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COVID-19 imaging, where do we go from here? Bibliometric analysis of medical imaging in COVID-19

Ru Wen[1,2,3] · Mudan Zhang[4] · Rui Xu[3] · Yingming Gao[5] · Lin Liu[6] · Hui Chen[2] · Xingang Wang[2] · Wenyan Zhu[7] · Huafang Lin[7] · Chen Liu[2] · Xianchun Zeng[3]

Abstract

Objectives We conducted a systematic and comprehensive bibliometric analysis of COVID-19-related medical imaging to determine the current status and indicate possible future directions.

Methods This research provides an analysis of Web of Science Core Collection (WoSCC) indexed articles on COVID-19 and medical imaging published between 1 January 2020 and 30 June 2022, using the search terms "COVID-19" and medical imaging terms (such as "X-ray" or "CT"). Publications based solely on COVID-19 themes or medical image themes were excluded. CiteSpace was used to identify the predominant topics and generate a visual map of countries, institutions, authors, and keyword networks.

Results The search included 4444 publications. The journal with the most publications was *European Radiology,* and the most co-cited journal was *Radiology*. China was the most frequently cited country in terms of co-authorship, with the Huazhong University of Science and Technology being the institution contributing with the highest number of relevant co-authorships. Research trends and leading topics included: assessment of initial COVID-19-related clinical imaging features, differential diagnosis using artificial intelligence (AI) technology and model interpretability, diagnosis systems construction, COVID-19 vaccination, complications, and predicting prognosis.

Conclusions This bibliometric analysis of COVID-19-related medical imaging helps clarify the current research situation and developmental trends. Subsequent trends in COVID-19 imaging are likely to shift from lung structure to function, from lung tissue to other related organs, and from COVID-19 to the impact of COVID-19 on the diagnosis and treatment of other diseases.

Key Points

• *We conducted a systematic and comprehensive bibliometric analysis of COVID-19-related medical imaging from 1 January 2020 to 30 June 2022.*

• *Research trends and leading topics included assessment of initial COVID-19-related clinical imaging features, differential diagnosis using AI technology and model interpretability, diagnosis systems construction, COVID-19 vaccination, complications, and predicting prognosis.*

• *Future trends in COVID-19-related imaging are likely to involve a shift from lung structure to function, from lung tissue to other related organs, and from COVID-19 to the impact of COVID-19 on the diagnosis and treatment of other diseases.*

Keywords COVID-19 · Medical imaging · Bibliometrics · CiteSpace · Treads

✉ Chen Liu
liuchen@aifmri.com

✉ Xianchun Zeng
zengxianchun04@foxmail.com

1 Medical College, Guizhou University, Guizhou 550000, People's Republic of China

2 Department of Radiology, Southwest Hospital, Army Medical University (Third Military Medical University), 30 Gao Tan Yan St, 400038 Chongqing, People's Republic of China

3 Department of Medical Imaging, Guizhou Provincial People Hospital, No.83, East Zhongshan Road, Nanming District, Guizhou Province 550000 Guiyang City, People's Republic of China

4 Guizhou Medical University, Guiyang, Guizhou Province 550000, People's Republic of China

5 College of Life Science, Guizhou University, Guiyang, Guizhou Province 550000, People's Republic of China

6 Department of Respiratory Medicine, Guizhou Provincial People Hospital, Guiyang City, Guizhou Province 550000, People's Republic of China

7 Medical Department, Yidu Cloud (Beijing) Technology Co., Ltd., Beijing 100191, People's Republic of China

Abbreviations

AI	Artificial intelligence
COVID-19	Coronavirus disease 2019
CT	Computed tomography
MRI	Magnetic resonance imaging
PET	Positron emission tomography
SARS-CoV-2	Severe acute respiratory syndrome-coronavirus-2
WoSCC	Web of Science Core Collection

Introduction

The coronavirus disease 2019 (COVID-19) has become one of the most threatening pandemics in human history. Severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) has infected more than 488 million people and has been associated with the death of more than 6.14 million persons worldwide to date [1]. Due to the Omicron strain mutation, the number of patients with COVID-19 continues to increase rapidly. Medical imaging can be applied to all stages of COVID-19 for diagnosis, treatment guidance, and prognosis prediction. Similarly, the guiding roles of imaging in pneumonia diagnosis, treatment, and rehabilitation evaluation have been increasingly recognized [2–5]. Publications on COVID-19-related imaging from various fields are rapidly increasing in number [6]. A large number of studies have promoted COVID-19 medical imaging research and promoted the development of COVID-19 diagnosis and treatment with new technology development. However, this explosive increase in publications may overwhelm researchers in terms of the vast amount of information available without an overall and comprehensive understanding of key developments in the field.

Therefore, a bibliometric analysis of COVID-19 literature in the imaging field during this timeframe is necessary [7–9]. Bibliometrics uses mathematical and statistical methods to analyze research publications on a specific topic quantitatively. This approach can also assess the quality of studies, identify the evolution of research trends, and predict potential directions of future inquiry [10–12]. Bibliometric analysis has been previously used to investigate leading research topics and research in relation to COVID-19 [9, 13–16]. In one bibliometric study, 3400 manuscripts published in the first 3 months of the pandemic were examined. The findings indicated that the scientific community had been able to quickly respond to this emerging global health threat by developing an increased understanding of the relevant etiological factors, disease spread, and effective preventative measures and mitigation strategies [17]. Radanliev et al. (2020) further assessed the scientific literature on coronavirus types and potential vaccine treatments [18]. Bibliometric analysis of the COVID-19 literature from different perspectives helps identify research priorities during this pandemic, suggests new perspectives and future trends in the field, and hopefully provides insights and research directions for academic researchers and policymakers in collaboration [18–20]. Bibliometrics-based research has also been conducted in the field of medical imaging, with computed tomography (CT) being found to have the highest association with COVID-19 and the most cited topic in medical imaging publications in 2020 [21, 22]. Magnetic resonance imaging (MRI) and positron emission tomography (PET)-CT have been used to supplement the basic evaluation of patients with COVID-19 [23]. Furthermore, another study found that female first authors and corresponding authors were overrepresented in low-ranking journals [24]. However, the overall status of research in the field of medical imaging, as well as trends and future research directions, are still unclear.

In this study, we collected scientific literature related to COVID-19 imaging from the Web of Science Core Collection (WoSCC). CiteSpace was used to analyze 4444 publications and generate knowledge maps. The main objective of this study was to assess the current status of research and development trends in COVID-19 imaging-related studies, and the secondary objective was to identify and summarize future research directions.

Materials and methods

Study design

This was a retrospective cross-sectional study on COVID-19-related medical imaging research.

Data acquisition and search strategy

This study employed an a priori protocol. Two senior radiology professors (Dr. Liu and Dr. Zeng) jointly discussed and determined the topic and that the "sample of interest" were the studies published in the WoSCC pertaining to COVID-19 and medical imaging, and formulated the literature search words, which were reviewed by a literature search professional (Mrs. Zhao). Finally, two other co-authors (Dr. Zhang and Dr. Xu) were included in the publication in accordance with the predetermined inclusion and exclusion criteria (Fig. 1) and any discrepancy was resolved by discussion. The following search terms were used to gather relevant literature from the WoSCC:

TS = ("SARS-CoV-2" or "COVID-19" or "COVID 19" or "coronavirus disease 2019 virus" or "2019 novel coronavirus*" or "coronavirus, 2019 novel" or "novel coronavirus, 2019" or "SARS-CoV-2 Virus*" or "SARS-CoV-2 Virus*" or "Virus, SARS-CoV-2" or "2019-nCoV" or "COVID-19 Virus*" or "COVID 19 Virus*" or "Virus, COVID-19" or "SARS coronavirus 2" or "coronavirus 2, SARS").

Fig. 1 Flow diagram of this study
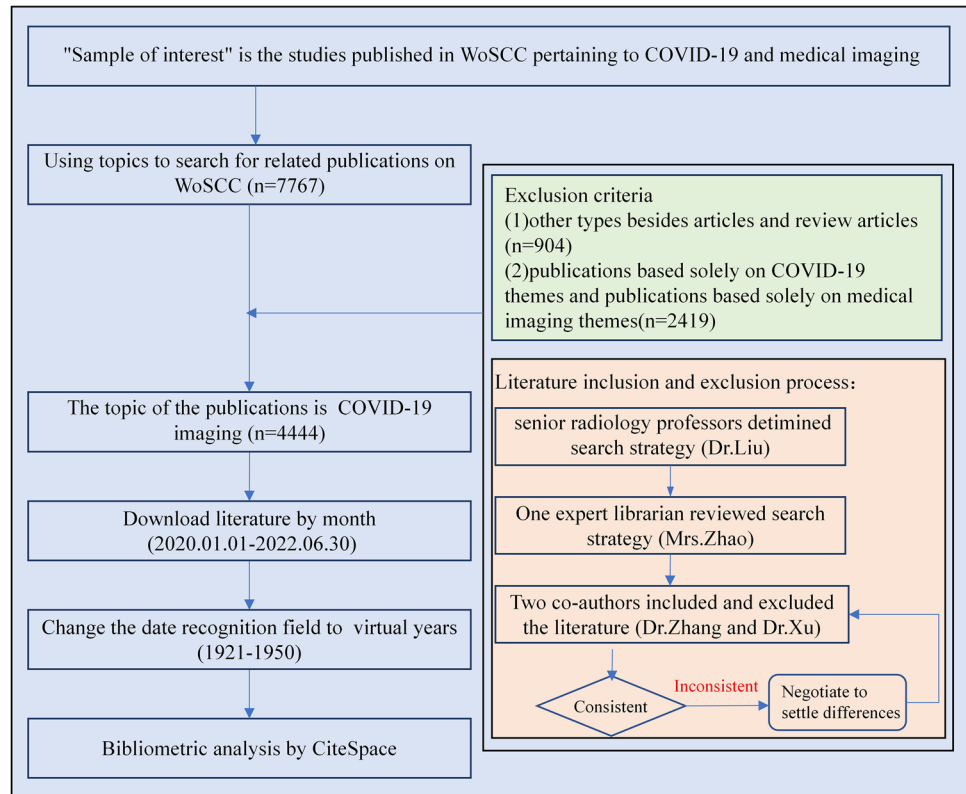
AND

TS = ("X-ray*" or "chest CT" or "chest radiology" or MRI or "magnetic resonance imaging" or "computed tomography" or "compute tomography" or "positron emission tomography" or "single-photon emission computed tomography" or "pet-ct" or "spect-ct" or "pet-mri" or "spect" or "SPECT/CT" or "PET/CT" or ultrasound or ultrasonography) from "DOP*=(2020–01-01/2020–01-31)" to "DOP=(2022–06-01/2022–06-30)."

Initially, 7767 articles were retrieved. Figure 1 illustrates the research steps in this study. Only "articles" and "review articles" were included. We had no language restrictions. The time span was 30 months, from 1 January 2020 to 30 June 2022. After retrieving the studies, publications based solely on COVID-19 themes or medical image themes were excluded, leaving a final sample of 4444 studies. Detailed inclusion and exclusion criteria are provided in Fig. 1. All data were downloaded directly from the database; therefore, no ethical statement or approval was required.

Data analysis

Bibliometric analysis and network visualization were performed using CiteSpace (Version 5.8 R1; https://sourceforge.net/projects/CiteSpace/files/latest/download). Using CiteSpace, we generated knowledge maps of journals, country co-authorship, institution co-authorship, author co-authorship, references, and keyword co-occurrence to visualise emerging trends and areas of COVID-19 imaging research [10]. To further explore the transitions in prevailing topics in COVID-19 imaging, five periods were distinguished: January 2020–June 2020, July 2020–December 2020, January 2021–June 2021, July 2021–December 2021, and January 2022–June 2022. Keywords were clustered in each period to analyze the research emphasis and relevant changes. Nodes in the knowledge maps represent analysis objects such as countries, institutions, authors, keywords, and the size of the rings around each node reflects the number of publications associated with that node [10, 11]. "Burst detection" and "betweenness centrality" are functions provided by the software to identify the nature of research frontiers and identify emerging trends and sudden changes. Betweenness centrality is an index to measure the importance of nodes in the network guided by the tree hole theory [25]. CiteSpace has been used with this index to discover and measure the importance of relevant literature, with purple circles employed to mark nodes with betweenness centrality greater than 0.1 [11]. In this study, the logarithmic likelihood ratio algorithm was used to extract noun phrases [7, 10]. We used modularity (Q value) and silhouette (S value) to evaluate the network structure and network homogeneity [26]. A Q value greater than 0.3 indicates that the community structure is significant and an S value greater than 0.7 indicates that the cluster is noteworthy [26]. More methodological details are provided in the Supplementary material. These parameters enabled us to determine the research status and trends in this field.

Results

Date of publication analysis

In total, 4444 publications were examined in this study, namely 3965 original articles (89.2%) and 479 reviews (10.8%). We counted the number of publications every month in the COVID-19-related imaging field. Figure 2 displays the chronological distribution of publications between January 2020 and June 2022. Approximately 146 publications (standard deviation: 69.88) were published each month. There was a rapid growth stage in COVID-19-related imaging studies at the beginning of the COVID-19 outbreak. In January 2020, there were 111 publications related to COVID-19-related imaging. After a sharp decrease of 96.4% in February, the number of publications increased rapidly in the months between February 2020 and July 2020 (growth rate: 17.42–342.86%), after which a more stable trend was maintained, with growth rates between −40% and 40% in the rest of the months except January 2021.

Analysis of cited journals

In total, 1009 journals had published articles or reviews in this area. Among the leading 20 journals with their impact factors, as shown in Table 1, *European Radiology* ranked first with 84 publications over the study period. Among the co-cited journals, there were 45,378 citations overall, and the leading 20 journals with the most influential publications in this field were cited 10,538 times, accounting for 23.2% of the total citations. *Radiology* was cited the most (2605 times), followed by *Lancet* (2026 times), and *The New England Journal of Medicine* (1887 times). Figure 3 illustrates a dual-map overlay of the journals in the field of COVID-19-related imaging research.

Analysis of country co-authorship and institution co-authorship distribution

Scholars from 114 regions and 984 institutions contributed to publications on COVID-19-related imaging. Supplementary Table 1 provides details of the ten leading countries and institutions. China (928) ranked first, followed by the USA (890), and Italy (525). The leading ten countries each contributed more than 100 publications. Cooperative relationships among countries are shown in Supplementary Fig. 1.

Cooperative relationships among institutions are shown in Supplementary Fig. 2. The institution with the highest productivity was Huazhong University of Science and Technology (121).
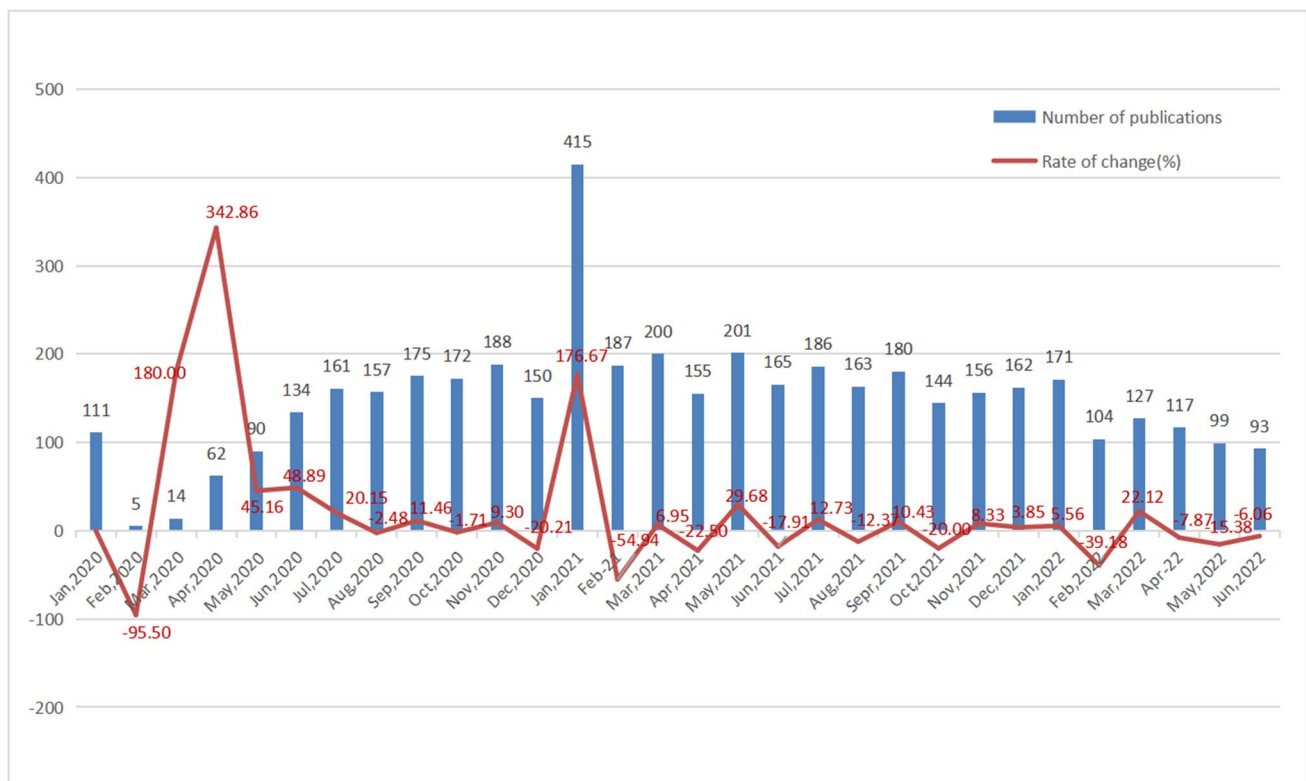

Fig. 2 Chronological distribution of publications on COVID-19-related imaging from January 2020 to June 2022

Table 1 Top-20 journals in COVID-19-related imaging research

Rank	Journal name	NOP	CJC	ANC	IF
1	*European Radiology*	84	1409	16.77	7.034
2	*Diagnostics*	82	176	2.15	3.992
3	*Computers in Biology and Medicine*	80	687	8.59	6.698
4	*Clinical Imaging*	77	270	3.51	2.42
5	*Scientific Reports*	70	769	10.99	4.379
6	*IEEE Access*	65	673	10.35	3.367
7	*Plos One*	58	780	13.45	3.24
8	*Journal of Clinical Medicine*	54	273	5.06	4.964
9	*Radiology*	50	2605	52.1	29.146
10	*CMC Computers Materials Continua*	46	97	2.11	3.86
11	*Frontiers in Medicine*	46	4	0.09	5.058
12	*Academic Radiology*	45	406	9.02	4.482
13	*Biomedical signal processing and control*	40	148	3.7	5.076
14	*Clinical Radiology*	39	286	7.33	3.389
15	*Journal of Ultrasound in Medicine*	39	236	6.05	2.754
16	*Radiologia Medica*	39	271	6.95	6.313
17	*Applied Soft Computing*	37	301	8.14	8.263
18	*European Journal of Radiology*	37	600	16.22	4.531
19	*IEEE Journal of Biomedical and Health Informatics*	32	233	7.28	7.021
20	*American Journal of Roentgenology*	31	956	30.83	6.582

Note: *NOP*, number of publications; *CJC*, cited journal Citations; *ANC*, Average number of citations; *IF*: impact factor; *Calculated in 2022
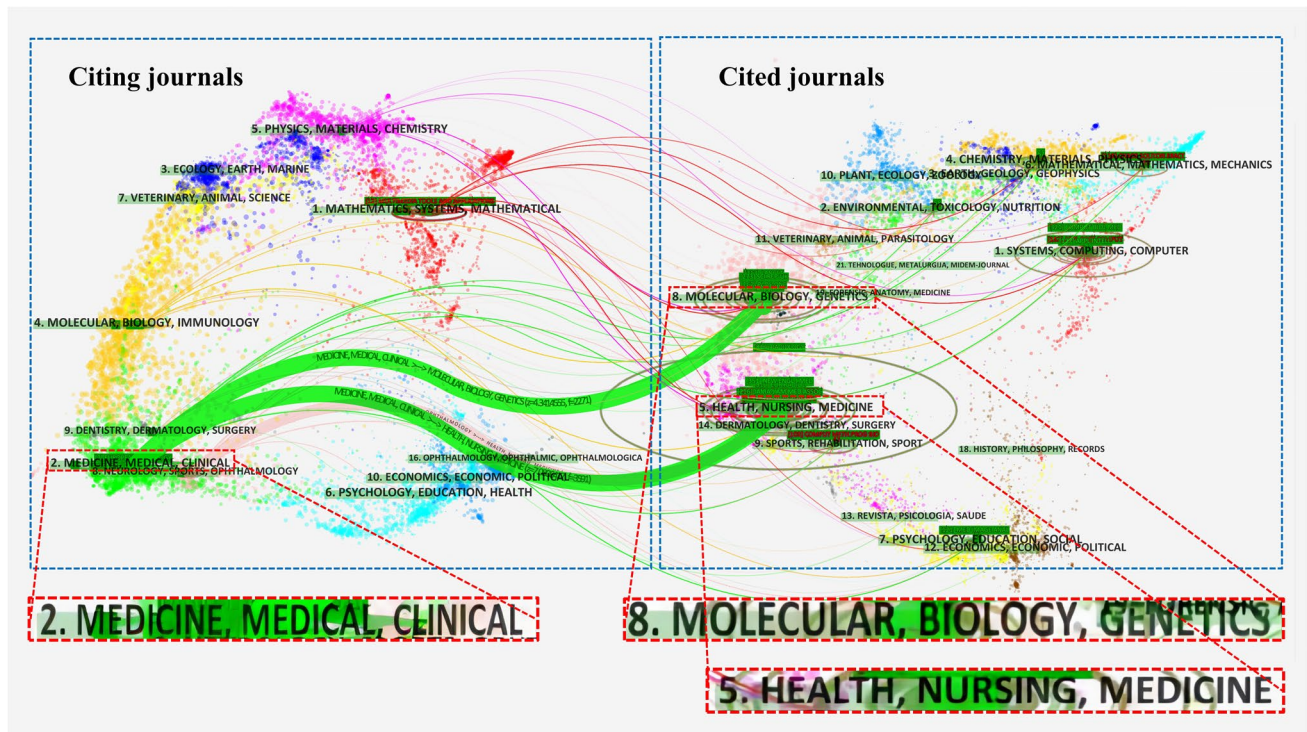

Fig. 3 Dual-map overlay of journals related to COVID-19 imaging. The citing journals appear on the left side of the map while the cited journals appear on the right side. Green wavy lines indicate that studies published in "medicine, medical, clinical" journals tended to cite journals predominately in the domains of "health, nursing, medicine" and "molecular, biology, genetics"

Table 2 The top 10 co-cited references

Rank	Title	Authors	Centrality	NOC*
1	Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China	C Huang et al	0.07	852
2	Correlation of Chest CT and RT-PCR Testing for Coronavirus Disease 2019 (COVID-19) in China: A Report of 1014 Cases	Ai, Tao et al	0.22	849
3	A Novel Coronavirus from Patients with Pneumonia in China, 2019	Zhu, Na et al	0.03	478
4	Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China	Wang, Dawei et al	0.05	437
5	Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study	Shi, Heshui et al	0.02	435
6	Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study	Chen, Nanshan et al	0.07	415
7	Automated detection of COVID-19 cases using deep neural networks with X-ray images	Ozturk, Tulin et al	0.11	404
8	Chest CT for Typical Coronavirus Disease 2019 (COVID-19) Pneumonia: Relationship to Negative RT-PCR Testing	Xie, Xingzhi et al	0.16	385
9	Covid-19: automatic detection from X-ray images utilizing transfer learning with convolutional neural networks	Apostolopoulos et al	0.09	380
10	Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective	Zhou, F et al	0.05	332

NOC: number of co-citations

Analysis of author co-authorship distribution

A total of 4574 authors were identified in publications. Jun Liu was the most prolific author (23), followed by Liming Xia (21) and Ali Gholamrezanezhad (20). The leading 10 authors are listed in Supplementary Table 2 and a graph displaying the cooperation among them is provided in Supplementary Fig. 3.

Analysis of cited references

There are ten co-cited references in Table 2; these represent important contributions to this field. Supplementary Table 3. Huang (2020) ranked first with the most citations (852). That publication reported the epidemiological, clinical, laboratory, and radiological characteristics and treatment and clinical outcomes of patients [27]. The keywords of the cited references were divided into 10 clusters, as shown in Fig. 4.

Analysis of keyword co-occurrence clusters

The network visualization shows the keywords with co-occurrence frequency greater than 50 (Supplementary Fig. 4). 'COVID-19' was the most frequently used search term in this field. After merging synonyms and excluding search words and broad keywords, we listed the leading 20 keywords by frequency in the relevant literature in Table 3. The popular topics in COVID-19-related imaging research were deep learning, differential diagnosis, convolutional neural networks, classification, artificial intelligence (AI), and machine learning. The leading 200 keywords with

strong burst strength in COVID-19-related imaging research are presented in Fig. 5 and Supplementary Table 3. "Wuhan" exhibited the greatest burst strength (34.51), and the term "epidemiology" achieved the longest duration, from January 2020 to April 2021. The term "clinical characteristics" exhibited a relatively high burst strength of 8.27 from

Table 3 Top 20 keywords

Rank	NOK	Centrality	Keywords
1	487	0.15	deep learning
2	304	0.07	diagnosis
3	229	0.05	convolutional neural network
4	211	0.1	classification
5	196	0.03	Wuhan
6	181	0.01	artificial intelligence
7	162	0.05	infection
8	156	0.04	machine learning
9	150	0.02	china
10	137	0.03	feature
11	107	0.01	transfer learning
12	98	0.03	pandemic
13	85	0.01	children
14	82	0.03	clinical characteristics
15	79	0.03	segmentation
16	71	0	mortality
17	67	0.01	prognosis
18	57	0	risk
19	52	0.06	feature extraction
20	51	0.08	management

Note: *NOK*, number of keywords

Fig. 4 Map of co-cited publications in COVID-19-related imaging research (Q=0.649, S=0.859). The red tags are the keywords clustered by the logarithmic likelihood ratio algorithm
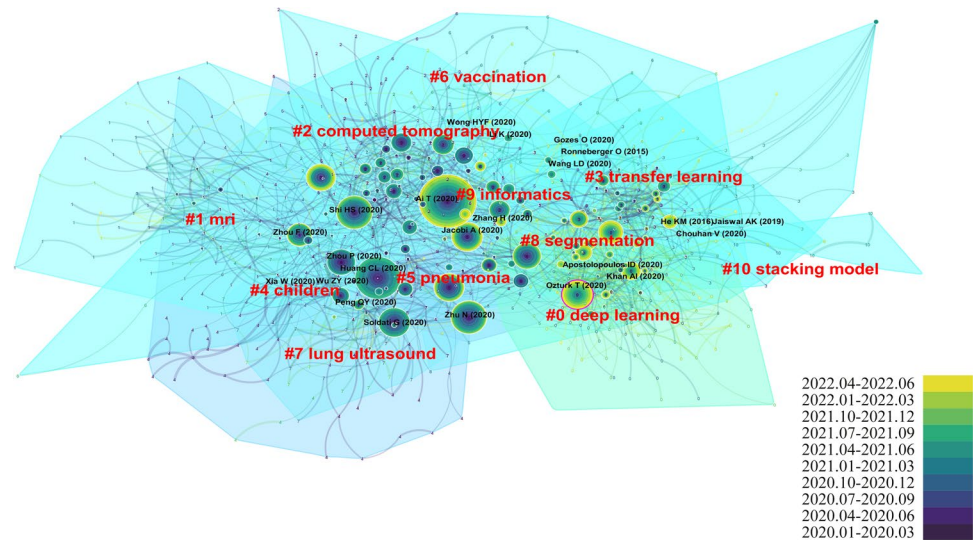
February 2020 to June 2020. The term "imaging feature" exhibited a high burst strength of 5.62 from January 2020 to November 2020. More analysis of keyword emergence is provided in the Supplementary material. These topics reflect the most recent research trends and frontiers.

Based on keyword analysis, we further analyzed the transfer of research hotspots; Fig. 6 shows the clustering of research hotspots in this field. Detailed information regarding the research hotspots during the previous 30 months is as follows:

1. From January 2020 to June 2020, in the initial stage of COVID-19-related imaging research, the focus was on clinical characteristics, dynamic chest CT evaluation, emerging technologies, COVID-19 classification, and clinical features.
2. From July 2020 to December 2020, studies primarily focused on lung infiltrates, right ventricular involvement, the nervous system, COVID-19 diagnosis, and myocardial injury. During this period, researchers primarily focused on the diagnosis and the functional damage caused by COVID-19.
3. From January 2021 to June 2021, studies predominately focused on classification methods, deep vein thrombosis, interpretable deep learning models, lung ultrasound findings, pulmonary embolisms, diagnosis, and automated severity assessment.
4. From July 2021 to December 2022, studies predominately focused on integrating deep feature extraction, 1-year follow-up, the radiographic appearance of complications, the medical diagnosis system, the COVID-19 vaccine, screening study, and retrospective cohort study.
5. From January 2022 to June 2022, studies predominately focused on COVID-19 vaccination, COVID-19 screening, textural feature use, and cerebral venous thrombosis.

Research trends and hot topics were the assessment of initial COVID-19-related clinical imaging features, the differential diagnosis using AI technology, and recent model interpretability; diagnosis systems construction, COVID-19 vaccination, complications, and predicting prognosis are the top of most concerns.

Discussion

We conducted a systematic and comprehensive bibliometric analysis of studies on COVID-19-related medical imaging from 1 January 2020 to 30 June 2022. Considering the rapid growth of COVID-19 imaging-related publications, we analyzed publications by month to avoid missing details, which is also a major innovation of this study. Our more fine-grained time scale can more accurately reflect the development of trends in COVID-19-related imaging. The highest number of publications on COVID-19-related imaging occurred in January 2021, probably due to factors such as the Christmas holiday period [28], the review cycle stage [29], and the fast-track review process during specific the pandemic and require further in-depth research.

In terms of countries, research from China and the United States predominated in terms of quantity, accounting for 43.9% of all publications. In terms of institutions, two Chinese and two American institutions were among the leading five institutions by the number of publications. COVID-19 was first identified in Wuhan, China [30]. Most initial publications in this field were written by authors in China, reporting the clinical manifestations and imaging features of COVID-19 in Wuhan [5]. Overall, China and the USA led the world in the field of COVID-19-related imaging, both in terms of the total number of publications and representative research institutions. In terms of journals, *European Radiology* ranked among the leading contributors to this field, with an impact factor of 7.034. *Radiology* published fewer articles but had the most co-citation counts, making it the most influential journal in this field, with an impact factor of 29.146.
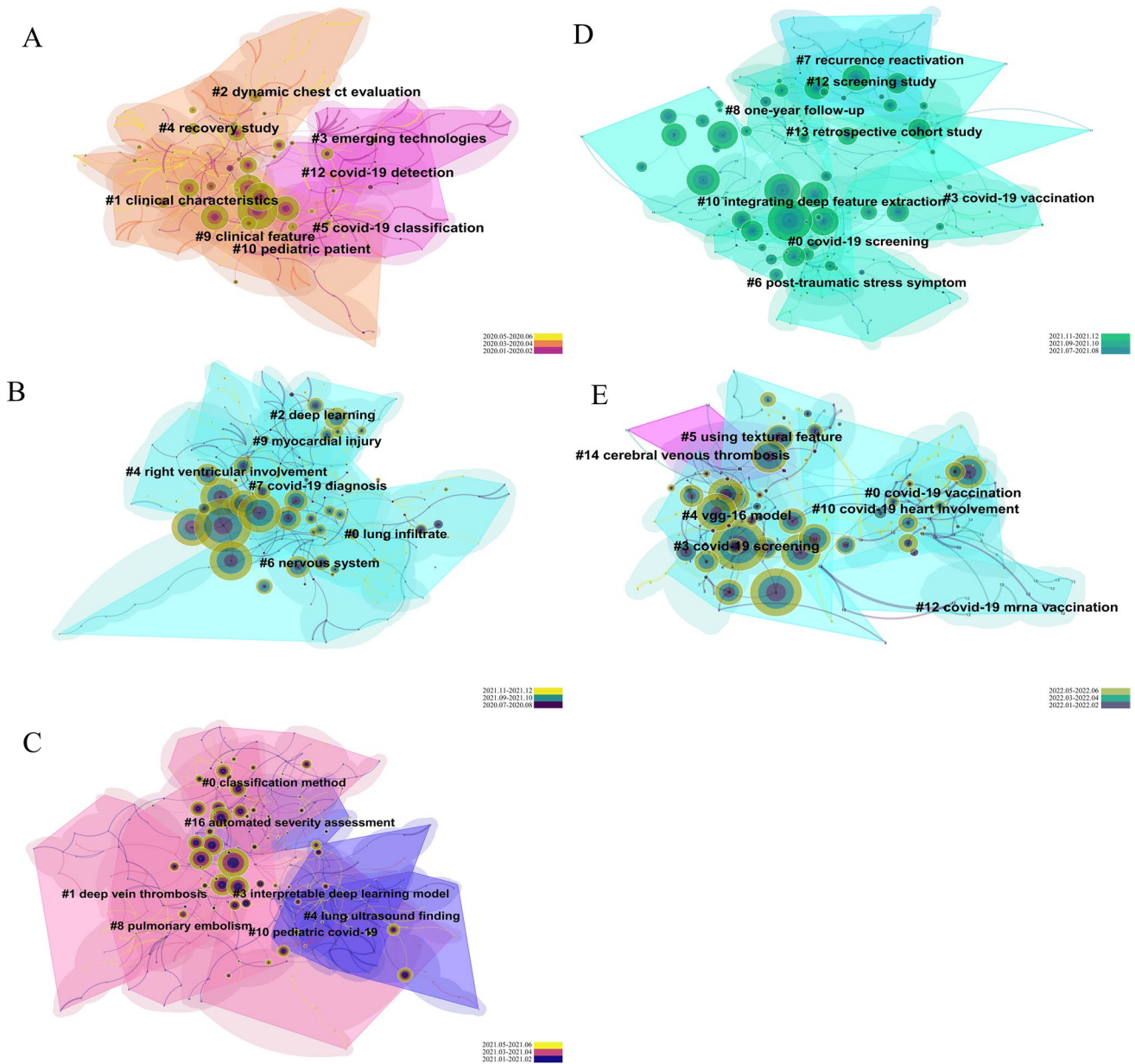
Top 200 Keywords with the Strongest Citation Bursts

Fig. 5 Top 200 keywords with the strongest citation burst values in COVID-19-related imaging research

Fig. 6 The knowledge map of keyword clustering. **A** Knowledge map of keyword clustering from January 2020 to June 2020 (Q=0.7211, S=0.9007). **B** Knowledge map of keyword clustering from July 2020 to December 2020 (Q=0.726, S=0.907). **C** Knowledge map of keyword clustering from January 2021 to June 2021 (Q=0.719, S=0.8885). **D** Knowledge map of keyword clustering from July 2021 to December 2021 (Q=0.7001, S=0.8862). **E** Knowledge map of keyword clustering from January 2022 to June 2022 (Q=0.7121, S=0.8983)

The keyword analysis revealed that deep learning was a popular topic in COVID-19-related imaging research. Deep learning networks are one of the most advanced methods for conducting medical imaging analysis tasks, such as image detection, segmentation, and classification [31–34]. In the keyword burst analysis, we identified the term "ground-glass opacity"; this also showed that, in the early stage of COVID-19-related imaging research, attention was primarily directed toward clinical and imaging features. Interestingly, we identified "vaccination" in the keyword emergence analysis. In recent studies,

[^{18}F]fluorodeoxyglucose([^{18}F]FDG)-PET/CT has been used to examine persistent COVID-19 states as well as alterations in metabolic states after mass vaccinations of the population [28].

We further analyzed changes in keywords according to the timeline. Expert radiologists' understanding of COVID-19 changed, with shifts from initial observation in early 2020 to diagnosis with AI in the second half of 2020 and the use of AI differential diagnosis technology and the radiographic appearance of COVID-19 complications in 2021, as well as developments in understanding COVID-19 vaccination, complications,

and predicting prognosis. At the pandemic's beginning, numerous publications primarily reported clinical features, and lung imaging data played a guiding role in patient treatment and rehabilitation evaluation [3, 35]. Multimodal imaging methods were utilized across the study period, ranging from initial X-ray and CT observations to the later use of modalities such as PET-CT, MRI, and ultrasound. The consistency and specificity of COVID-19 have been comprehensively observed in the lungs, nervous system, digestive system, endocrine system, reproductive system, and other organs [36]. Imaging experts worldwide have identified systemic changes in patients with COVID-19. Therefore, the latest AI technology combined with chest imaging can improve the speed and efficiency of COVID-19 diagnosis, differential diagnosis, and recovery prediction. Furthermore, deep learning can integrate additional modal information to assist in providing a comprehensive diagnosis and can introduce interpretable mechanisms, which may help resolve the "black box" problem of deep learning models [8, 33, 34, 37, 38]. After the recovery of patients with COVID-19, researchers began to focus on the post-recovery sequela of these patients [39, 40]. The application of AI technology in medical imaging was sufficiently mature before the COVID-19 outbreak; therefore, its use has enabled significant progress to be made in the field of COVID-19-related imaging. AI technology can be applied to the diagnosis and treatment of all stages of COVID-19. Its application in imaging is likely to promote early diagnosis, precise treatment, and faster recovery from COVID-19. In the second half of 2021, we identified themes involving follow-up and large cohort studies, wherein researchers focused on the long-term outcomes of patients with COVID-19 recovering from infection using relevant imaging findings. Most patients with COVID-19 have been found to have residual imaging abnormalities even after 1-year follow-up [41, 42].

There were some limitations to this study. First, as the relationship between co-citations is analyzed, only the citation database WoSCC can be selected, which may limit the inclusion of literature. Only the WoSCC database was used for article retrieval, therefore, some publications were not considered, and citation counts may be underreported. Second, CiteSpace was used to conduct a general bibliometric analysis of the current status of COVID-19-related imaging research. As full texts were not reviewed, some information may have been missed. Three, CiteSpace software allows for analysis of countries, institutions, and authors based on all co-authored countries, co-authored institutions, and co-authors; however, it cannot distinguish between first authors and corresponding authors.

Conclusion

Despite its devastating impact, COVID-19 has increasingly become part of everyday life. It remains necessary for medical imaging researchers to systematically evaluate the influence of COVID-19 through research on COVID-19-related imaging and to evaluate the ongoing effects of COVID-19 as assessed using specialized imaging tools, as well as consider how to reduce the adverse impact of COVID-19 through conducting imaging research. The future directions of COVID-19-related imaging research appear to be shifting into three new areas. First, COVID-19-related imaging research is shifting from lung structural changes to a greater focus on lung function, with the help of new technology and different modes of analysis as well as quantitative studies on lung micro-structural damage and change. Second, research is gradually shifting from the lungs to other parts of the body, including the nervous system, the circulatory system, and the digestive system. Third, imaging research is beginning to focus on the adverse effects of COVID-19 in the examination, diagnosis, and treatment of tumours, chronic diseases, and degenerative diseases. Radiologists need to develop guidelines or a consensus concerning the standardization of imaging assessment methods for assessing systemic changes related to COVID-19, which would be a challenging but immensely useful exercise.

Declarations

Guarantor The scientific guarantor of this publication is Dr. Chen Liu.

Conflict of interest The authors of this manuscript declare no relationships with any companies whose products or services may be related to the subject matter of the article.

Statistics and biometry No complex statistical methods were necessary for this paper.

Informed consent Written informed consent was not required for this study because data were downloaded directly from the database.

Ethical approval Institutional Review Board approval was not required because our study was a bibliometric analysis that used only publicly available data.

Methodology
- retrospective
- bibliometric analysis
- performed at one institution

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