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Original Article

Detection and Management of COVID-19 by Image Processing: A Scientometric Assessment of Global Publications

BM Gupta[1,*], Mallikarjun M Kappi[2], KK Mueen Ahmed[3] and Tarun Bala[4]

ABSTRACT

Background and Aim: Diagnosis of the Covid-19 disease is important to provide the best care to patients and reduce their burden in the health care system. Of late artificial intelligence and machine learning approaches have been playing an important role in image processing for the diagnosis of Covid-19. The aim of this study is to examine the global literature on "Detection and Management of Covid-19 by Image Processing" during 2020-21, using quantitative and qualitative methods and select bibliometric indicators. **Materials and Methods :** A systematic search strategy was developed and performed in Scopus database for "Detection and Management of Covid-19 by Image Processing" using keywords related to "Covid-19" and "Imaging" for identification of studies published up to 10 February 2022. **Results:** In all 2451 global articles were identified on this topic in Scopus database, which consisted of articles (62.55%), conference papers (15.46%) and reviews (8.36%). These together registered 11.77 citations per paper. The 19.95% (489) share of the global output received extra-mural funding support and registered 14.22 citations per paper. Only 2.12% (52) share of the global output are considered high-cited as they have received 100+ citations and registered 294.27 citations per paper. The 2451 global articles originated in 100 countries, with the participation of 1661 organizations and 11755 authors and published in 1088 journals and generated 9233 keyword plus and 3831 author keywords, Although USA (506 papers), China (412 papers) and India (362 papers) were the most productive countries, however, in terms of citation impact (citations per paper and relative citation index) China (27.02 and 2.30), Germany (26.23 and 2.23) and France (23.72 and 2.02) registered the highest citation impact. Although Harvard Medical School, USA (42 papers), Massachusetts General Hospital, USA (36 papers) and Shahid Beheshti University of Medical Sciences, Iran contributed the highest publication productivity; however, Icahn School of Medicine at Mount Sinai, USA (158.44 and 13.46), Sun Yat-Sen University, China (84.0 and 7.14) and Ministry of Education, China (71.78 and 6.10) registered the highest citation impact. Although A. Gholamrenzanezhad (USA) (14 papers), D. Shen (South Korea) (12 papers) and J. Liu (China)(11 papers) contributed the highest productivity, however A. Bernheim (USA) (235.83 and 20.04), N. Sverzellati (Italy)(135.86 and 11.54) and A. Gholamrenzanezhad (USA) (62.07 and 5.27) registered the highest citation impact. Although *Computers in Biology and Medicine* (38 papers), *Academic Radiology* (29 papers) and *Clinical Imaging* (28 papers) published the largest number of papers, however *Radiology* (153.09), *Journal of Infection* (105.75) and *Radiology Cardiothoracic* (64.94) registered the highest citation impact. The top three subjects contributing the largest share of global literature to this field were Medicine (57.36%), Computer Science (35.70%) and Engineering (21.95%). Besides Covid-19, the leading keywords were X-Ray (883), Computer-Assisted Tomography (836), Deep Learning (725), Diagnostic Imaging (692), Convolutional Neural Networks (464), Chest X-ray (398) and Diagnosis (325). **Conclusion:** Several artificial and machine learning models adopted by researchers, policy-makers and healthcare professionals to classify the images related to the diagnosis and management of COVID-19 were observed, which promised outcomes in terms of accuracy, cost, and detection speed. The analysis provide insights of the field, indicates the research trends, identifies the existing gaps and provides a perspective for future research. The need for active collaboration among countries, organizations and authors to improve research quality and impact was suggested.

Keywords: Covid-19, Image Processing, Artificial intelligence, Machine Learning, Global Publications, Bibliometrics, Scientometrics.

BM Gupta[1,*], Mallikarjun M Kappi[2], KK Mueen Ahmed[3] and Tarun Bala[4]

[1]Formerly with CSIR-NISTADS, New Delhi, INDIA.
[2]Government First Grade College, Jagalur, Karnataka, INDIA.
[3]Phcog.Net #17, Cox Town, Bengaluru, Karnataka, INDIA.
[4]C-717 Vikas Puri, New Delhi, INDIA.

***Correspondence**

Dr. BM Gupta
Formerly with CSIR-NISTADS, New Delhi-110 012, INDIA.

Email: bmgupta1@gmail.com

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INTRODUCTION

Coronavirus disease 2019 (Covid-19), which is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), emerged in December 2019 and rapidly developed into a global outbreak, resulting in a massive death toll. Covid-19 presents as an acute respiratory tract infection syndrome

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and is highly infectious. Critically ill patients with Covid-19 have a high mortality rate. By 4 March, 2022, there have been 440,807, 756 confirmed Covid-19 cases, including 5,978, 096 deaths in more than 200 countries reported by WHO.[1,2]

The typical clinical characteristics of Covid-19 cases include fever, respiratory symptoms, pneumonia, decreased white blood cell (WBC) count, and decreased lymphocyte count. The reverse-transcription polymerase chain reaction (RT-PCR) testing is considered as the standard method for screening suspected cases. However, the sensitivity of RT-PCR screening is relatively poor in some situations. Thus, SARS-CoV-2 infection cannot be entirely excluded, even if RT-PCR results from a suspected patient are negative. However, these tests have limitations in terms of accuracy, speed, cost, and supply and require to be replicated many times in some cases to confirm the results. All these aspects indicate that the need for other detection approaches. In this regard, WHO suggested that the medical imaging processing can be utilized for the detection the disease among other methods on October 2020.[3-4]

Medical imaging helps in identifying pathogenesis, the degree of pulmonary damage and the characteristics features in each imaging modality from numerous medical data sources such as chest radiography (Chest X-Ray), computed tomography (CT), ultrasound, magnetic resonance imaging (MRI), nuclear MRI and positron emission tomography (PET/CET). The chest computed tomography (CT), is often used as a complementary examination in the diagnosis and management of Covid-19. Typical imaging characteristics of lung in COVID-19 include lesions with ground-glass opacities (GGO), consolidation, bilateral patchy shadowing, pulmonary fibrosis, multiple lesions and crazy-paving pattern, and so on. These imaging interpretations played a key role not only in the diagnosis of Covid-19, but also in the monitoring of disease progression and the evaluation of therapeutic efficacy.[5]

For image processing for diagnosis Covid-19, current approaches utilized in several studies start from data pre-processing and augmentation, feature extraction (FA), feature selection to classification: (i) Image pre-processing basically aims to enhance the quality of images included in the dataset, (ii) Feature extraction identifies optical features that are present in Covid-19 patients such patchy ground-glass opacities, pneumonic consolidations, reticulonodular opaqueness] with the aid of a suitable approach; (iii) Feature Selection (FS) entails choosing a group of related features of an input image and deleting the less fitting ones, minimizing over fitting, and enhancing accuracy. FS approaches can be categorized into three classes: embedded, filter, and wrapper and (iv) Classification (also called Computer-Aided Diagnosis, CAD), process takes sample images as an input and provides the diagnosis variable as an output. This process aims to locate the disease in the image. The localization process is essential to locate some basic disease features.[4]

Various approaches of artificial intelligence, machine learning, deep learning, data mining and pattern recognition are currently utilized for extracting related features from Covid-19 image data sets,[6-7] thus mimicking expert data interpretation capacities.[8] These approaches transform images on a variety of tasks, like applying artistic filters, tuning an image for optimal quality, or enhancing specific image details to maximize quality for computer vision tasks. Machine learning have architectures, loss function, models and many other approaches that is used to determine and provide better image processing It is usually applied for image enhancement, restoration and morphing.[8] These approaches mainly concentrate on finding solutions and reaching suitable decisions regarding current and emergent problems. In general, disease datasets are pre-processed, segmented, the system is trained, tested, and then new data can be classified.[9]

Bibliometric analysis is widely used as a valid tool to quantitatively evaluate of literature to describe the trends in publications, the contributions and distribution of countries, organizations, authors and journals and information about research co-operations and collaborations and identify hotspots in research using keyword analysis.

In this study, we conducted bibliometric analysis and network visualization to provide a complete overview of the research trends, research domains, publication patterns, emerging topics, and global collaborations in the field of "Detection and management of Covid-19 by Image Processing". In particular it will identify leading countries, institutions, authors, journals and research areas; identify collaboration patterns between countries, organizations and authors; and identify research trends and hotspots. This will be accomplished by analyzing author keywords and high-cited papers.

Literature Review

A considerable number of bibliometric studies[10-16] have been published on utilizing artificial learning, machine learning, deep learning, data mining and pattern recognition approaches for extracting related features from medical image data sets. However, few bibliometric studies have been carried out on detection and management of Covid-19 by image processing techniques. Among them, Tasdelen and Ugur[17] examined global scientific output (5028 global records) on use of artificial intelligence research in Covid-19 pandemic, using publication data from the WoS till October 9, 2021. Islam *et al*.[18] examined 729 Covid-19-related artificial intelligence (AI) publications using WoS database during 2020-21 and provided insights and research directions for researchers, who wish to collaborate in this domain in the future. Abumalloh RA *et al*.[4] reviewed literature on detection and diagnosis of Covid-19 by modalities of medical imaging. They described the related research themes and presented the synthesis of the studies and reveals a conceptual map to elaborate on research themes in the surveyed studies. Jannis Born *et al*.[19] presented a meta-analysis (463 manuscripts) of AI in machine learning (MI) of Covid-19, addressing the utility of AI in imaging for Covid-19 patient care. A significant disparity between clinical and AI communities, in the focus on both imaging modalities (AI experts neglected CT and ultrasound, favoring X-ray) and performed tasks (71.9% of AI papers centered on diagnosis). The majority of manuscripts were found to be deficient regarding potential use in clinical practice, but 2.7% (n = 12) publications were assigned a high maturity level. Rivera-Sotelo *et al*.[20] identified and evaluated the studies (326) that allow us to understand the implications of imaging studies in MRI and PET/CT related to COVID-19 research during 2019-21 Latif *et al*.[21] presented use cases where data science have addressed Covid-19 challenges, provided the details of available datasets and resources and review contributions including image analysis, textual data mining, audio analysis, and embedded sensing. Finally it presented a bibliometric analysis of the Covid-19 related papers

MATERIALS AND METHODS

The study identified, retrieved and downloaded the relevant literature from Scopus database on "Detection and Management of Covid-19 by Image Processing" till 10 February 2022. A search strategy was developed to collect relevant articles and extracted bibliographic information (e.g., country, research area, sources, and author). The search strategy used "Covid-19" and "Image" related keywords in the "Keyword" and "Title" tags. VOSviewer (Leiden University) and Bibliometrix (R package) were used to visualize the co-occurrence networks of authors, sources, countries, institutions, global collaborations, citations, co-citations, and keywords. The VOSviewer application utilizes a unique clustering method that concentrates on the overall number of objects. The clustering

procedure begins with the bibliometric analysis of publications and their assignment to each cluster. As a result, each and every publication is allocated to a cluster. The CiteSpace program highlights trends and significant changes in scientific fields over time. For cluster labelling, it employs latent semantic analysis (LSA), log-likelihood ratio (LLR), and mutual information (MI) algorithms.

RESULTS AND DISCUSSION

Overall Output

In all (2451) (2020=768; 2021=768; 2022=159) publications were indexed in Scopus database on "Detection and Management of Covid-19 by Image Processing" during 2020-22 which received 29949 citations, averaging 11.77 citations per paper. Of the 2451 papers, only 19.95% (489 papers) received extramural funding support from 150+ national and international funding agencies and these 489 papers have received 6952 citations, averaging 14.22 citations per paper. The leading funding agencies supporting research in this area (along with their output) are: National Natural Foundation of China (108 papers), National Institute of Health (63 papers), National Key R&D Program of China (38 papers), Fundamental Research Funds for the Central Universities (20 papers), National Cancer Institute (19 papers), Natural Science and Engineering Research Council of Canada (19 papers), National Center for Scientific Research and Technological Development, Brazil (18 papers), King Saud University (16 papers), European Research Development Fund (12 papers), National Research Foundation of Korea (12 papers), etc.

Of all 2451 publications, articles constituted the largest publications share (62.55%), followed by conference papers (15.46%), reviews (8.36%), letters (5.26%), notes (3.10%), editorials (2.73%), book chapters (1.43%) and others (erratum, short survey and data papers) (1.10%).

Contribution of Leading Countries

A total of 100 countries have participated in 2451 papers on "Detection and Management of Covid-19 by Image Processing" during the period from 2020 to 2022. The top 15 countries contributed 65 to 506 papers and together contributed 2451 papers and 28849 citations, constituting more than 100.0% share each in global publications and citations. On further analysis, it was observed that: (i) Only four countries contributed papers above the average publication productivity (165.47) of 15 countries: USA (506 papers), China (412 papers), India (362 papers) and U.K. (173 papers) and (ii) Seven countries registered citation per paper and relative citation index above the average group values (17.64 and 1.50): China (27.02 and 2.30), Germany (26.23 and 2.23), France (23.72 and 2.02), U.K. (21.63 and 1.84), Turkey (20.92 and 1.78), Italy (19.76 and 1.68) and USA (18.11 and 1.54). The international collaborative papers share of top 15 countries varied from 25.14% to 63.51%, with an average value of 43.80 % (Table 1).

Publications were defined as internationally cooperative if the paper was coauthored by researchers from more than one country. The collaboration network diagram of the 15 most productive countries that have contributed on this topic is shown in Figure 1, based on the co-occurrence matrix. The size of the circles is proportional to the degree of contribution each country. The lines among these circles represent the cooperation between countries and the thickness of the lines implies the total number of collaborative publications. The collaboration network consists of 2 clusters, red and green. The largest community is the one that evolved around the USA.The 15 most productive countries had intensive collaboration among themselves.

The total collaborative linkages (among top 15 countries) of each country varied from 24 to 295 and individual country to country collaborative linkages varied from 1 to 57. The top four countries with highest number of collaborative linkages (295, 187, 146 and 143) are depicted by USA. U. K, China and Italy and top four countries having least number of linkages (24, 56. 57 and 60) partnership depicted by Turkey, Brazil, Egypt and Iran. The United States was the most active country that had the strongest collaborative partnership and linkages with China in 47 papers, followed by USA-Canada (38 linkages), USA-U.K. (33 linkages), etc. (Table 2).

Table 1: Profile of Top 15 Most Productive Countries on "Detection and Management of Covid-19 by Image Processing".

Sl. No	Name of the country	TP	TC	CPP	HI	ICP	%ICP	RCI	TCL (NOC)
1	USA	506	9166	18.11	32	201	39.72	1.54	295 (14)
2	China	412	11131	27.02	43	141	34.22	2.30	146 (13)
3	India	362	3346	9.24	23	91	25.14	0.79	101(13)
4	UK	173	3742	21.63	24	109	63.01	1.84	187 (14)
5	Italy	150	2964	19.76	21	73	48.67	1.68	143 (12)
6	Canada	115	1879	16.34	18	66	57.39	1.39	101 (12)
7	Turkey	110	2301	20.92	18	17	15.45	1.78	24(11)
8	Iran	109	1179	10.82	14	53	48.62	0.92	60(14)
9	Saudi Arabia	91	1557	17.11	11	72	79.12	1.45	85 (14)
10	Australia	88	723	8.22	15	61	69.32	0.70	73(14)
11	Germany	81	2125	26.23	16	49	60.49	2.23	111 (15)
12	Egypt	74	734	9.92	11	47	63.51	0.84	57(11)
13	Spain	74	741	10.01	15	39	52.70	0.85	85(13)
14	France	72	1708	23.72	18	42	58.33	2.02	84(15)
15	Brazil	65	492	7.57	8	26	40.00	0.64	56(12)
	Total of top 15 countries	2482	43788	17.64	287	1087	43.80	1.50	
	Global Output	2451	28849	11.77					

TP=Total papers; TC=Total citations; CPP=Citations per paper; HI=Hersh Index; ICP=International collaborative papers; RCI-Relative citation index; TCL=Total collaborative linkages; NOC=Number of countries.

Contribution of Leading Subject Areas

Table 3 shows the top 5 research areas, which published maximum papers on "Detection and Management of Covid-19 by Image Processing". These subjects are based on subject classification used in Scopus database. The largest contribution (57.36%) in this theme has come from Medicine, followed by Computer Science (35.70%), Engineering (21.95%), Mathematics (9.47%) and Biochemistry, Genetics and Molecular Biology (8.69%). In terms of impact, Medicine registered the highest citation impact per paper (16.32) and Mathematics the least (5.09).

Profile of Top 30 Most Productive Organizations

In all 1661 organizations participated in research on "Detection and Management of Covid-19 by Image Processing". Of them, the top 30 organizations publications varied from 14 to 42 papers and together contributed 550 papers and 16491 citations, constituting 22.44% and 57.16% share of global publications and citations. Of the top 30 organizations, 9 were from USA, 8 from China, 5 from U.K., 3 each from Canada and Iran and 1 each from France and Saudi Arabia.

Table 2: Top 20 Country Pairs with Highest Collaborative Linkages.

Country Pairs	NOCL	Country Pairs	NOCL
USA-China	57	U.K.-Germany	18
USA-Canada	38	USA-India	16
USA-U.K.	33	USA-Spain	16
USA – Iran	27	U.K.-Canada	16
U.K.-Italy	28	Italy-France	15
USA-Germany	24	China-Australia	14
India-Saudi Arabia	21	U.K. –Spain	14
U.K.-France	20	Italy-Spain	13
Italy-Germany	19	China-U.K	13
Saudi Arabia-Egypt	19	Italy-Spain	13

NOCL=Number of collaborative linkages

Table 3: Contribution of Subject Areas in "Detection and Management of COVID-19 by Image Processing".

Sl. No	Name of the field	TP	TC	CPP	%TP
1	Medicine	1406	22952	16.32	57.36
2	Computer Science	875	7458	8.52	35.70
3	Engineering	538	4188	7.78	21.95
4	Mathematics	232	1181	5.09	9.47
5	Biochemistry, Genetics and Molecular Biology	213	2449	11.50	8.69
	Global total	2451	28849	11.77	100.00

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

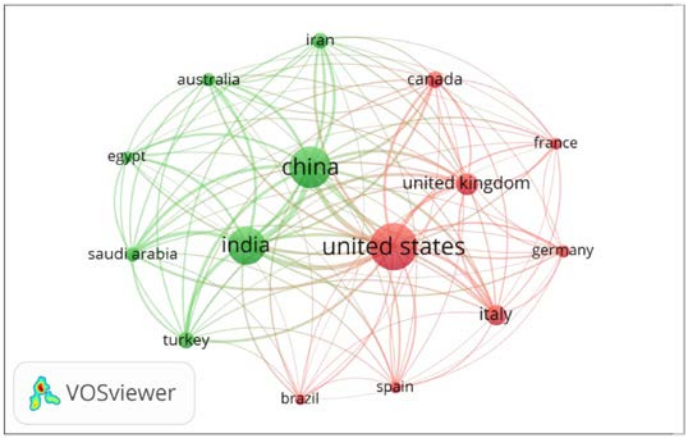

Figure 1: Top 15 Countries Collaboration Network in "Detection and Management of Covid-19 by Image Processing".

On further analysis it was observed that: (i) Nine organizations contributed papers above the average productivity (18.33) of top 30 organizations: Harvard Medical School, USA (42 papers), Massachusetts General Hospital, USA (36 papers), Shahid Beheshti University of Medical Sciences, Iran and Huazhong University of Science and Technology, China (29 papers each), University of Toronto, Canada (23 papers), Tongji Medical College, China (21 papers), Central South University, China, Central South University, China and Tehran University of Medical Sciences, Iran (19 papers each); and (ii) Twelve organizations registered citations per paper and relative citation index above the group average (29.98 and 2.55): Icahn School of Medicine at Mount Sinai, USA (158.44 and 13.46), Sun Yat-Sen University, China (84.0 and 7.14), Ministry of Education, China(71.78 and 6.10), Imperial College London, U.K. (71.14 and 6.04), University of British Columbia, Canada (62,67 and 5.32), West China School of Medicine/West China Hospital of Sichuan University, China (59.450 and 5.05), Keck School of Medicine of USC, USA (57.93 and 4.92), University of Southern California, USA (50.53 and 4.29), Wuhan University, China (40.88 and 3.47), Royal Free London NHS Foundation Trust, U.K. (35.29 and 3.0), Huazhong University of Science and Technology, China (31.55 and 2.68) and Tongji Medical College, China (31.0 and 2.63). The international collaborative publication share of top 30 organizations varied from 13.33% to 81.25%, with an average of 49.18% (Table 4).

Figure 2 shows the collaboration network map of the top 50 institutions. The network consists of 5 clusters, blue, green, lavender, red, and orange colors. Cluster 1 (in blue) included Harvard Medical School, Massachusetts General Hospital, Icahn School of Medicine at Mount Sinai, University of Toronto, Mayo Clinic, Tabriz University of Medical Sciences, and Urmia University of Medical Sciences. Cluster 2 (in green) included Huazhong University of Science and Technology, Wuhan University, Fudan University, and Zagazig University. Cluster 3 (in lavender) included Sun Yat-Sen University, Central South University, Capital Medical University, Tsinghua University, University of Electronic Science and Technology of China, Renmin Hospital of Wuhan University, and Sichuan University. Cluster 4 (in red) included Shahid Beheshti University of Medical Sciences, Tehran University of Medical Sciences, and Iran University of Medical Sciences. Cluster 5 (in orange) included the University of Ottawa, University of Oxford, and University Medical Centre, Utrecht.

The total collaborative linkages (among top 30 organizations) of each organization varied from 1 to 49 and individual country to country collaborative linkages varied from 0 to 21. The top four organizations with highest number of collaborative linkages (49, 44, 31 and 28) are depicted by Harvard Medical School, USA, Massachusetts General Hospital, USA, Huazhong University of Science and Technology, China and Tongji Medical College, China and top four countries having least number of linkages (1, 4. 5 and 5) depicted by Capital Medical University, China, Ministry of Education, China, Wuhan University, China and INSERM, France. In terms of organization-organization collaborative linkages, Harvard Medical School, USA - Massachusetts General Hospital, USA together collaborated in 25 papers, followed by Huazhong University of Science and Technology, China – Tongji Medical College, China (21 linkages), University of Southern California - Keck School of Medicine of USC, USA (14 linkages), Central South University, China - Second Xiangya Hospital of Central South University, China (13 linkages), Shahid Beheshti University of Medical Sciences, Iran – Tehran University of Medical Sciences, Iran (11 linkages), Harvard Medical School, USA – Brigham and Women's Hospital, USA and University College London Hospitals NHS Foundation Trust, U.K. – Royal Free London NHS Foundation Trust, U.K (7 linkages each), etc. (Table 3). The strongest collaborations are among themselves are between 9 USA organizations, followed by 8 Chinese, 5 U.K. and 3 Iran organizations. However, there are substancial collaborative linkages between organizations across countries such as USA, China, U.K., Canada, Iran and France.

Profile of Top 30 Most Productive Authors

A total of 11755 authors participated in global research on "Detection and Management of Covid-19 by Image Processing" during 2020-22. Among them, top 30 authors publications varied from 6 to 14 papers and together contributed 225 papers and 7199 citations, constituting

Table 4: Profile of Top 30 Organizations in "Detection and Management of Covid-19 using Image Processing".

S. No	Name of the organization	TP	TC	CPP	HI	ICP	%ICP	RCI	TCL (NOO)
1	Harvard Medical School, USA	42	493	11.74	12	22	52.38	1.00	49(16)
2	Massachusetts General Hospital, USA	36	393	10.92	10	15	35.71	0.93	44(11)
3	Shahid Beheshti University of Medical Sciences, Iran	29	223	7.69	8	9	21.43	0.65	18(4)
4	Huazhong University of Science and Technology, China	29	915	31.55	10	15	35.71	2.68	31(9)
5	University of Toronto, Canada	23	163	7.09	7	12	28.57	0.60	13(8)
6	Tongji Medical College, China	21	651	31.00	9	10	23.81	2.63	28(8)
7	Central South University, China	19	124	6.53	5	9	21.43	0.55	
8	Sun Yat-Sen University, China	19	1596	84.00	7	7	16.67	7.14	12(4)
9	Tehran University of Medical Sciences, Iran	19	131	6.89	6	9	21.43	0.59	22(6)
10	Ministry of Education, China	18	1292	71.78	5	7	16.67	6.10	4(4)
11	Icahn School of Medicine at Mount Sinai, USA	18	2852	158.44	7	7	16.67	13.46	9(4)
12	Taif University, Saudi Arabia	18	69	3.83	5	15	35.71	0.33	0
13	University of California, San Francisco, USA	17	170	10.00	6	8	19.05	0.85	12(5)
14	University of Southern California, USA	17	859	50.53	8	5	29.412	4.29	16(3)
15	University of Oxford, U.K.	16	241	15.06	7	13	81.25	1.28	12(6)
16	Wuhan University, China	16	654	40.88	8	10	62.5	3.47	5(3)
17	INSERM, France	15	316	21.07	8	8	53.333	1.79	5(2)
18	University of Pennsylvania, USA	15	46	3.07	4	9	60	0.26	10(7)
19	University of Texas, MD Anderson Cancer Center, USA	15	103	6.87	6	6	40	0.58	12(6)
20	Keck School of Medicine of USC, USA	15	869	57.93	8	4	26.667	4.92	16(3)
21	Brigham and Women's Hospital, USA	15	135	9.00	5	11	73.333	0.76	23(10)
22	University College London Hospitals NHS Foundation Trust, U.K.	15	432	28.80	8	2	13.333	2.45	15(7)
23	Iran University of Medical Sciences, Iran	15	401	26.73	7	10	66.667	2.27	17(5(
24	Capital Medical University, China	15	328	21.87	6	6	40	1.86	1(1)
25	University of Ottawa, Canada	15	161	10.73	6	7	46.667	0.91	12(7)
26	West China School of Medicine/West China Hospital of Sichuan University, China	15	891	59.40	8	6	40	5.05	15(5)
27	Second Xiangya Hospital of Central South University, China	15	111	7.40	5	6	40	0.63	25(6)
28	University of British Columbia, Canada	14	876	62.57	7	9	64.286	5.32	14(10)
29	Imperial College London, U.K.	14	996	71.14	6	10	71.429	6.04	8(4)
30	Royal Free London NHS Foundation Trust, U.K.	14	494	35.29	10	5	35.714	3.00	7(1)
	Total of top 30 organizations	550	16491	29.98	204	267		2.55	
	Global total	2451	28849						

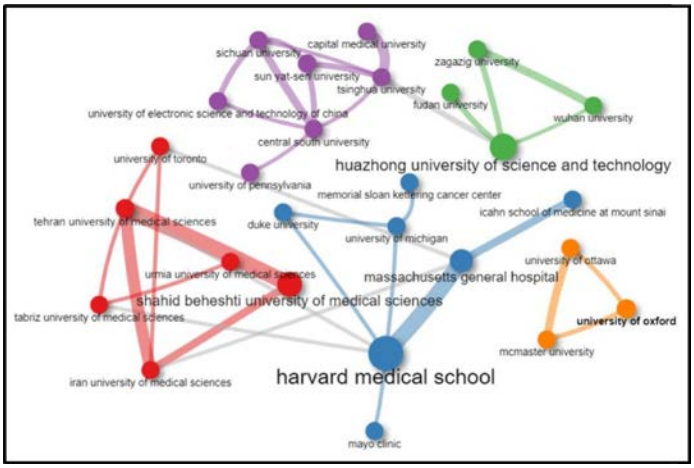

Figure 2: Top 50 organizations Collaborative Linkages Network Map on "Detection and Management of Covid-19 by Image Processing".

9.18% and 24.95% share of global publications and citations. Of the top 30 authors, 7 each were from China and U.K. 3 each from USA and Italy, 2 each from India, Iran and Qatar and 1 each from Australia, Canada, Saudi Arabia and South Korea. On further analysis it was observed that: (i) Ten authors have contributed papers above the average productivity (7.5) of top 30 authors: A. Gholamrenzanezhad (USA) (14 papers), D. Shen (South Korea) (12 papers), J. Liu (China)(11 papers), S.S. Hare (U.K.)(10 papers), J. Jacob (U.K.), L. Saba (Italy) and R. Sarkar (India) (9 papers each), C. Dennie (Canada), S. Mirjalili (Australia) and F. Shi (China)(8 papers each); and (ii) Eleven authors registered citations per paper and relative citation index above the group average (32.0 and 2.72): A. Bernheim (USA)(235.83 and 20.04), N. Sverzellati (Italy)(135.86 and 11.54), A. Gholamrenzanezhad (USA)(62.07 and 5.27), A. Nair (U.K.) (54.29 and 4.61), F. Shi (China)(42.75 and 3.63), J. Jacob (U.K.)(42.22 and 3.59),, S.S. Hare (U.K.)(41.20 and 3.50), A. Edey (38.50 and 3.27), A. Johnstone (U.K.)(38.50 and 3.27), JCL Rodriques (U.K.)(33.0 and 2.80), D. Shen (South Korea) (32.17 and 2.73). The international

collaborative publication share of top 30 authors varied from 0.0% to 100.0%, with an average of 48.0% (Table 5).

Figure 3 visualizes the collaboration network of the 50 most collaborating authors. The network constructed by analyzing the bibliographic data of the co-authors with the VOSviewer. The size of the node in the network reflects the number of collaborations with other nodes in the network and the node with a bigger size has more collaboration links with other nodes. Density of the links shows the strength of association between two nodes, and link between two nodes signifies higher number of collaborations between the two nodes. The network contains the 5 clusters: red (15 authors), green (12 authors), blue (9 authors), yellow (8 authors) and lavender (6 authors). The author network analysis also shows that Liu J., Zhao W, Li X, Li Y, and Zhang Y are among the most collaborating authors, as they share the highest collaboration links with other authors.

Figure 3 shows the co-authorship associations between top 50 authors. The author collaboration network was spread over 5 clusters. The path strength indicates the strength of the co-authorship association of a particular author with other authors.

Among top 30 most productive authors, only 19 have collaborative linkages among themselves. The total collaborative linkages (among top 19 authors) varied from 1 to 34 and individual author to author collaborative linkages varied from 1 to 8. The top four authors with highest number of collaborative linkages (34, 32 30 and 30) are depicted by A. Edey (U.K.), A. Johnstone, U.K., J. Jacob (U.K.) and J.C. L Rodrique (U.K.). Among top 19 authors, the largest number of author to author linkages (8) are depicted by D. Shen – F. Shi, followed by J. Jacob and A. Nair (U.K.) (7 linkages), etc. We also observed that there is a strong collaboration among 7 authors from U.K., 5 Chinese authors and 2 Qatar authors. Collaboration across countries is observed among South Korea –Chinese authors, U.K.-USA authors and Canada –USA authors, etc (Table 5).

Table 5: Top 33 Author Pairs with Highest Collaborative Linkages among Top 30 Authors.

Name of author Pairs	NCL	Name of author pairs	NCL	Name of author pairs	NCL
D. Shen (S.Kor) – F. Shi (China)	8	J. Liu – F. Shan (China)	2	A..Johnstone–G. Robinson (U.K)	6
D. Shen (S Kor) – Y. Gao (China)	7	Y. Gao – L. Xia (China)	2	A.Johnstone–S,S. Hare (U.K.)	2
D. Shan (S.Kor)–F. Shan (China)	4	MEH. Chowdhury–S. Kiranyaz (Qatar)	7	S.S.Hare – J. Jacob (U.K.)	5
D. Shan (S.Kor)- L. Xia (China)	4	A. Edey–A. Johnstone (U.K.)	6	S.S.Hare – A. Nair (U.K.)	5
Y. Gao – F. Shi (China)	4	A. Edey – S.S.Hare (U.K.)	4	S.S.Hare(U.K)– C. Dennie (Canada)	3
Y. Gao – F. Shan (China)	4	A.Edey – J.Jacob (U.K.)	6	J. Jacob – A.Nair (U.K)	7
L. Xia – F.Shi (China)	3	A.Edey – A.Nair (U.K.)	6	J. Jacob – G. Robinson (U.K.)	6
F. Shan – F.Shi (China)	3	A.Edey – G. Robinson (U.K.)	6	A.Nair – G.Robbins (U.K)	6
F. Shan- L. Xia (China)	3	A.Edey– JCL Rodrique (U.K.)	6	G.Robinson – JCL.Rodrique (U.K.)	6
F. Shi – J. Liu (China)	3	A..Johnstone–J. Jacob (U.K.)	6	JCL.Rodrique – A.Johnstone (U.K.)	6
F. Shi – L.Xia (China)	3	A..Johnstone – A.Nair (U.K.)	6	JCL.Rodrique – A.Nair (U.K.)	6

NCL=Number of collaborative linkages

Profile of Top 30 Most Productive Journals

Of the total 2451 publications on "Detection and Management of Covid-19 by Image Processing", 2044 (83.40%) publications appeared in 1088 journals, 295 (12.04%) in conference proceedings, 105 (4.28%) in book series and the rest as books (9.20%) and trade journal (0.08%). Of the 1088 journals, 124 journals published 1-10 papers each, 27 published 11-20 papers each, 8 published 21-30 papers each, and one journal published 38 papers during 2020-22.

The top 30 journals contributed 10 to 38 papers and together contributed 519 papers and 14188 citations, constituting 21.18% and 49.18% share of global papers and citations. The top 8 most productive journals were: *Computers in Biology and Medicine* (38 papers), *Academic Radiology* (29 papers), *Clinical Imaging* (28 papers), *Diagnostics and Radiology* (22 papers each), *European Journal of Nuclear Medicine and Molecular Imaging* and *European Radiology* (21 papers each) and *IEEE Access* (20 papers). The top 8 journals in terms of citations per paper were: *Radiology* (153.09), *Journal of Infection* (105.75), Radiology Cardiothoracic (64.94), *European Radiology* (53.76), *American Journal of Roentgenology* (50.19), *Computers in Biology and Medicine* (42.08), *Informatics in Medicine Unlocked* (36.27) and *Applied Intelligence* (28.15) (Table 6).

Figure 4 shows the journals co-citation collaboration network map with 30 nodes, which reveals the most important collaborative partners between journals. Thus, co-citation focuses on references coming frequently in pairs. The size of the node represents the activity of the journal and the number of publications. The colors of nodes represent different subject clusters, and a line represents a reference relationship. According to the subject categories of the cited literature, these

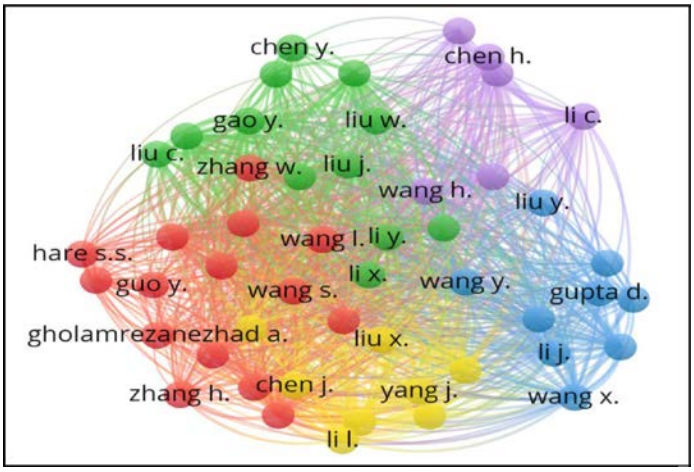

Figure 3: The Top -50 Authors Collaboration Visualization Network Map on "Detection and Management of Covid-19 by Image Processing".

journals can be divided into five clusters. The journals in the green area on the top right-hand corner, represented by the *Biomedical Signal Processing and Control, Applied Intelligence, Computers, Materials and Continua, IEEE Access, IEEE Journal of Biomedical and Health Informatics*, etc., relates to computer, health Informatics and IoT

Table 5: Profile of Top 30 Most Productive Authors in "Detection and Management of Covid-19 using Image Processing".

S.No	Name of the author	Affiliation of the author	TP	TC	CPP	HI	ICP	%ICP	RCI
1	L. Saba	Azienda Ospedaliero Universitaria di Cagliari, Italy	9	181	20.11	6	9	100.00	1.71
2	S. Mirjalili	Yonsei University, Australia	8	99	12.38	4	8	100.00	1.05
3	MEH Chowdhury	Qatar University, Qatar	6	59	9.83	4	6	100.00	0.84
4	M.K. Kalra	Massachusetts General Hospital, USA	6	31	5.17	4	6	100.00	0.44
5	S. Kiranyaz	Qatar University, Qatar	6	59	9.83	4	6	100.00	0.84
6	R. Sarkar	Jadavpur University, Kolkata, India	9	64	7.11	4	8	88.89	0.60
7	F. Shan	Shanghai Public Health Clinical Center, China	6	63	10.50	4	5	83.33	0.89
8	D. Shen	Korea University, South Korea	12	386	32.17	6	9	75.00	2.73
9	C. Dennie	University of Ottawa, Canada	8	143	17.88	6	6	75.00	1.52
10	F. Shi	Shanghai United Imaging Intelligence Co. Ltd, China	8	342	42.75	4	6	75.00	3.63
11	Y. Gao	Shanghai United Imaging Intelligence Co. Ltd, China	7	56	8.00	3	5	71.43	0.68
12	N. Sverzellati	University of Parma, Italy	7	951	135.86	5	5	71.43	11.54
13	M. Masud	Taif University, Saudi Arabia	7	38	5.43	4	4	57.14	0.46
14	L. Xia	Huazhong University of Science and Technology, China	7	202	28.86	3	4	57.14	2.45
15	A. Bernheim	Icahn School of Medicine at Mount Sinai, USA	6	1415	235.83	4	3	50.00	20.04
16	S.S. Hare	Royal Free London NHS Foundation Trust, U.K.	10	412	41.20	9	4	40.00	3.50
17	J. Liu	Second Xiangya Hospital of Central South University, China	11	64	5.82	4	4	36.36	0.49
18	J.J. Wang	Donald and Barbara Zucker School of Medicine at Hofstra/ Northwell, USA	6	89	14.83	4	2	33.33	1.26
19	A. Gholamrenzanezhad	Keck School of Medicine of USC, USA	14	869	62.07	8	4	28.57	5.27
20	S.Haseli	National Research Institute of Tuberculosis and Lung Disease, Tehran, Iran	6	103	17.17	3	1	16.67	1.46
21	R. Wang	Guighou Province People's Hospital, China	6	41	6.83	2	1	16.67	0.58
22	A.Cuocolo	University of Naples Federico II, Italy	7	27	3.86	3	1	14.29	0.33
23	JCL Rodriques	The New Castle Upon Tyne Hospital NHS Foundation Trust, U.K.	7	231	33.00	5	1	14.29	2.80
24	J. Jacob	University College London, U.K.	9	380	42.22	6	0	0.00	3.59
25	A. Nair	University College London, U.K.	7	380	54.29	6	0	0.00	4.61
26	A. Edey	The New Castle Upon Tyne Hospital NHS Foundation Trust, U.K.	6	231	38.50	5	0	0.00	3.27
27	A. Johnstone	The New Castle Upon Tyne Hospital NHS Foundation Trust, U.K.	6	231	38.50	5	0	0.00	3.27
28	A. Mahajan	Tata Memorial Hospital, Mumbai, India	6	17	2.83	2	0	0.00	0.24
29	G. Robbins	The New Castle Upon Tyne Hospital NHS Foundation Trust, U.K.	6	23	3.83	5	0	0.00	0.33
30	X. Wang	Changsha University of Science and Technology, China	6	12	2.00	2	0	0.00	0.17
			225	7199	32.00	134	108	48.00	2.72
			2451	28849	11.77			0.00	1.00
			9.18	24.95					

discipline. The journals in the red area in the middle left-hand corner represented by *Academic Radiology, American Journal of Roentgenology, Clinical Imaging, Clinical Radiology*, etc., relates to radiology disciplines. The journals in the blue area in the upper left-hand corner, represented by *Applied Soft Computing, PLOS One, Radiology, Emergency Radiology,* etc. The journals in the center yellow area are *Diagnostics, Sensors, Applied Sciences* (Switzerland), Radiology: Cardiothoracic Imaging, etc. The journals in the lower right-hand lavender area are the *Scientific Reports and Diagnostic and Interventional Radiology.* The two journals' *Diagnostics and Computers in Biology and Medicine* are connected to all the five clusters.

Research Hotspots and Trends

In all 9233 keywords plus and 3831 author keywords were generated from these 2451 publications. Of these only 78 keywords from author keywords were found significant based on their importance and frequency of occurrence. Table 7 and Figure 5 show the listing of top 78 (with frequency from 03 to 1158) significant keywords which characterize the research trends on this theme. The largest frequency (1158) was recorded by keyword Covid-19, followed by Coronavirus 2019 (1035), X-Ray (883), Computer-Assisted Tomography (836), Deep Learning (275), etc. (Table 7).

A visualization guided by quantitative evaluation of the co-occurrence of keywords was prepared, as depicted in Figure 5. All these 78 keywords spread over in three clusters red, green, and blue. Cluster 1 included 30 keywords, Cluster 2 included 26 keywords and Cluster 3 included 21 keywords. The size of the node and the word indicate the importance of the node. The size of the circle shows the significance of the word. The distance between two nodes indicates the strength of the relationship

Table 6: Top 30 journals publishing papers in "Detection and Management of Covid-19 using Image Processing".

S.No	Name of the journal	Source country	TP	TC	CPP	TLS
1	Computers in Biology and Medicine	UK	38	1599	42.079	141
2	Academic Radiology	USA	29	360	12.414	22
3	Clinical Imaging	USA	28	182	6.500	27
4	Diagnostics	Switzerland	22	68	3.091	57
5	Radiology	USA	22	3368	153.091	87
6	European Journal of Nuclear Medicine and Molecular Imaging	Germany	21	585	27.857	23
7	European Radiology	Germany	21	1129	53.762	63
8	IEEE Access	USA	20	400	20.000	44
9	PLOS One	USA	20	179	8.950	42
10	Scientific Reports	UK	20	459	22.950	44
11	Biomedical Signal Processing and Control	Netherlands	18	146	8.111	19
12	Clinical Radiology	UK	18	397	22.056	13
13	Radiology Cardiothoracic	USA	17	1104	64.941	20
14	American Journal of Neuroradiology	USA	16	139	8.688	0
15	American Journal of Roentgenology	USA	16	803	50.188	11
16	Egyptian Journal of Radiology and Nuclear Medicine	Egypt	16	20	1.250	19
17	Emergency Radiology	USA	16	84	5.250	11
18	Applied Soft Computing	Netherlands	15	174	11.600	14
19	Applied Sciences Switzerland	Switzerland	14	111	7.929	39
20	IEEE Journal of Biomedical Health Informatics	USA	14	135	9.643	14
21	Applied Intelligence	Netherlands	13	366	28.154	45
22	Expert Systems with Applications	UK	13	217	16.692	27
23	Pattern Recognition	UK	13	103	7.923	28
24	Computers Materials and Continua	USA	12	95	7.917	11
25	International Journal of Imaging Systems and Technology	USA	12	48	4.000	25
26	Journal of Infection	UK	12	1269	105.750	29
27	Informatics in Medicine Unlocked	UK	11	399	36.273	30
28	International Journal of Environmental Research and Public Health	Switzerland	11	116	10.545	23
29	Sensors	Switzerland	11	51	4.636	35
30	Diagnostic and Interventional Radiology	Turkey	10	82	8.200	1
	Total of 30 journals		519	14188		
	Global total		2451	28849		

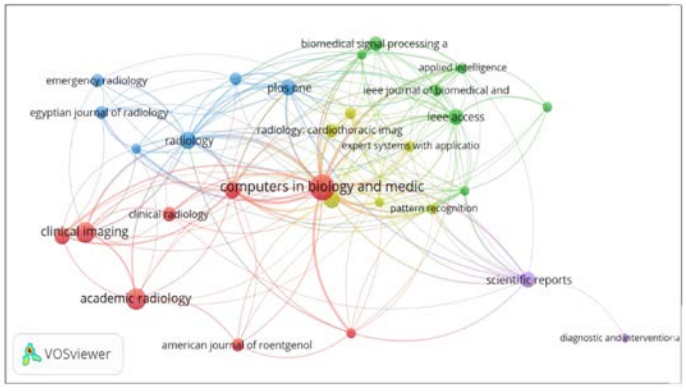

Figure 4: Top 30 Journal Collaboration Network on "Detection and Management of Covid-19 by Image Processing".

between the two nodes. In general the shorter the distance, the more evident is the relationship. The line between two keywords indicates that they appear together. The thicker the line, the more simultaneous it occurs. Nodes of the same color belong to the cluster. Figure 5.

High-Cited Papers

Of the 2451 papers on "Detection and Management of Covid-19 by Image Processing", only 52 papers (2.12%) received 101 to 1354 citations and together registered 15302 citations, averaging 294.27 citations per paper. The distribution of these 52 high-cited (HCP) papers is skewed: 29 papers are in citation range 101-200, 8 papers in citation range 213-288, 5 papers in 303-383 citation range, 3 papers in 440-487 citations range, 5 papers in 676-772 citations range and 2 papers 1121-1354 citation range (Table 8).

Of the 52 papers (constituting 43 articles, 5 reviews, 2 notes and 1 each as short survey and editorial), 7 papers involve zero collaboration and 45 papers involve the participation of 2 or more organizations (25 national collaborative and 20 international collaboratives.

Among the 52 high-cited papers, China is involved in 25 papers, followed by USA (12 papers), U.K. (11 papers), Italy and Turkey (6 papers each), France, India and Germany (4 papers each), Canada, Iran, Japan and Netherlands (3 papers each), Australia, Bangladesh, Egypt, Norway and Singapore (2 papers), and 23 other countries (1 paper each)

In all 181 organizations and 422 authors participated in research in this area. Of the 313 participating organizations, the largest number of papers are contributed by Imperial College, London, U.K. and Royal Brompton and Harefield NHS Foundation Trust, U.K. (4 papers each), followed by Huazhong University of Science and Technology, China, Wuhan University, China, Renmin Hospital of Wuhan University, China

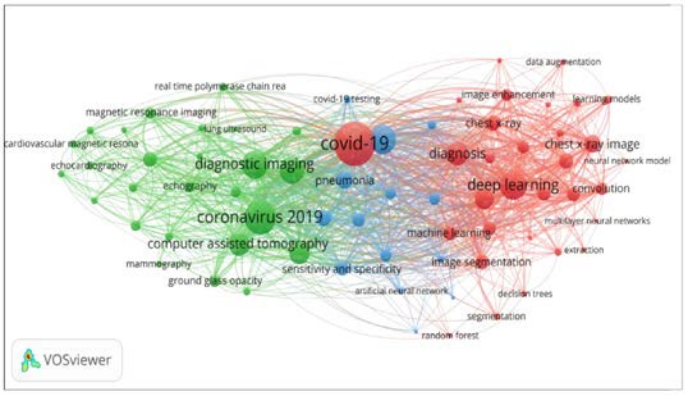

Figure 5: Co-occurrence Network of Top 78 Significant Keywords on "Detection and Management of Covid-19 by Image Processing".

Table 7: List of Top 77 Keywords on Topic in "Detection and Management of Covid-19 using Image Processing".

S.No	Name of the Keyword	Frequency	S.No	Name of the Keyword	Frequency	S.No	Name of the Keyword	Frequency
1	Covid-19	1158	27	Diagnostic Accuracy	128	53	Neuroimaging	39
2	Coronavirus 2019	1035	28	Image Enhancement	128	54	Learning Algorithms	35
3	X-Ray	883	29	Classification	117	55	Data Augmentation	34
4	Computer-Assisted Tomography	836	30	Magnetic Resonance Imaging	113	56	Lung Ultrasound	34
5	Deep Learning	725	31	Algorithms	112	57	Segmentation	34
6	Diagnostic Imaging	692	32	Ground Glass Opacity	112	58	Learning Algorithms	33
7	SARS-CoV-2	596	33	Echography	111	59	Computer Tomography Angiography	30
8	Convolutional Neural Networks	464	34	Thoracic Radiography	103	60	Decision Trees	30
9	Chest X-Ray	398	35	Positron Emission Tomography	96	61	Computer Vision	29
10	Diagnosis	325	36	Computer Neural Networks	75	62	Artificial Neural Networks	28
11	Chest X-Ray Imaging	272	37	Computerized Neural Networks	75	63	Adversarial Networks	22
12	Pneumonia	265	38	Differential Diagnosis	75	64	Extraction	22
13	Transfer Learning	219	39	Radiography	74	65	Automatic Detection	19
14	Image Analysis	216	40	Lung Embolism	72	66	Multilayer Neural Network	19
15	Nuclear Magnetic Resonance Imaging	193	41	Learning Models	71	67	Neural Network Models	19
16	Image Segmentation	185	42	Real Time Polymerase Chain Reaction	70	68	Random Forests	18
17	Reverse Transcription Polymerise Chain Reaction	183	43	Cardiovascular Magnetic Resonance	59	69	Classification Models	17
18	Image Classification	180	44	Covid-19 Testing	57	70	Feature Selection	17
19	Machine Learning	180	45	Support Vector Machines	57	71	Lymphadenopathy	17
20	Learning Systems	173	46	Echocardiography	55	72	Mammography	14
21	Artificial Intelligence	162	47	Statistical Tests	53	73	Logistic Regression	10
22	Computer-Assisted Diagnosis	160	48	Myco-carditis	52	74	Logistic Regression	10
23	Sensitivity and Specificity	154	49	Ultrasound	44	75	Logistic Regression	10
24	Convulsion	147	50	Transfer of Learning	43	76	Ultrasonography	6
25	Deep Neural Network	143	51	Ultrasonography	43	77	Long Short Term Memory	3
26	Image Processing	129	52	Cardiac Imaging	39	78	Computer Tomography Angiography	3078

Table 8: List of Top 10 HCP on "Detection and Management of Covid-19 by Image Processing".

Sl. No.	Paper	DOI	TC
1	CHUNG M, 2020, RADIOLOGY	10.1148/radiol.2020200230	1358
2	RODRIGUEZ-MORALES AJ, 2020, TRAVEL MED INFECT DIS	10.1016/j.tmaid.2020.101623	1126
3	POYIADJI N, 2020, RADIOLOGY	10.1148/radiol.2020201187	773
	OZTURK T, 2020, COMPUT BIOL MED	10.1016/j.compbiomed.2020.103792	758
5	SALEHI S, 2020, AM J ROENTGENOL	10.2214/AJR.20.23034	689
6	PUNTMANN VO, 2020, JAMA CARDIOL	10.1001/jamacardio.2020.3557	684
7	APOSTOLOPOULOS ID, 2020, PHYS ENG SCI MED	10.1007/s13246-020-00865-4	680
8	NG M-Y, 2020, RADIOL CARDIOTHORAC IMAGING	10.1148/ryct.2020200034	489
9	YANG W, 2020, J INFECT	10.1016/j.jinf.2020.02.016	485
10	XU X, 2020, EUR J NUCL MED MOL IMAGING	10.1007/s00259-020-04735-9	440

and Icahn School of Medicine at Mount Sinai, USA (3 papers each), Tongji Medical College, China, Ministry of Education, China, University College, London, U.K. and Royal Free London NHS Foundation Trust, U.K. (2 papers each), etc.

These 52 high-cited papers are published in 34 journals, of which *Radiology* published 5 papers, followed by *Computers in Biology and Medicine, Journal of Infection* and *European Radiology* (4 papers each). *Radiology Cardiothoracic* (3 papers), *Computer Methods and Programs in Biomedical Engineering, IEEE Transactions in Biomedical Engineering and Informatics in Medicine Unlocked* (2 papers each), and 1 paper each by 26 other journals. Table 8 shows the top-10 highly cited papers in terms of title, journal, Authors, publication year, citation numbers, and etc.

CONCLUSION

On the topic "Detection and Management of Covid-19 by Image Processing", 2451 global publications were identified and analyzed from Scopus database, which mainly comprised articles (62.55%), conference papers (15.46%) and reviews (8.36%). The 2451 global publications received 29949 citations, averaging 11.77 citations per paper. Only 19.95% (489) share of global output received funding support from 100+ international funding agencies, which registered comparatively higher citation impact (14.22 citations per paper).

The 2451 global articles originated in 100 countries, with participation from 1661 organizations and 11755 authors and publishing in 1088 journals, generated 9233 keyword plus and 3831 author keywords.

Among 100 participating, although USA (506 papers), China (412 papers) and India (362 papers) were the most productive countries, however, in terms of citations per paper and relative citation index China (27.02 and 2.30), Germany (26.23 and 2.23) and France (23.72 and 2.02) registered the highest citation. Although the contribution came from both developed and developing countries in publication output, but research impact of publications originated in China, North America and Western Europe was much higher. In order to improve global research, the need for global collaboration between developed and developing countries need to be enhanced. Among 1661 participating organizations, although Harvard Medical School, USA (42 papers), Massachusetts General Hospital, USA (36 papers) and Shahid Beheshti University of Medical Sciences, Iran registered the highest productivity; however, Icahn School of Medicine at Mount Sinai, USA (158.44 and 13.46), Sun Yat-Sen University, China (84.0 and 7.14) and Ministry of Education, China (71.78 and 6.10) registered the highest citation impact.

Among different organizations, collaboration is largely confined within their countries but across countries it is comparatively weak. Among 11755 authors, although A. Gholamrenzanezhad (USA) (14 papers), D. Shen (South Korea) (12 papers) and J. Liu (China)(11 papers) registered the highest productivity, however A. Bernheim (USA) (235.83 and 20.04), N. Sverzellati (Italy)(135.86 and 11.54) and A. Gholamrenzanezhad (USA)(62.07 and 5.27) registered the highest citation impact. THe collaboration linkages among global authors is very weak and confined to our countries only.

Among 1088 participating journals, although *Computers in Biology and Medicine* (38 papers), *Academic Radiology* (29 papers), *Clinical Imaging* (28 papers) published the largest number of papers, however *Radiology* (153.09), *Journal of Infection* (105.75) and *Radiology Cardiothoracic* (64.94) registered the highest citation impact. The top three subjects contributing the largest share of literature to this field were Medicine (57.36%), Computer Science (35.70 %) and Engineering (21.95%). Besides Covid-19, the leading keywords were X-Ray (883), Computer-Assisted Tomography (836), Deep Learning (725), Diagnostic Imaging (692), Convolutional Neural Networks (464), Chest X-ray (398) and Diagnosis (325). Only, a small share (2.12%) of the global publications, are considered here as high-cited as they have received 100+ citations and registered 294.27 citations per paper.

The analysis presented above through light on several artificial and machine learning models adopted by researchers, policy-makers and healthcare professionals to classify the images related to the diagnosis and management of Covid-19. The adopted models have presented promising outcomes in terms of accuracy, cost, and detection speed. The study identified the key players such as countries, organizations and authors in global research and studied collaborative linkages among them. It identified the important channels of publishing global research and identified core journals both in terms of productivity and impact. It also highlighted the important keywords which alone or in in co-occurence with other keywords throw light on the research trends and identified the existing gaps and therefore may provide a new perspective for future research. Suggest also the need for active collaborative collaboration among countries, organizations and authors to improve research quality and impact.

The study provided evidence to the fact that artificial intelligence and machine learning approaches play a key role in identification and management of COVID-19. To help facilitate the use of artificial intelligence and machine learning throughout the Covid-19 crisis, policy-makers should encourage the sharing of medical, molecular, and scientific datasets and models on collaborative platforms to help global researchers to build effective tools for the medical community, and should ensure that researchers have access to the necessary computing capacity.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

COVID-19: Coronavirus Disease 2019; **SARS-CoV-2:** Severe Acute Respiratory Syndrome Coronavirus 2; **WBC:** White Blood Cell; **RT-PCR:** Reverse-Transcription Polymerase Chain Reaction; **CT:** Computed Tomography; **MRI:** Magnetic Resonance Imaging; **GGO:** Ground-glass Opacities; **FS:** Feature Selection; **CAD:** Computer-Aided Diagnosis; **AI:** Artificial Intelligence; **LSA:** Latent Semantic Analysis; **LLR:** Log-Likelihood Ratio; **MI:** Mutual Information.

REFERENCES

1. WHO. WHO coronavirus (Covid-19) dashboard [cited 7.3.2022]. Available from: Covid19.WHO.int.
2. Pal M, Berhanu G, Desalegn C, Kandi V. Severe acute respiratory syndrome Coronavirus-2 (SARS-CoV-2): an update. Cureus. 2020;12(3):e7423. doi: 10.7759/cureus.7423, PMID 32337143.
3. Alam NA, Ahsan M, Based MA, Haider J, Kowalski M-Alam, *et al*. Covid-19 detection from chest X-ray images using feature fusion and deep learning. Sensors (Basel). 2021;21(4):1480. doi: 10.3390/s21041480, PMID 33672585.
4. Abumalloh RA, Nilashi M, Yousoof Ismail M, Alhargan A, Alghamdi A, Alzahrani AO, *et al*. Medical image processing and Covid-19: A literature review and bibliometric analysis. J Infect Public Health. 2022;15(1):75-93. doi: 10.1016/j.jiph.2021.11.013, PMID 34836799.
5. Safiabadi Tali SHS, LeBlanc JJ, Sadiq Z, Oyewunmi OD, Camargo C, Nikpour B, *et al*. Tools and techniques for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)/COVID-19 Detection. Clin Microbiol Rev. May 12 2021;34(3). doi: 10.1128/CMR.00228-20, PMID 33980687.
6. Choy G, Khalilzadeh O, Michalski M, Do S, Samir AE, Pianykh OS, *et al*. Current applications and future impact of machine learning in radiology. Radiology. 2018;288(2):318-28. doi: 10.1148/radiol.2018171820, PMID 29944078.
7. Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJWL. Artificial intelligence in radiology. Nat Rev Cancer. 2018;18(8):500-10. doi: 10.1038/s41568-018-0016-5, PMID 29777175.
8. Kaheel H, Hussein A, Chehab A. AI-based image processing for COVID-19 detection in chest CT scan images. Front Comms Net. 2021;2. doi: 10.3389/frcmn.2021.645040, PMID 645040.
9. Shen D, Wu G, Suk HI. Deep learning in medical image analysis. Annu Rev Biomed Eng. 2017;19:221-48. doi: 10.1146/annurev-bioeng-071516-044442, PMID 28301734.
10. Lu X, Hao J, Shan B, Gu A. Determinants of the Intention to Use Smart Healthcare Devices: A Framework and Public Policy Implications. J Healthc Eng. 2021;2021:4345604. doi: 10.1155/2021/4345604. PMID 34777734.
11. Hu Y, Yu Z, Cheng X, Luo Y, Wen C. A bibliometric analysis and visualization of medical data mining research. Med (Baltim). 29 May 2020;99(22):e20338. doi: 10.1097/MD.0000000000020338, PMID 32481411, PMCID PMC7748217.
12. Zhang B, Rahmatullah B, Wang SL, Zhang G, Wang H, Ebrahim NA. A bibliometric of publication trends in medical image segmentation: quantitative and qualitative analysis. J Appl Clin Med Phys. 2021;22(10):45-65. doi: 10.1002/acm2.13394, PMID 34453471.
13. Abd Karim SA, Nohudd PNE. Bibliometric analysis of data mining on medical imaging. J Phys Conf Ser. 1997:012017.
14. Tran BX, Vu GT, Ha GH, Vuong QH, Ho MT, Vuong TT, *et al*. Global evolution of research in artificial intelligence in health and medicine: A bibliometric study. J Clin Med. 2019;8(3):360. doi: 10.3390/jcm8030360, PMID 30875745.
15. Guo Y, Hao Z, Zhao S, Gong J, Yang F. Artificial Intelligence in health Care: bibliometric analysis. J Med Internet Res. 2020;22(7):e18228. doi: 10.2196/18228, PMID 32723713.
16. Liao Huchang, Tang M, Luo L, Li C, Chiclana F, *et al*. A bibliometric analysis and visualization of medical big data research. Sustainability. 2018;10(2):166. doi: 10.3390/su10010166.
17. Tasdelen A, Ugur AR. Artificial Intelligence Research on COVID-19 Pandemic: A bibliometric analysis. Available from: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9604573 [cited 21.3.2022].
18. Islam MM, Poly TN, Alsinglawi B, Lin LF, Chien SC, Liu JC, *et al*. Application of artificial intelligence in covid-19 pandemic: bibliometric analysis. Healthcare (Basel). 2021;9(4):[441]. doi: 10.3390/healthcare9040441, PMID 33918686.
19. Born J, Beymer D, Rajan D, Coy A, Mukherjee VV, Manica M, *et al*. On the role of artificial intelligence in medical imaging of COVID-19. Patterns (N Y). 2021;2(6):100269. doi: 10.1016/j.patter.2021.100269, PMID 33969323.
20. Rivera-Sotelo N, Vargas-Del-Angel RG, Ternovoy SK, Roldan-Valadez E. Global research trends in COVID-19 with MRI and PET/CT: A scoping review with bibliometric and network analyses. Clin Transl Imaging. 2021;9(6):625-39. doi: 10.1007/s40336-021-00460-x, PMID 34414137.
21. Latif S, Usman M, Manzoor S, Iqbal W, Qadir J, Tyson G, *et al*. 2020. Leveraging data science to combat COVID-19: A comprehensive review. TechRxiv [preprint]. doi: 10.36227/techrxiv.12212516.v1.

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