Animal Models in Covid-19 Research: A Scientometric Assessment of Indian Publications during 2020-21

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ABSTRACT

Background: Animal studies are an indispensable part of fundamental and applied research essential for the advancement of human and veterinary health, including the current global quest for treatments and a vaccine development to combat the infectious diseases. This necessity is now clearly highlighted by the ongoing Covid-19 pandemic More recently a growing number of studies are published on this theme. Therefore, a bibliometric analysis of research on "Animal models in Covid-19" research is necessary and it is likely to focus on current status of research and indicate future direction in this study. **Materials and Methods:** The India's originated literature is searched on " Animal Models in Covid-19" using two set of keywords related to Covid-19 and animals in "Keyword" and "Title" (Title of articles) tags to reach the relevant publications. VOSviewer was applied to perform the bibliometric analysis of these articles. Bibliographical data obtained from above search strategy was analysed by using well-established bibliometric indices. **Results:** The bibliometric analysis of India's literature on the topic "Animal Models in Covid-19" research indicates that there were 2343 India's publications indexed in Scopus database during 2020-21. The topic witnessed the uneven participation of more than 160 countries, where 88.63% and more than 100.0% share of the global publications and citations share caming from top 10 countries. USA leads the ranking with global publication share of 28.16% share, followed by China (13.30%, U.K. (10.67%), Italy (9.93%). India's research output on this topic registered 7.46% share to global output. The 496 organizations and 869 authors participated in India's research on "Animal Model in Covid-19", of which the top 25 Indian organizations and 25 authors contributed 46.58% and 22.60% share to India's national publication output and 61.19% and 48.8% share to India's citation output respectively. AIIMS - New Delhi , PGIMER- Chandigarh, and IVRI- Bareilly were the most productive organizations (with 118, 115 and 68 publications). IVRI-Bareilly, PGIMER-Chandigarh and College of Veterinary Science, Mathura were the impactful organizations in terms of citation per paper and relative citation index. K. Dharma, R. Tiwari and Y.S. Malik were the most productive authors (with 63, 35 and 27 papers). H. Harapan, A.K.Singh and A Misra were the most impactful authors (with 90.42, 88.20 and 73.31 CPP).. *International Journal of Research in Pharmaceutical Sciences, Indian Journal of Medical Research* and *Diabetes and Metabolic Syndromes. Clinical Research and Review* were the most productive journals (with 72, 56 and 50 papers). **Conclusion:** The paper provides a understanding of the current research on animal models presently used in Covid-19 research in India, identify key players and their collaboration patterns and key sub-fields, which may be useful to practicing scholars and clinicians to advance their future research in a more effective manner and to policy-makers in deciding the area of research to be funded in future.

Key words: Covid-19, Animal Models, Global publications, Indian Publications, Bibliometrics, Scientometrics1.

INTRODUCTION

The remarkable anatomical and physiological similarities between humans and animals, particularly mammals, have prompted researchers to investigate a large range of mechanisms and assess novel therapies in animal models before applying their discoveries to humans.[1] Animal models have the same receptors as those present in humans, which help viruses during the attachment and entry process, and the outcome of infection should match the severity observed in humans. But in many emerging diseases, *in vitro* studies cannot completely simulate human pathophysiology. Besides, the immunological components are very complex in humans, which cannot be proven in the *in vitro* experiments. However, despite differences between animal models and humans, critical information related to the pathogenesis, prevention and treatment of newly emerging infectious diseases can still be discovered.[2] In February 2020, the World Health Organization (WHO) assembled an international panel to develop animal models for Covid-19 to accelerate the testing of vaccines and therapeutic agents.[3] Recent detection of coronavirus virus in pet, zoo, wild, and farm animals have compelled inquiry regarding the zoonotic (animal-to-human) and reverse zoonotic (human-to-animal) transmissibility of SARS-CoV-2 with the potential of Covid-19 pandemic evolving into a panzootic.[4] Results obtained from experimental studies indicate that animal species such as cats, ferrets, raccoon dogs, cynomolgus macaques, rhesus macaques, white-tailed deer, rabbits, Egyptian fruit bats, and Syrian hamsters are susceptible to SARS-CoV-2 infection, and that cat-to-cat and ferret-to-ferret transmission can take place via contact and air. However, natural infections of SARS-CoV-2 have been reported only in pet dogs and cats, tigers, lions, snow leopards, pumas, and gorillas at zoos, and farmed mink and ferrets. Even though human-to-animal spillover has been reported at several instances, SARS-CoV-2 transmission from animals-to-humans has only been reported from mink-to-humans in mink farms.[5] Continued refinement and development of animal models for Covid-19 will contribute to the development of vaccines, therapeutic agents and other countermeasures. Large-scale clinical trials are currently underway to test multiple candidate preventative and therapeutic interventions in humans. The outcomes of these clinical-efficacy trials will allow an unprecedented opportunity for the back-validation and refinement of these animal models.[3]

Literature Review

Although quite a large number of bibliometric studies have been conducted on Covid-19, but no studies have been undertaken on animal models in Covid-19. Among bibliometric studies in particular on Covid-19, Gupta, Dhawan, Ahmed and Mamdapur[6] evaluated global research (103054 records) on Covid-19 on select bibliometric indicators. It presents a bibliometric profile of most influential countries, organizations, authors and journals, and also describes their collaborative linkages. It identifies broad subject areas of research, most significant keywords and highly-cited papers related to Covid-19. Among studies related to animal models in general, Wang, Chen, Xu and Cui[7] used a bibliometric method to analyze the studies (8636 articles) of rat and mouse Parkinson's Disease (PD) models based on research published between 2009 and 2018 in the Web of Science (WOS) database using CiteSpace V software. According to the bibliometric analysis, studies on PD were focused on the mechanisms of oxidative stress, neuro inflammation, and autophagy.

Since there were no bibliometric studies available on this topic, the authors therefore decided to undertake a study on bibliometric assessment of India's research on use of animal models in Covid-19 research. The main objective was to identify the current status and trends of research, to identify major subject areas and important keywords, to identify important players (organizations and authors), to identify important sources used and to analyse the characterstics of high cited papers. The study mainly used publication, citations and international collaborative papers to understand the research activity on this topic.

METHODOLOGY

Research publications on the theme "Animal Models in Covid-19" were identified, retrieved and downloaded from the Scopus database (https://www.scopus.com), using two sets of keywords related to topic under study. The keywords were incorporated in field tags, "Keyword" or "Title" (Article Title) and limited the search to 2020-21 publication years. The search yielded a total 2343 records published by India. The publications data after downloading was analyzed using additional analytical provisions as available in the Scopus database.

Publication characteristics were tabulated, including titles, authors, co-cited authors, journal sources, keywords, affiliations of authors, countries or regions to which the authors belong. Co-cited authors means that the authors have been cited together. Biblioshiny software was utilized to analyze the relationships among the most productive countries, research institutions, and among frequently used keywords. The study performed cluster analysis and generated social network maps (consist of nodes and links) for countries, institutions and keywords by Biblioshiny. Cluster was also obtained by Biblioshiny via analyzing the frequency of the same keywords appearing within the different papers.

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 (nonhuman* OR animal* OR ferret* OR hamster* OR mice* OR monkey* OR redent* OR rat* OR rabbit* OR cats OR dog OR macaqies* OR pig OR tiger OR bat) AND (LIMIT-TO (AFFILCOUNTRY,"India").

RESULTS

Overall Output

As seen from the Scopus database, the global research on the topic of "Animal Models in Covid-19" studies accumulated a total 31402 during 2000-21. India's contribution to Animal Model in Covid-19 research during the period was 2343 publications, a 7.46% global share (2020=1360; 2021=983). The distribution of global research output by participating countries (160) is highly skewed. For example, 53 countries contributed 1-10 papers each, 19 countries 11-20 papers each, 22 countries 21-50 papers each, 13 countries 51-100 papers each, 36 countries 101-500 papers each, 6 countries 501-100 papers each, 6 countries 1001-2000 papers each and 5 countries 2343-8843 papers each.

The top 10 countries together accounted for a 90.23% share. The USA tops the list of most productive countries with a 28.16% share, followed by China, U.K. and Italy (13.3%, 10.67% and 9.93% respectively). India ranks at the fifth position in the tally with a 7.46% share (Table 1). The global share of Germany, France, Canada, Spain and Iran ranges from 3.49% to 4.73%.

India's on research on "Animal Models in Covid-19" (2343 publications) received 24595 citations since publication and scored an average of 10.50 citations per paper. The citation count was taken on 18.8.2021.

A 20.91% share (490) of India's 2343 publications received extra-mural funding support from 100+ agencies and accrued 6608 citations during the period. The citation performance of funded papers was an average of 13.48 citations per paper. The leading global funding agencies were Department of Science and Technology, India (98 papers), Indian Council of Medical Research (66 papers), Department of Biotechnology, India (64 papers), Science and Engineering Board, India (58 papers), Council of Scientific and Industrial Research, India (57 papers), National Institute of Health, USA (40 papers), University Grants Commission, India (28 papers), etc.

Of the total India's publications on this theme, articles constituted the largest group (a 47.41% share), followed by reviews and letters (28.68% and 14.0%), notes, editorials and conference papers (3.67%, 3.07% and 2.05%), short surveys, book chapters and retracted (0.60%, 0.47% and 0.04%).

A 32.37% share (756) of India's publications on "Animal Models in Covid-19" research, were involved in international collaboration with 50 + countries. These 756 International collaborative papers received

Table 1: Global Contribution of Top 10 Countries in "Animal Models in Covid-19" Research during 2021-21.

S.No	Name of the country	TP	%TP
1	USA	8843	28.16
2	China	4178	13.30
3	U.K..	3350	10.67
4	Italy	3117	9.93
5	India	2343	7.46
6	Germany	1486	4.73
7	France	1399	4.46
8	Canada	1282	4.08
9	Spain	1242	3.96
10	Iran	1095	3.49
	Total	28335	90.23
	Global total	31402	

11699 citations, an average of 15.47 citations per paper. India's collaboration with the USA the most, a 41.67% of collaborative papers (756), followed by U.K. (20.9%), Saudi Arabia (10.49%), Australia (10.45%),China (9.65%), Italy (8.46%), South Korea (7.93%), Germany (7.14%) and Japan (7.01%). Figure 1 provides a visual chart of international collaborating countries network of India with other top countries in the subject.

Subject-Wise Distribution of Publications

The 2343 publications on "Animal Models in Covid-19" were classified by Scopus classification (Table 2). Medicine accounts for the most publications in the research studies (a 92.82% share), followed by Biochemistry, Genetics and Molecular Biology (25.88%), Immunology and Microbiology (7.85%), Pharmacology, Toxicology and Pharmaceutics (3.34%) and Neurosciences (3.01%). In terms of citation performance, publications on Biochemistry, Genetics and Molecular Biology registered the highest citations per paper (11.13) and the least by Immunology and Microbiology (5.72 CPP).

Significant Keywords

Keywords allude to some broad ideas about the ongoing research trends on the theme of the topic under study. 75 significant keywords were identified from the literature on "Animal Models in Covid-19". The frequency of their occurrence in the literature varied from 81 to 2221 times. The keyword 'Covid-19' occurred the most number of time (2221), followed by keyword "Non-Human (1341), Pandemic (1141), 'Virus Pneumonia' (578), "Betacoronovirus(520), "Virology" (420), etc. Among animal models, the maximum emphasis was on non-humans (1341), followed by animals (289), rats (66), bat (47), mouse (39), Choroptera (27), dogs (18), cats (16), camel (14), monkeys (13), pigs

Table 2: Subject-Wise Distribution of Publications on "Animal Models in Covid-19" 2020-21.

S.No	Name of the Subject	TP	TC	CPP	%TP
1	Medicine	556	5404	9.72	92.82
2	Biochemistry, Genetics and Molecular Biology	155	1725	11.13	25.88
3	Immunology and Microbiology	47	269	5.72	7.85
4	Pharmacology, Toxicology and Pharmaceutics	20	143	7.15	3.34
5	Neurosciences	18	114	6.33	3.01
	Global Total	599	5878	9.81	100.00

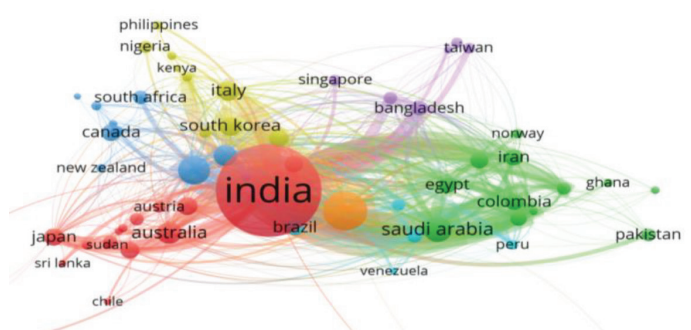TP=Total papers; TC=Total citations; CPP=Citations per paper

Figure 1: Network Chart of Countries in International collaboration with India in 'Animal Models in Covid-19 Research.

(12), etc. (Table 3). Figure 2 presents a conceptual structure map of significant keywords and also carried out to Correspondence analyses (MCA) of Significant Keywords

Type of Studies

Animal Models in Covid-19' research studies can be classified under various types. It was observed that studies related to "Treatment" type accounts for the most number of publications (a 28.08% share), followed by "Clinical Studies" type (21.47%), "Epdemiology" (16.46%), "Pathophysiology" (14.90%), "Genetics" (10.20%), "Risk Factors"(8.11%) and "Complications" (6.40%). In terms of performance on citations, "Complications" type registered the most citations per paper (19.95) and "Epidemiology" type for the least number (11.65 CPP) (Table 4)

Profile of Top 25 Organizations

In all 496 organizations from India contributed to "Animal Models in Covid-19" research but their research productivity varied widely. For instance, 277 organizations contributed 1-5 papers each, 112 organizations 6-10 papers each, 71 organizations 11-20 papers each, 30 organizations 21-50 papers each, 4 organizations 51-69 papers each and just 2 organizations 115-188 papers each.

The top 25 organization contributed 24 to 118 papers each and together they contributed a 42.08% share (986 out of 2343 papers) and received a 53.84% share in global citations (13243). On further analysis, it was observed that: (i) Eight of 25 organizations individually contributed more number of papers than their group average (16.76) and (ii) Six organizations individually registered their performance in terms of citations per paper and relative citation index above their group average (32.11 CPP and 3.06 (global av being 1) respectively). Table 5 lists the performance of 7 most productive and 7 most impactful organizations. Figure 3 provides a visual view of institutional collaborative networks in 'Animal Models in Covid-9' research in India during 2020-21.

Profile of Top 25 Authors

In all 869 authors from 469 organizations from India contributed to "Animal Models in Covid-19" research but their productivity is spread out widely. For instance, 769 authors contributed 1-5 papers each, 75 authors 6-10 papers each, 18 authors 11-20 papers each and 7 authors 21-63 papers each.

The top 25 authors individually contributed 9 to 63 papers each and together they contributed a 16.03% share (96) and a 8.97% share (527) in global citations. On further analysis, it was observed that: (i) Seventeen of 25 top authors contributed more number of papers than their group average (3.84) and (ii) Nine authors registered their performance in citations per paper and relative citation index above their group average (5.49 CPP and 0.61 (global av being 1)). Table 6 lists the top 7 most productive authors and 7 most impactful authors. Figure 4 provides a networks of top 25 collaborating authors

Profile of Top 25 Journals

Of the total 2343 publications by India on "Animal Models in Covid-19", a 97.61% share (2287 publications) appeared as articles in 367 journals, 1.84% (43) in conference proceedings and 0.55% (13) in book series. The contribution by research authors to 367 journals is widely spread out. For instance, 280 journals contributed 1-5 paper each, 44 journals 6-10 papers each, 32 journals 11-20 papers each, 9 journals 21-50 papers each and 2 journals 56-72 papers each. The contribution to top 25 journals individually varied 14 to 72 papers and together they accounted for a 27.20% share of total output by India in this research field.

On further analysis it was found that (I) the top seven productive journals include *International Journal of Research in Pharmaceutical*

Table 3: List of Significant Keywords appearing in Literature on "Animal Models in Covid-19".

S.No.	Keywords	TP	S.No	Keywords	TP	S.No	Keywords	TP
1	Covid-19	2221	26	Quarantine	151	51	Dexamethasone	81
2	Non-Human	1341	27	Vaccination	150	52	Cardiovascular Disease	82
3	Pandemic	1141	28	Interleuken 6	141	53	Case Reports	82
4	Virus Pneumonia	578	29	Hypertension	137	54	Diarrhea	82
5	Betacoronovirus	520	30	Tocilizumab	136	55	Drug Design	83
6	Virology	420	31	Favipiravir	133	56	Lockdown	82
7	Angiotensin Converting Enzyme 2	344	32	Virus RNA	127	57	Hand Washing	81
8	Hydroxycholoroquine	297	33	Inflammation	126	58	Rats	66
9	Animals	289	34	Azithromycin	122	59	Bat	47
10	Remdesivir	268	35	Pathogenesis	120	60	Mouse	39
11	Immunology	243	36	C.Reactive Protein	118	61	Choroptera	27
12	Antiviral Agents	250	37	Molecular Dynamics	108	62	Dogs	18
13	Drug Effect	234	38	Tumor Necroosis Factor	108	63	Cats	16
14	Immune Response	213	39	Drug Safety	107	64	Camel	14
15	CHoloroquine	208	40	Ribavirin	107	65	Monkeys	13
16	Comorbidity	195	41	Computer Model	106	66	Pigs	12
17	Adult Respiratory Distress Syndrome	184	42	Computer-Assisted Tomography	102	67	Hamster	10
18	Molecular Docking	184	43	THroax Radiography	102	68	Bovine	9
19	Coronovirus Spikr Glyoprotein	177	44	Immunomodulation	100	69	Tiger	7
20	Dyspnea	168	45	Intensive Care Unit	98	70	Swine	5
21	Diabetes Mellitus	167	46	Lopinavir	97	71	Cattele	5
22	Virus Genome	159	47	Ritonavir	97	72	Rodents	5
23	Drug Repositioning	158	48	Social Distancing	89	73	Horse	4
24	Cytokine Storm	158	49	Corticosteroid	87	74	Horse	4
25	Lopinavir Plus Ritonavir	152	50	Molecular Docking Simulation	86	75	Ferrets	3
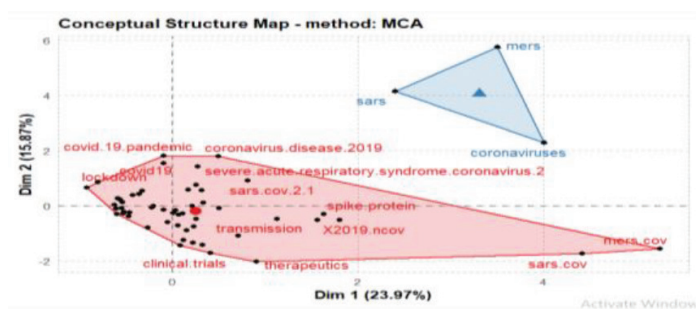
Figure 2: Conceptual Structure: Map-method Correspondence analysis (MCA) of Significant Keywords.

Table 4: Distribution of Publications by Types of Study.

S.No.	Type of Study*	TP	TC	CPP	%TP
1	Clinical Studies	503	8154	16.21	21.47
2	Pathophysiology	349	5107	14.63	14.90
3	Epidemiology	395	4601	11.65	16.86
4	Genetics	239	2957	12.37	10.20
5	Risk Factor	190	2873	15.12	8.11
6	Complications	150	2993	19.95	6.40
7	Treatment	658	8937	13.58	28.08
	Total	2343			

There is overlapping of studies under various types of studies

Sciences (72 papers), *Indian Journal of Medical Research* (56 papers), *Diabetes and Metabolic Syndromes. Clinical Research and Review* (50 papers), *Medical Hypothesis* (38 papers), *Journal of Medical Virology* (29 papers), *Journal of Pure and Applied Microbiology* (28 papers) and Indian Journal of Critical Care Medicine (25 papers) and; and (ii) the performance of top seven reporting journals in terms of citations per paper was as follows: *Indian Journal of Pediatrics* (78.67 CPP), *Journal of Biomolecuar Structure and Dynamics* (51.3 CPP), *Science of the Total Environment* (37.71 CPP), *Diabetes and Metabolic Syndromes. Clinical Research and Review* (28.34 CPP), *Journal of Medical VIrology* (21.97 CPP), *Asian Journal of Psychiatry* (21.59) and *Human Vaccine and Immunotherapeutics* (20.94 CPP). Figure 5 provides a three fields plot of the journals analysis: (Left field: Journals; Middle field: Titles; Right field: Authors)

Table 5: Profile of Top 7 Most Productive and Most Impactful Organizations from India on Animal Models in Covid-19 Research- 2020-21.

S.No	Name of the Organization	TP	TC	CPP	HI	ICP	% ICP	RCI
	Top 7 Most Productive Organizations							
1	All India Institute of Medical Sciences (AIIMS), New Delhi	118	1000	8.47	14	12	10.17	0.81
2	Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh	115	1441	12.53	17	15	13.04	1.19
3	Indian Veterinary Research Institute (IVRI), Bareilly	68	2697	39.66	19	48	70.59	3.78
4	Datta Megha Institute of Medical Sciences	53	57	1.08	4	1	1.89	0.10
5	Amity University, Noida	39	220	5.64	8	13	33.33	0.54
6	Manipal Acdemy of Higher Education (MAHE)	38	297	7.82	8	12	31.58	0.74
7	Sanjay Gandhi Postgraduate Institute of Medical Sciences (SGPGIMS), Lucknow	37	417	11.27	9	11	29.73	1.07
	Top 7 Most Impactful Organizations							
1	U.P. Pandit Deen Dayal Upadhayaya Pashu Chiksa Vigyan Vishwaavidalaya Evam Go Anusandhan	29	1300	44.83	15	24	82.76	4.27
2	College of Veterinary Science, Mathura	36	1437	39.92	16	28	77.78	3.80
3	Indian Veterinary Research Institute (IVRI), Bareilly	68	2697	39.66	19	48	70.59	3.78
4	Jamia Millia Islamia, New Delhi	27	625	23.15	10	9	33.33	2.20
5	Christian Medical College (CMC), Vellore	35	732	20.91	9	7	20.00	1.99
6	Indian Institute of Technology (IIT), New Delhi	29	437	15.07	9	6	20.69	1.44
7	Postgraduate Institute of Medical Education and Research (PGUIMER), Chandigarh	115	1441	12.53	17	15	13.04	1.19

TP=Total papers; TC=Total citations; CPP=Citations per paper; ICP=International collaborative papers; HI=*h*-Index; RCI=Relative citation index

Figure 3: 'Animal Models of Covid-19' research in India - Network Chart of Collaborating Organizations.

High-Cited Papers

A 1.54% share (36 publications) of 2343 publications by India on "Animal Models in Covid-19 research, (assumed as high-cited here) received 103-1010 citations per paper since their publication. Together these highly cited papers received 8910 citations, an average of 247.5 citations per paper. Of the 36 highly cited papers, 21 received 103-192 citations, 8 received 204-253 citations, 5 received 327-503 citations and 2 papers received 932-1010 citations.

Among 36 high-cited papers, the USA accounts for the most publications in collaboration with India (8 papers), followed by China, Columbia, Saudi Arabia, Thailand and U.K. (4 papers each), Australia, South Korea and Spain (3 papers each), France, Iran, Japan, Nepal, Netherlands and Peru (2 papers each) and 20 other countries collaborated with India in 1 paper each.

These 36 high-cited papers by publication type include 19 articles, 14 reviews, 2 letters and 1 note. In all 232 authors from 291 organizations from India contributed to 36 highly cited papers. Seven of these highly cited papers were non-collaborative papers and 29 as collaborative papers (13 national collaborative and 16 international collaborative).

The 36 high-cited papers were published in 26 journals, with 4 papers in *Journal of Molecular Structure and Dynamics*, 3 in *Diabetic and Metabolic Syndromes. Clinical Research and Review*, 2 each in *The BMJ*, *Asian Journal of Psychiatry, Clinical Microbiological Review, Journal of Medical Virology and Science of the Total Environment* and 1 paper each in 19 other journals. Figure 6 provides a word cloud title analysis.

RESULTS

About 160 countries contributed to "Animal Models in Covid-19" research and generated a total of 31402 global publications during 2020-21. Despite witnessing a global level participation, research in the subject was dominated mainly by top 10 countries, with a 90.23% global share. The USA contributed the most number of publications with a 28.16% global share, followed by China, U.K. and Italy (13.3%, 10.67% and 9.93%), etc. India ranks at the fifth position in the tally with a meagre 7.46% share (2343 publications).

India contributed a 7.46% global share (2343 publications), received a total of 24595 citations, an average of 10.5 citations per publication. Only a 1.54% share (36) India's publications received high citations 103 to 1010 citations. Together these 36 highly cited papers registered 8910 citations, an average of 247.5 citations per paper. A 20.91% share (490) of the total output by India received extramural funding support and it accounted for 6608 citations, averaging 13.48 citations per publication. Most publications by India, a 92.82% share, appeared in "Medicine" journals. Most publications organized by type of studies belonged to 'treatment' category (28.08%), followed by 'clinical studies' type studies (25.88%).

Table 6: Profile of Top 7 Most Productive and Most Impactful Authors on "Animal Models in Covid-19" Research in India - 2020-21.

S.No	Name of the Author	Affiliation of the Author	TP	TC	CPP	HI	ICP	%ICP	RCI
		Top 7 Most Productive Authors							
1	K. Dhama	IVRI – Bareiilly	63	2606	41.37	18	47	74.60	3.94
2	R. Tiwari	IVERI – Bareilly	35	1438	41.09	16	28	80.00	3.91
3	Y.S.Malik	IVRI – Bareilly	27	1292	47.85	13	21	77.78	4.56
4	K.Sharun	IVRI – Bareilly	21	790	37.62	12	13	61.90	3.58
5	V.Wiwanitkit	Dr S.Y.Patil Vidyapeeth, Pune	21	56	2.67	5	18	85.71	0.25
6	B.Medhi	PGIMER-Chandigarh	20	406	20.30	8	0	0.00	1.93
7	P.Sarma	PGIMER-Chandigarh	18	406	22.56	8	0	0.00	2.15
		Top 7 Most Impactful Authors							
1	H.Harapan	IVRI – Bareilly	12	1085	90.42	7	12	100.00	8.61
2	A.K.Singh	G.D.Hospital and Diabetes Institute, Kolkata	10	882	88.20	9	2	20.00	8.40
3	A.Misra	Diabetes Foundation India, New Delhi	13	953	73.31	3	4	30.77	6.98
4	Y.S.Malik	IVRI – Bareilly	27	1292	47.85	13	21	77.78	4.56
5	M.I.Yatoo	Sher-e-Kashmir University of Agricultural S&T of Kashmir	10	443	44.30	8	9	90.00	4.22
6	K. Dhama	IVRI – Bareiilly	63	2606	41.37	18	47	74.60	3.94
7	R. Tiwari	IVERI – Bareilly	35	1438	41.09	16	28	80.00	3.91

TP=Total papers; TC=Total citations; CPP=Citations per paper; ICP=International collaborative papers; HI=*h*-Index; RCI=Relative citation index

Figure 4: 'Animal Models of Covid-19' research in India - Networks of Collaborating Authors.

Figure 6: Word Cloud for Title Analysis.

Figure 5: Three fields Plot of the Journals analysis: (Left field: Journals; Middle field: Titles; Right field: Authors).

In all, a total of 869 authors from 496 organizations contributed to research in India. The top 25 organizations and authors together contributed 42.08% and 16.03% share respectively and received 53.84% and 8.97% share in citations respectively. The top three most productive organizations are -- AIIMS- New Delhi (118 papers), PGIMER – Chandigarh (115 papers), and IVRI-Bareilly (68papers). The top three most cited organizations are -- U.P.Pandit Deen Dayal Upadhayaya Pashu Chiksa Vigyan Vishwaavidalaya Evam Go Anusandhan (44.83 and 4.27), College of Veterinary Science, Mathura (39.92 and 3.8), IVRI- Bareilly (39.66 and 3.78). The most productive India's authors are K. Dhama (IVRI – Bareiilly)(63 papers), R. Tiwari (IVRI – Bareilly)(35papers), and Y.S.Malik (IVRI – Bareilly)(27 papers). The most cited authors are H.Harapan (IVRI – Bareilly)(90.42 and 8.61), A.K.Singh (G.D.Hospital and Diabetes Institute, Kolkata)(88.2 and 8.4), and A.Misra (Diabetes Foundation India, New Delhi) (73.31 and 6.98). The top three most productive journals in the subject are *International Journal of Research in*

Pharmaceutical Sciences (72 papers), *Indian Journal of Medical Research* (56 papers), *and Diabetes and Metabolic Syndromes. Clinical Research and Review* (50 papers). The most cited journals are -- *Indian Journal of Pediatrics* (78.67), *Journal of Biomolecuar Structure and Dynamics* (51.3), *and Science of the Total Environment* (37.71).

CONCLUSION

Biomedical studies involving animal models have greatly contributed to the public health response to SARS-CoV-2 by assisting in the development of Covid-19 vaccines and treatments. Animal studies will continue to provide vital information as new SARS-CoV-2 variants emerge and new questions arise as to the transmissibility of these variants, whether they are more harmful to people, and if they remain sensitive to available vaccines. Animal models play a critical role in pandemic response efforts as they are necessary for evaluating the safety and effectiveness of new vaccines and therapeutics. Scientists will continue building on the lessons learned from Covid-19 to develop animal models as part of our pandemic preparedness efforts to target other emerging or re-emerging infectious diseases.

The current Covid-19 crisis highlights the reality that animal research remains essential to find solutions for human and animal health in relation to many different disorders. In the case of Covid-19, and the virus that causes it, SARS-CoV-2, the indispensability of animal research is clear. The interaction between Covid-19 and other diseases that may increase risk for death (including diabetes and heart disease) cannot be investigated in organoids. An organoid cannot model the immune system or inter-organ metabolic homeostasis mediated by, for example, hormones, neural networks and gut microbiota,[6] let alone behavior and cognition. Additionally, although adaptive immunity to SARS-CoV-2 can be predicted by a variety of *in vitro* methods, it can only be validated in animals. This is essential for vaccine development.

Finally It is suggested that governments amd policy makers should realize that animal studies are an indispensable part of fundamental and applied research in Covid-19 and also essential for the development of new medical treatments. Rigorous research and development through extensive government and non-government funding for animal research remains necessary to secure our future health.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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