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Pro-Metrics

RESEARCH ARTICLE

COVID-19 associated mucormycosis: A bibliometric analysis of Indian research based on Scopus

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ABSTRACT

Objective. Invasive fungal infections, specifically mucormycosis, showed a massive surge during the COVID-19 pandemic, forcing the global medical fraternity to research this highly fatal co-infection. India has contributed significantly to COVID-19-associated mucormycosis (CAM) research, but a bibliometric analysis of this research topic is scarce. Using established bibliometric methods, we aimed to provide the yield and impact of CAM research in India.

Design/Methodology/Approach. The publication data on CAM was extracted from Scopus. Data was analyzed using quality indices such as citations per paper (CPP), relative citation index (RCI), and total linkage strength (TLS).

Results/Discussion. India contributed 640 (61.2%) to 1045 global publications on CAM research involving 548 authors from 247 organizations. Only 62 (9.8%) and 96 (15.0%) publications were funded and collaborative. The CAM research was focused on clinical features (36.5%), complications (21.7%), risk factors (19.2%), epidemiology (12.3%), diagnostics and imaging (6.8%), treatment outcomes (4.5%), prognosis (3.4%) and pathophysiology (3.1%). The average CPP of Indian publications was 7.8 compared to 28.2 CPP in France, 17.8 CPP in the USA, 8.7 CPP in Saudi Arabia, 8.3 CPP in Bangladesh, and 8.1 CPP in Iran. The major collaborations were with the USA, Bangladesh, Saudi Arabia, the UK, Pakistan, Malaysia, and UAE. The most productive organizations were PGIMER-Chandigarh (n=47), AIIMS-New Delhi (n=44), and AIIIMS-Jodhpur (n=17), whereas the most impactful organizations were SMS Medical College, Jaipur, SGPGIMS, Lucknow and BJ Medical College, Ahmedabad. The most productive authors were A. Chakrabarti, V. Muthu, and R. Agarwal, and the most impactful were I.S. Sehgal, R. Agarwal, and V. Muthu. The most preferred journals were the Indian Journal of Ophthalmology, the Indian Journal of Otolaryngology and Head & Neck Surgery, and BMJ Case Reports.

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Conclusions. Even though India is the topmost contributor to global CAM research, the quality of its publications is lower than those from France and the USA. The CAM research is largely non-funded. There is a need to improve international collaboration and increase focus on pathophysiology, epidemiology, and pediatric aspects. This may lead to an improved understanding of CAM and increase survival in affected patients.

Keywords: Covid-19; invasive fungal infections; mucormycosis; Covid-19-associated mucormycosis; bibliometrics.

INTRODUCTION

The COVID-19 pandemic has been the most devastating threat to humankind in recent history (Mohamadi *et al.,* 2022). The pandemic has adversely affected the healthcare systems worldwide, especially in developing economies, resulting in almost seven million deaths since it began in 2019 (Worldometer, 2023; Dayal *et al.,* 2020). The mortality due to COVID-19 is exceptionally high in individuals with preexisting comorbidities such as obesity, diabetes, and other illnesses (Alhasan *et al.,* 2021). Additionally, co-infections and super-infections by various pathogens increase the mortality risk in COVID-19 patients (Scendoni *et al.,* 2023). Of the various infections that occur in COVID-19 patients, invasive fungi such as Aspergillosis and Mucormycosis are amongst the most frequent pathogens, comprising about one-fourth of all infections and resulting in several-folds increase in morbidity and mortality (Alhasan *et al.,* 2021; Scendoni *et al.,* 2023). These invasive fungi were more commonly found in COVID-19 patients belonging to low- or low-middle-income countries, a trend like the pre-pandemic times (Amin *et al.,* 2021; Dayal *et al.,* 2015; Prakash and Chakrabarti, 2019). In particular, COVID-19-associated mucormycosis (CAM) posed an enormous challenge in management during the pandemic (Yasmin *et al.,* 2019).

It is well known that the optimum management of CAM involves an early diagnosis, surgical debridement of the affected tissues, antifungal therapy, and adequate control of the predisposing illness (Yasmin et al, 2019; Dayal, 2016; Dayal and Bakshi, 2016). Diagnostic delays are expected in CAM due to the non-specificity of initial symptoms and signs (Yasmin *et al.,* 2019). In addition, it is often challenging to perform surgeries during the pandemic. In a recent report, only about 50% of CAM patients could undergo surgical debridement (Choksi *et al.,* 2022). Adequate control of the predisposing immunocompromised state in COVID-19 requires the withdrawal of immunomodulatory therapy, which is otherwise essential for controlling the inflammation in these patients (Sen *et al.,* 2021). For a better outcome, all these challenges in managing CAM must be surmounted through further research. For example, several authors have suggested researching newer regimens of corticosteroids, immunosuppressants, and antibiotics with lesser doses and duration (Yasmin *et al.,* 2021; Choksi *et al.,* 2022; Sen, 2021). The regional differences in the epidemiology of CAM also need to be studied further (Muthu *et al.,* 2021).

Describing and quantifying previously conducted research is essential to guide further research. Such an assessment is often done through bibliometric analysis of published research that helps to identify knowledge gaps and allows researchers to focus on areas that need more attention than others (Cooper, 2015). In addition, the bibliometric studies help identify researchers and organizations with a common interest, which is vital for developing collaborations that are more likely to yield impactful research (Gupta and Dayal, 2020; Dayal *et al.,* 2022; Dayal *et al.,* 2022). Hence, a bibliometric mapping of CAM research published so far is essential to guide future research. However, the available bibliometric literature on CAM research is scarce. Previous bibliometric assessments of mucormycosis research involved either pre-COVID time span or before the highest surge in CAM infections during the COVID-19 peak (Gupta, Mamdapur and Dayal, 2021; Gupta *et al.,* 2021; Sivankalai and Sivasekaran, 2021). Other bibliometric studies that included the CAM surge period appear to have provided analyses of fewer publications than expected of an intensely researched topic like CAM (Mallikarjun, 2021; Sharma and Dubey, 2021). Two other assessments that

analyzed publications on mucormycosis before and during the COVID-19 pandemic did not separately analyze the details of the Indian contribution to global research on CAM (Dayal, Gupta, and Kappi, 2022; Ram, Sharma, and Rai, 2023). We, therefore, aimed to provide a comprehensive bibliometric analysis of Indian research on CAM using the Scopus database.

Objective

We aimed to examine Indian publications on CAM as indexed in the Scopus database since the onset of the COVID-19 pandemic until May 5, 2023. The study focused on the analysis of characteristics and trends of research by overall growth and research quality, collaborations and funding, identifying the leading organizations, authors, and journals, distribution of publications by subject categories, keywords and type of CAM, and bibliographic features of highly-cited papers (HCP).

MATERIAL AND METHODS

The Indian publications on CAM research were identified and downloaded from the Scopus database (http://www.scopus.com), using a pre-defined search strategy similar to our previous bibliometric studies (Dayal *et al.,* 2021a,b). The following search string was used:

TITLE-ABS-KEY ("COVID 19" OR "2019 novel coronavirus" OR "coronavirus 2019" OR "SARS-CoV-2" OR "SARS-CoV 2" OR "coronavirus disease 2019" OR "2019-novel CoV" OR "2019 ncov" OR "COVID 2019" 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 "Novel Coronavirus") AND (LIMIT-TO (AFFILCOUNTRY, "India")) AND (LIMIT-TO (EXACTKEYWORD, "Mucormycosis"), wherein keywords related to COVID-19 and Mucormycosis were searched in Title and Keywords fields. The search was limited to India using the affiliation field. The data were further evaluated using analytical provisions of Scopus. Several quantitative and qualitative indicators were used to describe the output of CAM research in India. We used the complete counting method wherein each author or organization of multi-author publications was fully counted. The challenge of synonyms or homonyms in authors' names was overcome using other specific fields, such as affiliations. The quality of publications was assessed by indices such as citations per paper (CPP) and relative citation index (RCI). The CPP was obtained by dividing the total citations by the number of publications. The RCI was calculated by dividing the number of citations received by any publication by the average citations usually received by an article in the same field and then benchmarking that number against the median RCI for all papers. We also determined the two standard weight attributes, i.e., links and total link strength (TLS). These indicate the number of links of an item with other items and the total strength of the links of an item with other items. In the case of authors, the TLS attribute indicates the total strength of the co-authorship links of a given researcher with other researchers. All publications that had received more than 100 citations were considered HCP. The citations were counted from publication until May 5, 2023.

Ethical considerations

Our study involved secondary data, which does not require approval from the ethics committees for research on humans. However, all ethical principles recommended for such analysis were followed by respecting ideas, citations, and referencing authors and publications appropriately.

RESULTS

Indian vis-à-vis global output

The Scopus database lists 1045 publications on CAM since the onset of the COVID-19 pandemic until May 5, 2023. These publications registered 8867 citations, averaging 8.4 CPP. Eighty-five countries participated in global research on CAM, of which 15 countries contributed 1-10 papers each, 17 countries 11-50 papers each, two countries 61-98 papers each, and one country 640 papers. The top 12 countries contributed 15 to 640 papers each (average 85.5) and together accounted for 1030 (98.5%) publications (Table 1). The two countries that showed greater than average productivity were

India (640 papers, 61.2% share) and the USA (98 papers, 9.4% share). Top countries' average CPP and RCI were 8.8 and 1.0, and only three countries registered more than this average impact. These were France (28.2 and 3.3), the USA (17.8 and 2.1), and Australia (12.5 and 1.4).

No.	Country	TP	TC	CPP	RCI	ICP	%ICP	TLS
1	India	640	5027	7.8	0.9	97	15.1	177
2	USA*	98	1747	17.8	2.1	53	54.0	96
3	Iran	61	496	8.1	0.9	12	19.6	22
4	Egypt	38	230	6.0	0.7	15	39.4	26
5	Pakistan	36	132	3.6	0.4	18	50.0	53
6	United Kingdom	34	151	4.4	0.5	23	67.6	41
7	Bangladesh	28	233	8.3	0.9	16	57.1	45
8	Saudi Arabia	23	201	8.7	1.0	22	95.6	51
9	France*	21	594	28.2	3.3	9	42.8	24
10	Turkey	18	105	5.8	0.6	5	27.7	10
11	Russia	18	47	2.6	0.3	5	27.7	17
12	Australia*	15	188	12.5	1.4	12	80.0	28
Total of 12 countries		**1030**	**9151**	**8.8**	**1.0**	**287**	**27.8**	**590**
Global total		**1045**	**8867**	**8.4**	**1.0**			

Table 1. The productivity and impact of the top 12 countries in COVID-associated mucormycosis research. Abbreviations: TP= total publications; TC= total citations; CPP= citations per paper; ICP= international collaborative papers; RCI= relative citation index; TLS= total link strength. * More impactful than other countries.

Outline of Indian publications

India reported 640 publications on CAM: 2 in 2020, 210 in 2021, 350 in 2022, and 78 in 2023 till May 5. These received 5056 citations, averaging 7.9 CPP, slightly less than the global average of 8.4. Only 63 (9.8%) publications were funded and received 504 citations, averaging 6.0 CPP. The primary funding agencies were *AIIMS-New Delhi, Department of Science & Technology, India* and *Science & Engineering Board* (6 papers each), *Hyderabad Eye Research Foundation* (5 papers), *BHU-Varanasi, PGIMER-Chandigarh, Meso Scale Diagnostics* and *ICMR* (3 papers each). Ninety-six (15.0%) publications involved international collaboration and together registered 934 citations, averaging 9.7 CPP. These international collaborative papers (ICPs) involved the USA (25 papers, 26.0% share) followed by Bangladesh (14 papers, 14.5%), Saudi Arabia, and the UK (13 papers, 13.5% each), Pakistan (12 papers, 12.5%), Malaysia (8 papers, 8.3%, and the UAE (7 papers, 7.2%).

The distribution of publications by the age groups studied was as follows: adults (34.6%), middle-aged (22.5%), elderly (15.5%), and children & adolescents (4.5%). The research topics were clinical studies (36.5%), complications (21.7%), risk factors (19.2%), epidemiology (12.3%), diagnostics & imaging (6.8%), treatment outcomes (4.5%), prognosis (3.4%) and pathophysiology (3.1%). According to the type of CAM, rhino-orbital-cerebral constituted the largest share of 19.1%, followed by renal (2.9%), pulmonary (2.3%), and cutaneous (0.9%), respectively. The most studied risk factor was diabetes mellitus (35.3% publications), followed by corticosteroid therapy (12.0%), diabetic ketoacidosis (5.4%), immunocompromised host (3.7%), chronic kidney disease (3.5%), hemodialysis (2.3%) and neutropenia (2.0%). The publication types were journal articles (631, 98.5%) and books or book series (9, 1.5%). The journal publications were articles (n=392), reviews (n=128), letters (n=60), notes (n=26), editorials (n=13), conference papers (n=10), and short surveys (n=8). We identified several keywords that illustrate the focus and trends in CAM research in India (Table 2).

No.	Keyword	Occurrence frequency	No.	Keyword	Occurrence frequency
1	Mucormycosis	640	33	Headache	33
2	Covid-19	574	34	Fungal Sinusitis	34
3	Diabetes Mellitus	202	35	Fungal Hyphae	32
4	Amphotericin B	152	36	Exophthalmos	31
5	Steroids	127	37	Ferritin	31
6	Amphotericin B Lipid Complex	86	38	Fungal Eye Infection	31
7	Orbit Disease	74	39	Orbital Exoneration	29
8	Antifungal Therapy	69	40	Voriconazole	29
9	Mucorales	69	41	Face Pain	27
10	Corticosteroids	68	42	Hypertension	27
11	Surgical Debridement	68	43	Maxillary Sinus	27
12	Dexamethasone	61	44	Sinusitis	27
13	Comorbidity	56	45	C-Reactive Protein	26
14	Hyperglycemia	54	46	Orbit Infection	26
15	Remdesivir	53	47	Ophthalmoplegia	25
16	Black Fungus	50	48	Ptosis (Eyelid)	25
17	Oxygen Therapy	45	49	Systematic Mycosis	25
18	Hospitalization	44	50	Corticosteroid Therapy	24
19	Methylprednisolone	44	51	Endoscopic Sinus Surgery	24
20	Paranasal Sinus	44	52	Insulin	24
21	Immunosuppressive Treatment	43	53	Immunocompromised Patients	24
22	Dyspnea	41	54	Chronic Kidney Failure	23
23	ICU	41	55	Brain Infection	22
24	Artificial Ventilation	40	56	Rhizopus	22
25	Hemoglobin A1c	39	57	Steroid Therapy	22
26	Tocilizumab	39	58	Vaccination	22
27	Rhizopus oryzae	38	59	Amphotericin B Deoxycholate	21
28	Isavuconazole	37	60	Ethmoid Sinus	21
29	Mycosis	37	61	Aspergillus	20
30	Aspergillosis	36	62	Glucocorticoid	19
31	Antibiotic Agents	35	63	Ground Glass Opacity	19
32	Diabetic Ketoacidosis	35	64	Endoscopic Sinus Surgery	24

Table 2. List of top significant keywords.

Profile of research organizations

Of the 247 Indian organizations that participated in CAM research, 207 contributed 1-5 papers each, 33 organizations 6-10 papers each, and seven organizations 11-47 papers each. The top 20 organizations contributed 8 to 47 papers each (average 13.4) and collectively contributed 268 papers that received 2227 citations, constituting 41.8% and 44.0% share of India's total publications and citations. The three organizations that contributed publications above their group average were *PGIMER-Chandigarh* (47 papers), *AIIMS-New Delhi* (44 papers), and *AIIIMS-Jodhpur* (17 papers). Six organizations registered CPP and RCI above their group average: *SMS Medical College, Jaipur* (25.5 and 3.2), *Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow* (24.3 and 3.0), *BJ Medical College, Ahmedabad* (23.0 and 2.9), *PGIMER, Chandigarh* (21.0 and 2.6), *L.V. Prasad Eye Institute, Hyderabad* (9.5 and 1.2) and *Kasturba Medical College, Manipal* (8.6 and 1.0). In terms of TLS, the largest (n=177) was shown by *PGIMER, Chandigarh,* followed by *AIIMS, New Delhi* (n=114), *Deenanath Mangeshkar Hospital*

& Research Centre, Pune (N=62), *Saveetha Institute of Medical & Technical Sciences* (n=54), *Saveetha Dental College & Hospital* (n=52) and *AIIMS, Patna* (n=50). The bilateral collaborative linkages among the top 20 organizations varied from 1 to 8, with the highest linkages (n=8) represented by institutional pair *"Saveetha Dental College and Hospital* and *Saveetha Institute of Medical and Technical Sciences,"* followed by *"PGIMER, Chandigarh* and *AIIMS, New Delhi"* and *"MAHE-Manipal* and *KMC, Manipal"* (n=5 each). (Table 3).

No.	Organization	TP	TC	CPP	RCI	ICP	%ICP	TLS
1	Postgraduate Institute of Medical Education & Research (PGIMER), Chandigarh*	47	988	21.0	2.6	6	12.7	177
2	All India Institute of Medical Sciences (AIIMS), New Delhi	44	50	1.1	0.1	3	6.8	114
3	AIIMS, Jodhpur	17	38	2.2	0.2	1	5.8	31
4	King George's Medical University, Lucknow	13	23	1.7	0.2	1	7.6	32
5	Maulana Azad Medical College, Delhi	12	42	3.5	0.4	0	0.0	12
6	Datta Meghe Institute of Higher Education & Research	12	12	1.0	0.1	0	0.0	2
7	Saveetha Institute of Medical & Technical Sciences	12	55	4.5	0.5	7	58.3	54
8	Manipal Academy of Higher Education	10	51	5.1	0.6	1	10.0	23
9	Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow*	10	243	24.3	3.0	1	10.0	39
10	Saveetha Dental College & Hospital	10	70	7.0	0.8	6	60.0	52
11	L.V. Prasad Eye Institute, Hyderabad*	9	86	9.5	1.2	1	11.1	32
12	SMS Medical College, Jaipur*	8	204	25.5	3.2	0	0.0	38
13	Dr. Ram Manohar Lohia Hospital, New Delhi	8	7	0.8	0.1	0	0.0	9
14	Kasturba Medical College, Manipal*	8	69	8.6	1.0	2	25.0	39
15	Banaras Hindu University, Varanasi	8	20	2.5	0.3	3	37.5	17
16	Aligarh Muslim University	8	29	3.6	0.4	3	37.5	42
17	Deenanath Mangeshkar Hospital & Research Centre, Pune	8	39	4.8	0.6	0	0.0	62
18	BJ Medical College, Ahmedabad*	8	184	23.0	2.9	2	25.0	26
19	AIIMS, Raipur	8	10	1.2	0.1	1	12.5	18
20	AIIMS, Patna	8	7	0.8	0.1	2	25.0	50
	Total of 20 organizations	**268**	**2227**	**8.3**	**1.0**	**40**	**14.9**	**869**
	India's total	**640**	**5056**	**7.9**	**1.0**			

Table 3. Top 20 Indian organizations in CAM research. Abbreviations: TP= total publications; TC= total citations; CPP= citations per paper; ICP= international collaborative papers; RCI= relative citation index; TLS= total link strength. * More impactful than others.

Leading authors

A total of 548 authors participated in India's CAM research, of which 527 authors contributed one paper each, 16 authors 6-10 papers each, and five authors 11-20 papers each. The top 20 authors contributed 175 papers (average 8.7 papers) and 4210 citations, constituting 27.3% and 83.2% share of total publications and citations. Seven authors contributed publications above their group average: *A. Chakrabarti* (n=20), *V. Muthu* (n=15), *R. Agarwal* (14), *S. M. Rudramurthy* (n= 13), *A. Thakar* (n=11), *R. Meher* and *A. Goyal* (n=9 each). Eight authors registered CPP and RCI above their group average of 24.0 and 3.0: *I. S. Sehgal* (81.1 and 10.2), *R. Agarwal* (47.5 and 6.0), *V. Muthu* (47.5 and 6.0), *H. Kaur* (44.0 and 5.5), *I. Xess* (39.8 and 5.0), *G. Singh* (39.8 and 5.0), *A. Chakrabarti* (38.2 and 4.8), and *S. M. Rudramurthy* (33.0 and 4.1). (Table 4). The bilateral collaborative linkages among the top 20 authors varied from 1 to 13, with the highest TLS (n=13) depicted by author pairs *"V. Muthu* and *R. Agarwal,"* followed by *"A. Chakrabarti* and *V. Muthu"* and *"A. Chakrabarti* and *S. M. Rudramurthy"* (n=12 each), *"A. Chakrabarti* and *R. Agarwal"* (n=10). *"S. M. Rudramurthy* and *V. Muthu," "R. Meher* and *R. Goel"* and *"R. Meher* and *J. Kumar"* (n=8 each).

No.	Author	Affiliation	TP	TC	CPP	RCI	TLS
1	A. Chakrabarti*	PGIMER-Chandigarh	20	764	38.2	4.8	161
2	V. Muthu*	PGIMER-Chandigarh	15	713	47.5	6.0	152
3	R. Agarwal*	PGIMER-Chandigarh	13	618	47.5	6.0	147
4	S. M. Rudramurthy*	PGIMER-Chandigarh	13	429	33.0	4.1	131
5	A. Thakar	AIIMS-New Delhi	11	50	4.5	0.5	122
6	R. Meher	MAMC-Delhi	9	37	4.1	0.5	77
7	A. Goyal	AIIMS-Jodhpur	9	28	3.1	0.3	161
8	J. Kumar	MAMC-Delhi	8	37	4.6	0.5	75
9	R. Goel	MAMC-Delhi	8	35	4.3	0.5	74
10	N. Wig	AIIMS-New Delhi	7	51	7.2	0.9	94
11	K. Soni	AIIMS-Jodhpur	7	25	3.5	0.4	157
12	K. Sikka	AIIMS-New Delhi	7	8	1.1	0.1	57
13	H. Kaur*	PGIMER-Chandigarh	7	308	44.0	5.5	56
14	I. Xess*	AIIMS-New Delhi	6	239	39.8	5.0	151
15	G. Singh*	AIIMS-New Delhi	6	239	39.8	5.0	146
16	I. S. Sehgal*	PGIMER-Chandigarh	6	487	81.1	10.2	77
17	H. S. Meshram	IKDRC-ITS, Ahmedabad	6	49	8.1	1.0	42
18	K. S. Malhotra	KGMU-Lucknow	6	22	3.6	0.4	113
19	T. V. Dave	LV Prasad Eye Institute-Hyderabad	6	57	9.5	1.2	29
20	V. Sharma	AIIMS-Jodhpur	5	14	2.8	0.3	127
Total of the top 20 authors			**175**	**4210**	**24.0**	**3.0**	**2149**
India's total			**640**	**5056**	**7.9**	**1.0**	

Table 4. The most productive and impactful authors in Indian CAM research. Abbreviations: TP= total publications; TC= total citations; CPP= citations per paper; ICP= international collaborative papers; RCI= relative citation index; TLS= total link strength. * More impactful than others.

Top journals

The top 20 of the 203 journals published 214 papers, constituting a 33.9% share of Indian CAM research. Table 5 shows the list of the most prolific and impactful journals.

Bibliometric features of high-cited publications

Only 13 (2.0%) publications were HCPs. Their total and average citations were 2288 and 176.0, respectively. Seven HCPs were published as original articles, two as reviews and letters, and one as a conference paper and editorial. Seven HCPs involved collaborative research; six of these were national and one international collaborative. The HCPs were published in 9 journals; the *Indian Journal of Ophthalmology* was the leading journal that published five HCPs, followed by one paper each by *BMJ Case Reports, Diabetes & Metabolic Syndromes. Research & Clinical Reviews, Emerging Infectious Disease, Journal of Laryngology & Otology, Journal of Maxillofacial & Oral Surgery, The Lancet Respiratory Medicine, Mycopathologia,* and *Mycoses.*

DISCUSSION AND FINAL CONSIDERATIONS

COVID-19-related mucormycosis was reported in many countries, but the research activities were mainly concentrated in low-and middle-income countries. This is perplexing as high-income countries are known to dominate the research landscape in any medical field (Gupta and Dayal, 2020; Dayal *et al.,* 2022a,b). A possible explanation for this paradox is that low-middle-income countries were severely affected by the dual burden of COVID-19 and CAM due to several factors that predispose patients to fungal infections (Amin *et al.,* 2021;

No.	Journal	TP	TC	CPP
1	Indian Journal of Ophthalmology*	45	987	21.9
2	Indian Journal of Otolaryngology and Head & Neck Surgery	35	132	3.7
3	BMJ Case Reports	14	151	10.7
4	Mycoses*	12	309	25.7
5	Journal of the Association of Physicians of India	9	4	0.4
6	Journal of Laryngology and Otology*	9	191	21.2
7	Indian Journal of Critical Care Medicine	9	12	1.3
8	Egyptian Journal of Radiology & Nuclear Medicine	9	17	1.8
9	Journal of Medical Mycology	8	34	4.2
10	QJM	7	52	7.4
11	Indian Journal of Pharmacology	7	33	4.7
12	European Archives of Oto Rhino Laryngology	7	21	3.0
13	Diabetes & Metabolic Syndrome. Clinical Research & Review*	7	490	70.0
14	Pan African Medical Journal	6	14	2.3
15	Mycopathologia*	5	354	70.8
16	Journal of Oral & Maxillofacial Pathology	5	0	0.0
17	Journal of Dutta Meghe Institute of Medical Science University	5	0	0.0
18	Indian Journal of Radiology & Imaging	5	2	0.4
19	Indian Journal of Medical Microbiology	5	58	11.6
20	Indian Journal of Anaesthesia	5	21	4.2
	Total of the top 20 journals	**214**	**2882**	**13.4**
	India's total journal papers	**631**		
	Share of top 20 journals in India's total journal papers	**33.9**		

Table 5. Bibliometric profile of the top 20 journals in CAM research. Abbreviations: TP= total publications; TC= total citations; CPP= citations per paper. * More impactful than others.

Prakash and Chakrabarti, 2019). But even though low-and middle-income countries were more productive, high-income countries such as Australia, France, and the USA led in research impact. Organizations and authors from high-income countries usually produce high-quality research due to several factors, such as the availability of infrastructure and financial support, collaborations, and commitment to research by the national governments (Moses *et al.,* 2015). On the other hand, the lack of research infrastructure and funding in low-income countries leads to low research quality even when it emanates from top organizations (Lakhotia, 2018; Devidayal *et al.,* 2013; Dayal *et al.,* 2015). In this context, high-income countries must support research endeavors in low-and middle-income countries that may lead to meaningful universal research in CAM, similar to research capacity-building initiatives for non-communicable illnesses (Haregu *et al.,* 2019).

Regarding India's contribution to global CAM research, the quantity of publications was not matched by quality. Even though India achieved the highest rank, the CPP was lower than the global average and almost one-fourth of the most impactful country. Surprisingly, the CPP of even the funded publications was lower than others. It is well known that funded research is more impactful (Heyard and Hottenrott, 2021). Our previous analysis showed a significantly higher CPP of funded compared to non-funded publications (77.2 versus 18.6)

(Gupta, *et al.,* 2021). Another reason for the lower impact of Indian CAM research could be the lack of significant collaborations with others. Only 15% of Indian publications were ICPs, generating higher CPP than non-collaborative research.

Publications on CAM epidemiology and pathophysiology constituted about 15% of all publications. These aspects of CAM are crucial to study for improving our understanding of the complex relationship between mucormycosis and COVID-19 (Al-Tawfiq *et al.,* 2021). Additionally, more research is required on children and adolescents due to the almost equal risk of CAM compared to adults and increased mortality and morbidity in those with co-morbid conditions (Saied, Metwally, and Dhama, 2021; Dayal, 2020).

India is the topmost contributor to global CAM research. However, the impact of its publications is lower than those from France and the USA. The CAM research is largely non-funded. There is a need to improve international collaboration and increase focus on pathophysiology, epidemiology, and pediatric aspects. This may lead to an improved understanding of CAM and increase survival in affected patients.

A limitation of our bibliometric analysis was using a single database, which could have led to missing some CAM publications and citations. Some authors have suggested a simultaneous search in Web of Science, PubMed, and Scopus to improve research mapping. However, such an approach may result in difficulties interpreting results owing to non-uniformity in analytical provisions across different databases (Kokol and Vošner, 2018). Notably, most bibliometric studies use a single database, and we chose Scopus due to its broader content, coverage, accuracy, availability of funding information, and citation analysis tools (Baas *et al.,* 2020).

Contribution statement

Conceptualization: Devi Dayal and B. M. Gupta.

Data Curation and visualization: Yogendra Singh and Jivesh Bansal.

Investigation, methodology, writing-original draft, and project administration: Devi Dayal and B. M. Gupta

Writing and editing the manuscript: Devi Dayal 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.

REFERENCES

Al-Tawfiq JA, Alhumaid S, Alshukairi AN, Temsah MH, Barry M, Al Mutair A, *et al.* (2021). COVID-19 and mucormycosis superinfection: the perfect storm. Infection, 49(5), 833-853.

Alhasan KA, Shalaby MA, Temsah MH, Aljamaan F, Shagal R, Al-Faadhel, T, *et al.* (2021). Factors That Influence Mortality in Critically Ill Patients with SARS-CoV-2 Infection: A Multicenter Study in the Kingdom of Saudi Arabia. Healthcare (Basel), 9(12), 1608.

Amin A, Vartanian A, Poladian N, Voloshko A, Yegiazaryan A, Al-Kassir AL, *et al.* (2021). Root causes of fungal Coinfections in COVID-19 infected patients. Infect Dis Rep., 13(4), 1018-1035.

Baas J, Schotten M, Plume A, Côté G, Karimi R. (2020). Scopus as a curated, high quality bibliometric data source for academic research in quantitative science studies. Quant Sci Stud., 1(1), 377-386.

Choksi T, Agrawal A, Date P, Rathod D, Gharat A, Ingole A, Chaudhari B, Pawar N. (2022). Cumulative Mortality and Factors Associated With Outcomes of Mucormycosis After COVID-19 at a Multispecialty Tertiary Care Center in India. JAMA Ophthalmol., 140(1), 66-72.

Cooper ID. (2015). Bibliometrics basics. J Med Libr Assoc., 103(4), 217-218

Dayal D. (2016). A multimodal approach is necessary to manage mucormycosis in patients with diabetes. J Clin Diagn Res., 10(9), SL01.

Dayal D. (2020). We urgently need guidelines for managing COVID-19 in children with comorbidities. Acta Paediatr., 109(7), 1497-1498

Dayal D, Bakshi J. (2016). Early diagnosis and surgery is crucial to survival outcome in rhinocerebral mucormycosis. Indian J Otolaryngol Head Neck Surg., 68(2), 261-262.

Dayal D, Bansal M, Bansal J, Gupta BM. (2022). Childhood Obesity: Scientometric Mapping of Indian Research during the Last Two Decades. Int J Med Public Health, 12(4), 180-185

Dayal D, Gupta BM, Bansal M, Nanda PM. (2021). Covid-19 and thyroid: A Scopus-based bibliometric assessment of research output. J Young Pharm., 13(3s), s84-88.

Dayal D, Gupta BM, Surulinathi M, Nanda PM. (2021). Covid-19 and Vitamin D deficiency: A Scientometric assessment of global publications during 2020-21. J Young Pharm., 13(3s), s89-94.

Dayal D, Gupta BM, Surulinathi M, Nanda PM. (2021). Covid-19 and Type 1 Diabetes: A Scientometric Assessment of Global Publications based on the Scopus Database. J Young Pharm., 13(3s), s95-s100.

Dayal D, Gupta BM, Mamdapur GM, Rohilla L, Nanda PM. (2022). Stem cell therapy for type 1 diabetes: a scientometric assessment of global research during the twenty-first century. J Diabetes Metab Disord., 21(2), 1679-1687.

Dayal D, Gupta BM, Kappi M. (2022). Scientometric Mapping of Mucormycosis Research in Relation to The COVID-19 Pandemic. Int J Med Public Health, 12(2), 50-55

Dayal D, Gupta S, Raithatha D, Jayashree M. (2020). Missing during COVID-19 lockdown: Children with onset of type 1 diabetes. Acta Paediatr., 109(10), 2144-2146

Dayal D, Jain P, Kumar R, Bakshi J, Menon P, Das A, *et al*. (2015). Clinical spectrum and outcome of invasive filamentous fungal infections in children with Type 1 diabetes: North Indian experience. Clin Pediatr Endocrinol., 24(2), 51-57.

Devidayal, Singh MK, Sachdeva N, Singhi S, Attri SV, Jayashree M, Bhalla AK. (2013). Vitamin D levels during and after resolution of ketoacidosis in children with new onset Type 1 diabetes. Diabet Med., 30(7), 829-834.

Dayal D, Saini AG, Jayashree M, Singhi S, Kumar R, Samprati M, *et al*. (2015). Hospital based incidence, patterns of presentation and outcome of type 1 diabetes: 12 years' data from a tertiary care center in North India. Int J Diabetes Dev Ctries., 35, 103-107.

Devidayal, Singh MK, Sachdeva N, Singhi S, Attri SV, Jayashree M, Bhalla AK. (2013). Vitamin D levels during and after resolution of ketoacidosis in children with new onset Type 1 diabetes. Diabet Med., 30(7), 829-834.

Gupta BM, Dayal D. (2020). Pediatric type 1 diabetes research in the 21st century: A scientometric review. Pediatr Endocrinol Diabetes Metab., 26(3), 132-139.

Gupta BM, Mamdapur GM, Dayal D. (2021). Black Fungus (Mucormycosis) Research in India during 1998-2021: A Scopus-based Scientometric Analysis. Int J Med Public Health, 11(3), 133-138.

Gupta BM, Mamdapur GM, Gupta S, Rohilla L, Dayal D. (2021). Global mucormycosis research: A bibliometric assessment based on Scopus database (1998-2021). J Young Pharm., 13(4), 356-362.

Gupta BM, Sikka P, Gupta S, Dayal D. (2021). Indian research in gestational diabetes mellitus during the past three decades: A Scientometric analysis. J Obstet Gynaecol India., 71(3), 254-61.

Haregu TN, Byrnes A, Singh K, Sathish T, Pasricha N, Wickramasinghe K, *et al*. (2019). A scoping review of non-communicable disease research capacity strengthening initiatives in low and middle-income countries. Glob Health Res Policy, 4, 31.

Heyard R, Hottenrott H. (2021). The value of research funding for knowledge creation and dissemination: A study of SNSF Research Grants. Humanit Soc Sci Commun., 8(1), 217.

Kokol P, Vošner HB. (2018). Discrepancies among Scopus, Web of Science, and PubMed coverage of funding information in medical journal articles. J Med Libr Assoc., 106(1), 81-86.

Lakhotia SC. (2018). Research fund crunch, real or created, is hitting India's Academia on the Wrong Side. Proc Indian Natl Sci Acad., 98(3), 545-547.

Mallikarjun K. (2021). Bibliometric Visualisation of Research Performance of Post COVID-19 and Mucormycosis: Where Do We Stand? J Drug Delivery Ther., 11(6), 31-39.

Mohamadi E, Olyaeemanesh A, Takian A, Yaftian F, Kiani MM, Larijani B. (2022). Short and Long-term Impacts of COVID-19

Pandemic on Health Equity: A Comprehensive Review. Med J Islam Repub Iran, 36, 179.

Moses H 3rd, Matheson DH, Cairns-Smith S, George BP, Palisch C, Dorsey ER (2015).. The anatomy of medical research: US and international comparisons. JAMA, 313(2), 174-189.

Muthu V, Rudramurthy SM, Chakrabarti A, Agarwal R. (2021). Epidemiology and Pathophysiology of COVID-19-Associated Mucormycosis: India Versus the Rest of the World. Mycopathologia, 186(6), 739-754.

Prakash H, Chakrabarti A. (2019). Global epidemiology of mucormycosis. J Fungi (Basel), 5(1), 26.

Ram S, Sharma H, Rai AK. (2023). Mucormycosis Research: A global outlook through bibliometric approaches. Iberoam J Sci Meas Comm., 3(1), 1-15.

Saied AA, Metwally AA, Dhama K. (2021). Our children are at risk of COVID-19- associated rhino-orbito-cerebral mucormycosis (ROCM). Ann Med Surg (Lond), 72, 103058.

Scendoni R, Bury E, Lima Arrais Ribeiro I, Cingolani M, Cameriere R, De Benedictis A, *et al.* (2023). Leading Pathogens Involved in Co-Infection and Super-Infection with COVID-19: Forensic Medicine Considerations after a Systematic Review and Meta-Analysis. Pathogens, 12(5), 646.

Sen M, Honavar SG, Bansal R, Sengupta S, Rao R, Kim U, *et al.* (2021). Epidemiology, clinical profile, management, and outcome of COVID-19-associated rhino-orbital-cerebral mucormycosis in 2826 patients in India - Collaborative OPAI-IJO Study on Mucormycosis in COVID-19 (COSMIC), Report 1. Indian J Ophthalmol., 69(7), 1670-1692.

Sharma P, Dubey G. (2021). Publications on post-Covid mucormycosis: A bibliometric study of WHO database. Bangladesh J Med Sci., 20(5), 144-147.

Sivankalai S, Sivasekaran K. (2021). Mucormycosis (Black Fungus) Maiming Covid Patients: Scientometrics analysis through prism of Biblioshiny. Libr Philos Pract., 5546.

Yasmin F, Najeeb H, Naeem A, Dapke K, Phadke R, Asghar MS, *et al.* (2021). COVID-19 associated mucormycosis: A systematic review from diagnostic challenges to management. Diseases, 9(4), 65.

Worldometer. COVID-19 coronavirus death toll; updated June 8, 2023. Available at: https://www.worldometers.info/coronavirus/coronavirus-death-toll