16.74 citations per paper for global research, and 25.39 citations per paper for the sponsored research. Only 1.95% (16 publications) share of 820 reported high citations above 100, between 101 and 977 citations per paper. The USA topped in the global ranking of most productive countries with a 34.88% global publication share, followed by China and India (15.98% and 12.68%), and 12 other most productive countries. Country-wise analysis of top 15 most productive countries reveal that only three countries - China, UK, and Netherlands had registered their citation performance above the group-15 average (14.33 CPP and 1.10 RCI). Furthermore, the study provides a window to key countries, key organizations, key authors, key source journals, popular areas of research interest, and significant keywords.

The USA, China, India have provided leadership in research studies on “Use of Convalescent Plasma Therapy for COVID-19 as most productive countries. But at the institutional level and the individual author level the picture about country performance in terms of research productivity is different. At institutional level, the USA is the home country to five out of top 10 global institutions. China to three, and the UK to two institutions. India is the home country to one institution but ranked at 11th position. At the individual author level, it is the USA which dominates as the home country to six out of top ten authors in the global output. Interestingly, international collaboration in convalescent plasma research is seen as the strongest among the USA, China, India vis-a-vis other top 12 countries.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Table 11: Top 25 Most Productive Journals in research on “Use of Convalescent Plasma Therapy for COVID-19.”

		TP	TC	CPP
1	Transfusion and Apheresis Science	29	93	3.21
2	Transfusion	21	56	2.67
3	JAMA-Journal of the American Medical Association	15	633	42.20
4	Journal of Medical Virology	13	781	60.08
5	Frontiers in Immunology	11	35	3.18
6	Frontiers in Pharmacology	10	27	2.70
7	Blood	9	72	8.00
8	International Journal of Research in Pharmaceutical Science	9	4	0.44
9	Frontiers in Medicine	8	6	0.75
10	International Immunopharmacology	8	106	13.25
11	Vox Sanguinis	8	81	10.13
12	International Journal of Infectious Diseases	7	11	1.57
13	Journal of Infectious Diseases	7	91	13.00
14	Critical Care	6	101	16.83
15	European Journal of Pharmacology	6	16	2.67
16	Mayo Clinic Proceedings	6	4	0.67
17	Science	6	58	9.67
18	Trials	6	13	2.17
19	British Journal of Haematology	5	49	9.80
20	Journal of Infection and Public Health	5	23	4.60
21	Life Sciences	5	63	12.60
22	Military Medical Research	5	1057	211.40
23	Nature Reviews Immunology	5	660	132.00
24	American Journal of Case Reports	4	1	0.25
25	BMJ	4	25	6.25
	Total of 25 journals	218	4066	18.65
	Global total in journals	820	10641	12.98
	Share of top 12 journals in global total	26.59	38.21	

TP = Total Publications TC = Total Citations, CPP = Citations per Paper

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