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Publications on COVID-19 in radiology journals in 2020 and 2021: bibliometric citation and co-citation network analysis

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Abstract

Objectives The pandemic caused by SARS-CoV-2 has led to the rapid publication of numerous radiology articles, primarily focused on disease diagnosis. The objective of this study is to analyze the intellectual structure of radiology research on COVID-19 using a citation and co-citation analysis.

Methods We identified all documents about COVID-19 published in radiology journals included in the Web of Science in the period 2020–2021, conducting a citation analysis. Then we identified all bibliographic references that were cited by these documents, generating a co-citation matrix that was used to perform a co-citation network.

Results Of the 3418 documents indexed in WoS, 857 were initially "Early Access," 2223 had citations, 393 had more than 20 citations, and 83 had more than 100 citations. The USA had the highest number of publications (32.62%) and China had the highest rate of funded studies (45.38%). The three authors with the most publications were affiliated with Italian institutions, while the five most cited authors were Chinese. A total of 647 publications were co-cited at least 12 times and were published in 206 different journals, with 49% of the documents found in radiology journals. The institutions with the greatest presence among these co-cited articles were Chinese and American.

Conclusion This co-citation analysis is the first to focus exclusively on radiology articles on COVID-19. Our study confirms the existence of interrelated thematic clusters with different specific weights.

Key Points

- *As the pandemic caused by SARS-Cov-2 has led to the rapid publication of numerous radiology studies in a short time period, a bibliometric review based on citation and co-citation analysis has been conducted.*
- *The co-citation analysis supported the identification of key themes in the study of COVID-19 in radiology publications.*
- *Many of the most co-cited articles belong to a heterogeneous group of publications, with authors from countries that are far apart and even from different disciplines.*

Keywords Bibliometrics · Co-citation · Radiology · SARS-CoV-2

Abbreviations

ESCI	Emerging Sources Citation Index
JIF	Journal Impact Factor™
SCIE	Science Citation Index Expanded
SJR	SCImago Journal Rank
SNIP	Source Normalized Impact per Paper
WoS	Web of Science

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Introduction

SARS-CoV-2 is a highly pathogenic β-coronavirus that infects humans and caused a pandemic, with the first case reported in China on December 31, 2019 [1]. The clinical presentation of the infection caused by coronavirus 2019 (COVID-19) can vary from an asymptomatic condition [2] to a critical disease [3]. Its early diagnosis is fundamental to

prevent the emergence of new cases; thus, several diagnostic methods have been used, mostly microbiological [4] and radiological. A large body of literature has been published on the latter methods, mostly aimed at clarifying the evolving role of imaging techniques such as chest radiography, ultrasound, or computed tomography (CT), in the diagnosis and management of patients with suspected or confirmed COVID-19 infection [5, 6].

A scientific document cited in a radiology article, as in any other subject, becomes part of a defined body of literature on that specific topic and shares stronger or weaker relationships with the other cited documents. Citation analysis is precisely the area of bibliometrics that studies those relationships [7], thereby constituting a very common method for evaluating the impact of different information entities in scientific processes (such as authors, institutions, publishers, countries, and publications) [8].

Another bibliographic method that can provide additional information on the study of citations is co-citation analysis, which is most valuable for its ability to identify research clusters and intellectual structures in disciplines within a given field [9, 10].

The objective of this study is to examine the intellectual structure of radiology research on COVID-19 based on citation and co-citation analysis using bibliographic data retrieved from the Web of Science (WoS) Core Collection and mapped with VOSViewer.

Materials and methods

To map systems thinking about COVID-19 from the perspective of radiology, bibliographic data were collected to construct co-citation networks. A co-citation between two documents was established when both were listed in the references of a third document.

Study methodology

Phase 1: Identification of the study subject and data acquisition

A literature search was conducted in the WoS Core Collection (Thomson Reuters) on January 3, 2022. We retrieved all document types in any language published in journals in the category of "Radiology, Nuclear Medicine, and Medical Imaging" of the Journal Citation Reports™ with a title including the words "COVID-19" or "SARS-CoV-2." The results were restricted to the period of 2020–2021. This time interval was selected since, although cases of the disease were already reported at the end of 2019, COVID-19 was considered a global phenomenon only in 2020 when the pandemic was declared by the World Health Organization (WHO) [11]. "Early Access" content (electronically published in a nearly final state before their assignment to a specific volume and issue) was not excluded.

All study data was publicly available and did not contain public health information. Therefore, approval by the Bioethics Committee was not applicable and informed consent was waived.

Phase 2: Data processing and construction of a co-citation matrix

The publications were classified according to document type descriptions used in WoS Core Collection, which includes articles (research papers, brief communications, technical notes, full papers, and case reports), letters (readers write, questions and answers, letters to the editor, and comments) and editorial material (editorials, interviews, post-paper discussions, round table symposia, conference summary, research highlights, etc.).

During this phase, the necessary data were extracted from the selected sources. From these, a descriptive analysis of multiple variables (such as document type, journals, authors, and citations in WoS) was conducted. Citation density was calculated by dividing the number of citations for an article by the number of years since it was published. For articles with international collaborations, the countries of all co-authors were considered. In contrast, only the affiliation of the corresponding author was considered when analyzing funding.

Second, for the construction of a co-citation matrix, pairs of co-cited references were identified based on the references of the full set of analyzed documents. This facilitated the identification of pairs of documents with a high degree of co-citation.

Phase 3: Creation of co-citation network analysis and data interpretation

Once the matrix with absolute frequencies of co-citation was obtained, the data were processed with VOSViewer version 1.6.18 and Gephi. The combined use of both programs was chosen to minimize their individual limitations. A co-citation network was constructed with lines connecting the co-cited documents. Therefore, the nodes represented cited documents and the edges represented instances of co-citation. The edge weights represented the number of times two documents were co-cited by third articles (Fig. 1). To obtain the final sample, only documents with a co-citation threshold equal to or greater than 12 were considered. Another important parameter was the degree of a co-cited document, which was equal to the number of edges and represented the number of neighboring documents. This allows for the classification of the co-cited

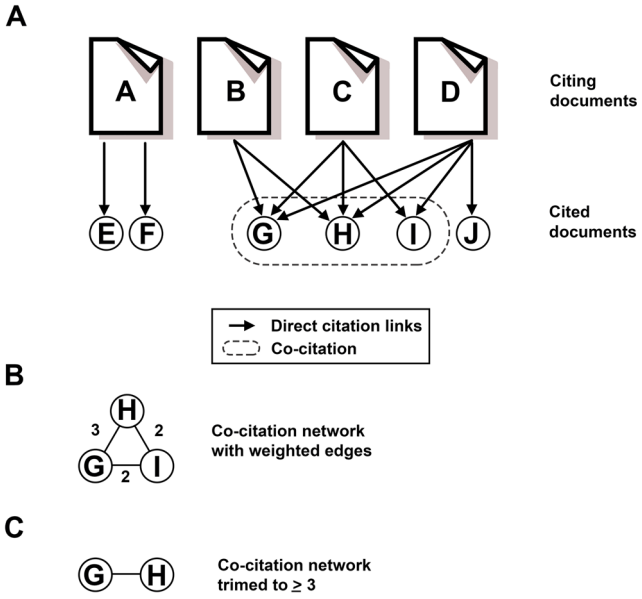

Fig. 1 Schematic summary of the relationships between nodes in a co-citation network. **A** Co-citation network. **B** Relationships between nodes and the value of their edges. **C** Co-citation network after excluding nodes with less than three co-citations

documents, thereby detecting close connections that allow inferring communities.

Network visualization

A graphic representation of the most significant associations between documents forms a network. It is thus possible to illustrate the strongest interrelationships between documents. Moreover, it is also possible to assess the structures formed by the components and subcomponents of the research, the links between the several subcomponents, and the documents that play an important role as intermediaries between nodes (Fig. 2).

Results

Descriptive analysis

Of the 3418 documents that met the inclusion criteria, 2561 (74.93%) were final publications and 857 (25.07%) were initially "Early Access" articles. During 2020, the final version of 1529 documents (44.74%) was published, which increased to 1759 (51.46%) in 2021. Ninety-three "Early Access" articles (2.72%) were assigned to an issue of a journal in 2022, while 37 (1.08%) were still in press. Most articles (79.29%) were indexed in the Science Citation Index Expanded (SCIE), and 19.95% were indexed in the Emerging Sources Citation Index (ESCI).

The different types of documents are presented in Fig. 3. Those published as articles stand out, followed by letters and editorial material. The category "other types" includes corrections (0.97%), proceeding papers (0.76%), news items (0.29%), and book reviews (0.03%). With the exception of 26 documents categorized as proceeding papers presented at a symposium or conference, the remaining 3392 (99.24%) were published in 175 scientific journals. Table 1 shows the 10 journals that published the highest number of articles.

Regarding citations in WoS, 2223 documents had citations (65.04%), 393 had more than 20 citations (11.48%), and 83 had more than 100 (2.43%). In total, they accumulated 47,475 citations, although 1195 documents did not receive any (34.96%). The distribution of the documents according to the degree of citation is shown in Fig. 4. The second issue of Radiology (volume 296) published on August 2020 stood out, receiving 9333 citations. The 10 most cited articles (Table 2) were published in open-access format in 2020 in journals indexed in SCIE; only three of them were funded.

The five authors with the highest number of publications were Ali Gholamrezanezhad (University of Sothern California, Los Angeles, USA) (n = 42), Riccardo Inchingolo and Andrea Smargiassi (Fondazione Policlinico Universitario Agostino Gemelli, Rome, Italy) (n = 18), Liming Xia (Huazhong University of Science and Technology, Wuhan, China) (n = 17), and Libertario Demi (University of Trento, Trento, Italy) (n = 17). In contrast, the five most cited authors were from China: Liming Xia (3995), Qian Tao (2684), Chenao Zhan (2684), Tao Ai (2643), and Zhenlu Yang (2591).

Table 3 lists the countries and organizations that published the highest number of documents. The first place is occupied by the USA (32.62%), followed by Italy (13.02%), China (12.64%), England (7.93%), and France (5.53%). Furthermore, six of the most prolific organizations were from the USA. China generated the first publications and, in contrast to the other top five countries, published nearly two-thirds of its research in 2020 (62.53%). Most documents were published in English (96.84%), except for a small percentage in other languages, namely, German (1.87%), Spanish (0.94%), and French (0.35%).

In total, 611 studies (17.88%) reported having received funding, either public or private, while 2807 did not (82.12%). The countries with the highest number of funded studies were China (45.38%), the USA (16.29%), Italy (16.8%), England (20%), and Germany (24.09%). Figure 5 shows the relationship between documents with and without funding in the 10 countries with the highest number of publications.

Co-citation analysis

A total of 33,496 co-citations were identified, with 7187 repeated in two or more documents. The co-citation network supported the identification of seven thematic research

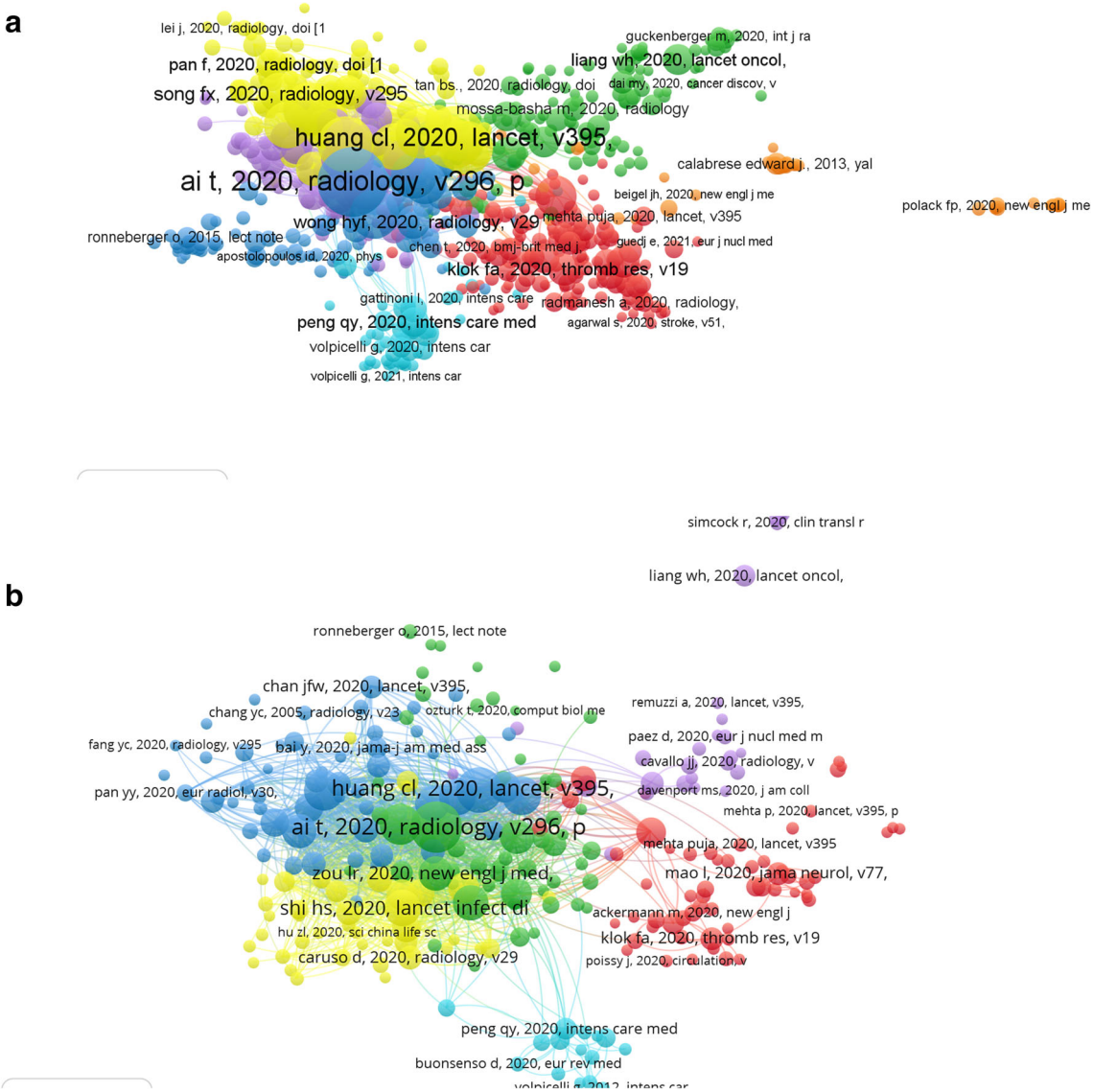

Fig. 2 Co-citation networks divided according to co-citation levels in **a** ≥ 12 edges, **b** ≥ 24, **c** ≥ 36, and **d** ≥ 48

clusters that together comprised 647 publications co-cited at least 12 times (Fig. 2a). Of all the publications collected in these clusters, most belonged to articles published after 2010 (97.06%, n = 628) and, essentially, from 2020 (85.78%, n = 555). Only three articles published before 2000 (1946, 1977, and 1988) were found.

The 647 documents were published in 206 different journals. Table 4 shows the main journals in decreasing order of importance based on the number of published documents. Regarding the research areas of the published documents and considering that a given article can belong to several areas, 319 (49%) were assigned to "Radiology, Nuclear Medicine, and Medical Imaging," while 120 (18.55%) belonged to "General Internal Medicine." Among the other 56 categories, "Cardiovascular System Cardiology" and "Oncology" stood out, with 48 (7.41%) and 38 (5.87%) documents, respectively. As for the place of origin of the authors, China and the USA were the countries with the highest number of researchers (Fig. 6). The most represented institutions were the Huazhong University of Science and Technology, with at least one author in 60 articles (9.27%), followed by Harvard University with 52 (8.04%), and Wuhan University with 34 (5.25%).

Concerning the type of published document, the most frequent were original articles (65.38%, n = 423), considerably ahead of other formats, such as editorial material (11.13%, n = 72), letters (10.66%, n = 69), and reviews (10.20%, n = 66). The other types of documents are a heterogeneous group of publications in which conference presentations or guidelines published by entities such as the WHO are particularly important.

Table 5 shows the most co-cited articles according to their community cluster. The first three communities are composed of documents primarily from high-impact factor radiology

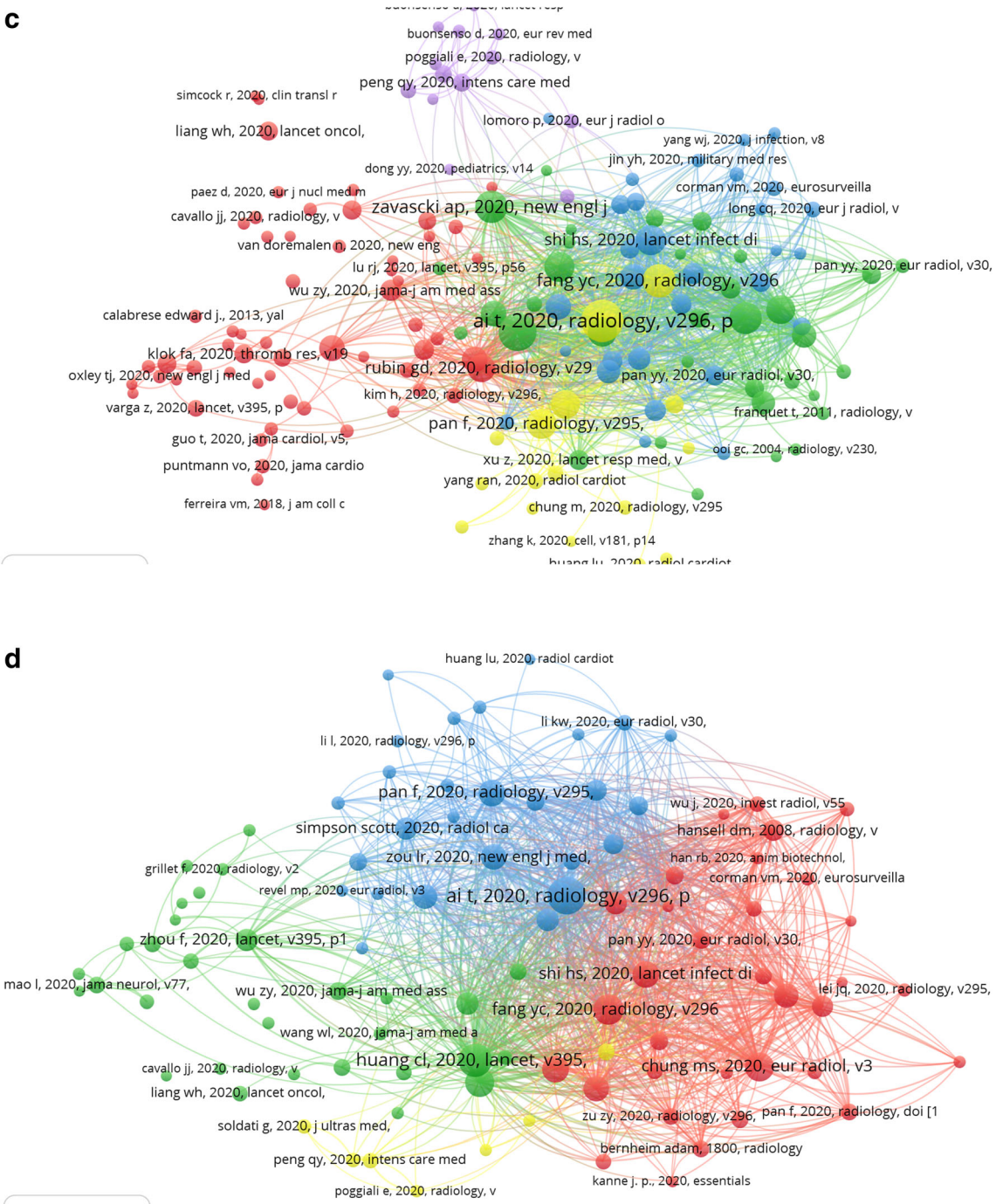

Fig. 2 (continued)

journals and mostly address the diagnosis of COVID-19 by chest radiography and CT. However, despite the similarities, nuances differentiate these three blocks. While the profile of the documents of the first community is more oriented towards interdisciplinary consensus or radiological severity indices, the other two communities provide documents focused on the correlation of radiology and laboratory parameters. Group two also includes some key articles on the evolution of COVID-19 in patients in intensive care units.

The documents of community four mostly focus on issues related to coagulation abnormalities observed in coronavirus-infected patients.

The fifth community is where most nuclear medicine articles are found. A few consensus documents and hospital

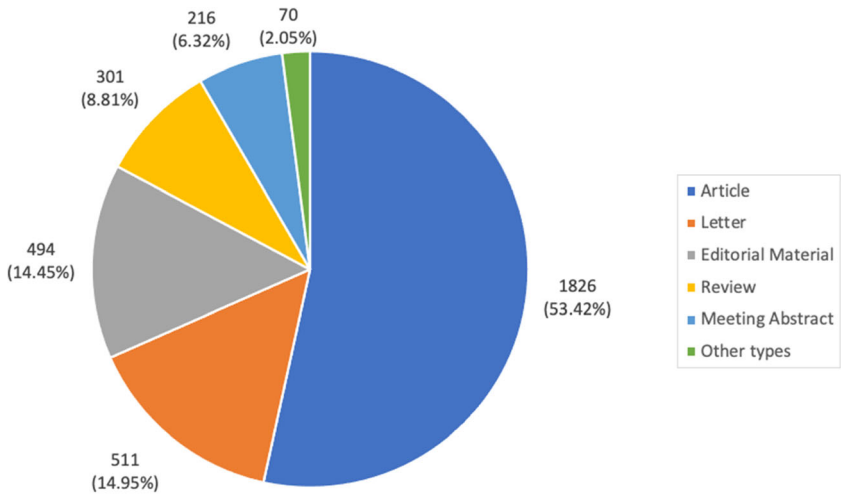

Fig. 3 Types of documents included in Web of Science that were published in the period of 2020–2021 and met the search criteria (absolute frequencies and percentages)

protocols that include recommendations for radiologists are also found in this group.

The sixth group features documents on the ultrasonographic diagnosis of pleuropulmonary manifestations of COVID-19.

Finally, the seventh group is composed of documents from clinical journals on topics such as artificial respiration in critical patients and corticosteroid treatment.

Of the 647 most co-cited articles, 32 were specific articles on artificial intelligence, obtaining a much higher citation average compared to the citation average of the rest of the articles (1864.59 and 1002.23, respectively). The documents with the most specific weight came from the Conference on computer vision and pattern recognition, and medical imaging computing journals, all of them published years before the pandemic.

Discussion

There are currently several articles that have conducted a co-citation analysis on COVID-19 [12–14] and some are even focused on a field of research [15] or a specific specialty [16]. However, this is the first study to focus specifically on publications in the specialty of radiology. This new approach provided a more detailed analysis of the most relevant topics from an imaging perspective, which might have been overlooked in a more generic study.

As shown in Table 4, more than 10% of the 647 most co-cited documents were published in the journal *Radiology*. Far behind is *European Radiology*. Noteworthy is the presence of *Radiology: Cardiothoracic Imaging* in fourth place, a journal that was created just a few months before the detection of the first cases of COVID-19 [17]. The relationship between the

Table 1 Top 10 radiology journals according to the number of articles published

Rank	Journal	Documents	WOS Index	JIF 2020	CiteScore 2020	SJR 2020	SNIP 2020
1	European Journal of Nuclear Medicine and Molecular Imaging	167	SCIE	9.236	11.6	2.313	2.054
2	Radiotherapy and Oncology	139	SCIE	6.280	8.0	1.892	1.651
3	Radiology	134	SCIE	11.105	-	3.118	-
4	Academic Radiology	123	SCIE	3.173	4.7	0.986	1.214
5	Clinical Imaging	114	SCIE	1.605	2.3	0.455	0.817
6	European Radiology	108	SCIE	5.315	7.7	1.606	1.749
7	American Journal of Roentgenology	97	SCIE	3.959	6.4	1.294	1.530
8	International Journal of Radiation Biology	94	SCIE	2.694	4.2	0.654	0.931
9	Egyptian Journal of Radiology and Nuclear Medicine	89	ESCI	-	0.5	0.190	0.291
10	American Journal of Neuroradiology	85	SCIE	3.825	5.8	1.391	1.596

JIF, Journal Impact Factor™; *WoS,* Web of Science; *SCIE,* Science Citation Index Expanded; *ESCI,* Emerging Sources Citation Index; *SJR,* SCImago Journal Rank; *SNIP,* Source Normalized Impact per Paper

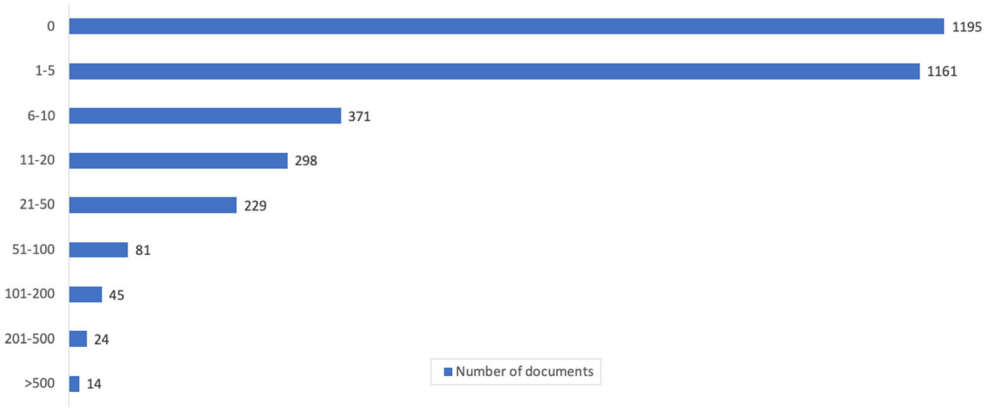

Fig. 4 Documents published in the period of 2020–2021 grouped according to the number of citations received in Web of Science (accessed January 3, 2022)

impact factor and the relative position of the publication in this classification is partially fulfilled in radiology journals, but not in clinical journals, such as *NEJM* or *The Lancet*, which have an impact factor that is much higher than the rest. This is expected, as radiology journals tend to frequently co-cite other radiology journals. However, as previously proposed by other authors, the impact factor is a poor measure of relative importance and is not always clearly associated with other bibliometric parameters [18]. Some of the journals in the category "Radiology, Nuclear Medicine, and Medical Imaging" that have received the most citations in the last decade [19] have had a lower relative weight in our co-citation clusters, as they address topics that are not strongly affected by the pandemic (cardiac imaging, neuroradiology, magnetic resonance imaging, and nuclear medicine).

As for the place of origin of the authors, China is the country with the highest number of researchers in our selection of co-citations, which is consistent with a previous article [19]. This contrasts with the low presence of Chinese journals in the group of 647 documents, which could indicate a potential loss of citations by foreign authors, since they are mostly written in Chinese.

The seven obtained communities are largely composed of articles investigating the radiological diagnosis of pulmonary manifestations of COVID-19. This is not surprising, since in 2020, the year in which most of these articles were published, the radiological diagnosis of pulmonary disease was attracting even more interest from researchers than the development of vaccines or treatments, according to the conclusions of another bibliometric study [20].

Community four is surely the best defined of all, since it focuses on hematology articles on the post-Covid hypercoagulable state. This has significant clinical and epidemiological relevance since an incidence of venous thromboembolism of up to 69% has been described in these patients [21].

Table 2 Top 10 radiology articles according to the number of citations received

Rank	Article title	Journal	Date of publication	Citations	Citation density
1	Correlation of Chest CT and RT-PCR Testing for Coronavirus Disease 2019 (COVID-19) in China: A Report of 1014 Cases	Radiology	August 2020	2552	1276
2	Sensitivity of Chest CT for COVID-19: Comparison to RT-PCR	Radiology	August 2020	1342	671
3	Chest CT for Typical Coronavirus Disease 2019 (COVID-19) Pneumonia: Relationship to Negative RT-PCR Testing	Radiology	August 2020	1016	508
4	Time Course of Lung Changes a Chest CT during Recovery from Coronavirus Disease 2019 (COVID-19)	Radiology	June 2020	999	499.5
5	COVID-19-associated Acute Hemorrhagic Necrotizing Encephalopathy: Imaging Features	Radiology	August 2020	800	400
6	Coronavirus Disease 2019 (COVID-19) A Perspective from China	Radiology	August 2020	705	352.5
7	Coronavirus Disease 2019 (COVID-19): A Systematic Review of Imaging Findings in 919 Patients	American Journal of Roentgenology	July 2020	655	327.5
8	Relation Between Chest CT Findings and Clinical Conditions of Coronavirus Disease (COVID-19) Pneumonia: A Multicenter Study	American Journal of Roentgenology	May 2020	549	274.5
9	Chest CT manifestations of new coronavirus disease 2019 (COVID-19): a pictorial review	European Radiology	August 2020	544	272
10	The Clinical and Chest CT Features Associated With Severe and Critical COVID-19 Pneumonia	Investigative Radiology	June 2020	537	268.5

Table 3 Top 10 countries and organizations according to the number of documents published

Rank		Country	Organization	Documents	Citations	Average citation per document
1		USA		1115	14372	12.889
	1		Harvard Medical School, Boston, USA	113	1089	9.637
	3		Massachusetts General Hospital, Boston, USA	64	857	13.390
	5		University of California, San Francisco, USA	51	871	17.078
	6		University of Texas MD Anderson Cancer Center, Houston, USA	51	253	4.960
	7		Icahn School of Medicine at Mount Sinai, New York, USA	44	1885	44.840
	8		University of Washington, Seattle, USA	41	413	10.073
2		Italy		445	7034	15.806
	4		University of Milan, Milan, Italy	59	542	9.186
3		China		432	21934	50.773
	2		Huazhong University of Science and Technology, Wuhan, China	71	7115	100.211
4		England		271	4568	16.856
5		France		189	3433	18.164
6		Germany		180	1840	10.222
7		India		169	546	3.230
8		Canada		160	1741	10.881
	10		University of Toronto, Toronto, Canada	41	173	4.219
9		Iran		135	1136	8.414
	9		Shahid Beheshti University Medical Sciences, Tehran, Iran	42	424	10.095
10		Spain		129	941	7.294

It is not surprising that ultrasound has its own community since it is an exam that attracted much interest at the beginning of the pandemic for its safety and accessibility [22, 23]. However, it has limitations. First, the doctor is very close to the patient when performing the ultrasound, with the risk of infection that this entails. Second, it is an operator-dependent technique.

Our results suggest that artificial intelligence has been underrepresented in terms of the total number of papers, despite the fact that this topic has received a higher number of citations on average. This is in line with other published work, in which articles on COVID-19 that include artificial intelligence have a higher number of citations and are published in journals with a higher impact factor [24].

Despite their recent publication, almost two-thirds of the analyzed articles had been cited and had a high total citation (47,475). Although the percentage exceeding 100 citations (2.43%) was similar to that described in a systematic review and meta-analysis of high-impact radiology journals (2.88%), the study used a much longer time window [25]. Furthermore,

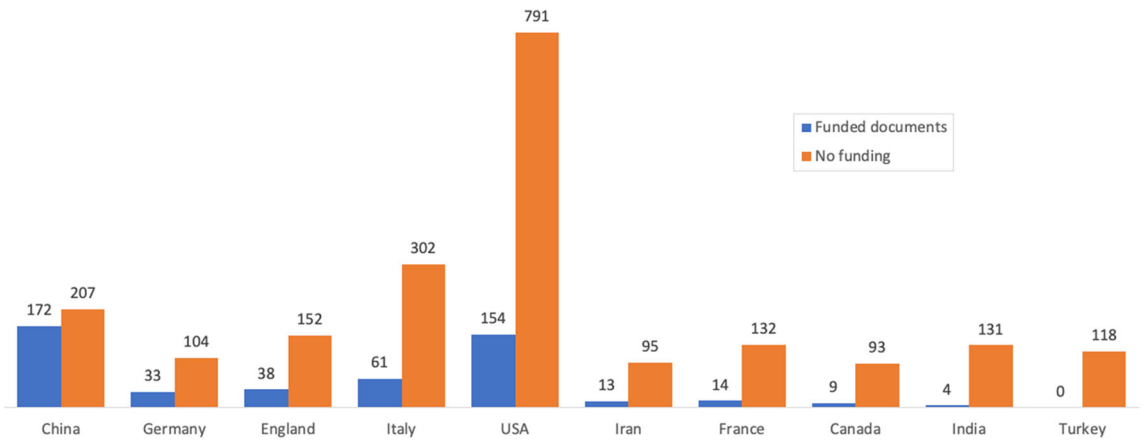

Fig. 5 Studies with and without funding in the 10 countries with the highest number of documents published in the period of 2020–2021 based on the affiliation of the corresponding author

Table 4 Ranking of the 10 journals with the highest number of co-cited documents in the main thematic clusters

Rank	Journals	Documents	Percentage (%)
1	Radiology	67	10.35
2	European Radiology	32	4.95
3	The New England Journal of Medicine	27	4.17
4	American Journal of Roentgenology	23	3.55
5	Radiology: Cardiothoracic Imaging	21	3.24
6	The Lancet	17	2.63
7	JAMA Journal of the American Medical Association	16	2.47
8	Academic Radiology	14	2.16
9	Journal of the American College of Radiology	12	1.85
10	Intensive Care Medicine	11	1.70
	Others	407	62,90

the most cited articles were published in open-access format, which results in faster dissemination and is associated with a higher number of citations and downloads compared to subscription journals [26–28].

COVID-19 disease gave rise to an unprecedented number of radiology publications starting in the second quarter of 2020, the number of which was even higher in 2021 (1529 as opposed to 1759). This is consistent with the trend observed in other disciplines, which peaked in March 2021, following an increase in overall incidence in late 2020 and early 2021 [29]. Simultaneously to this phenomenon, which can cause a saturation effect that hinders identifying and citing novel papers with relevant contributions [30, 31], scientific production in other fields of medicine decreased [32].

The speed at which such a volume of publications was generated can be read in two ways. On the one hand, it responds to the effort to produce and share new knowledge on the role of imaging in an emerging disease. On the other hand, many journals prioritized publications on COVID-19 [32] and, to this end, modified the editorial process, which is key to ensuring rigorous and quality studies. Thus, reduced acceptance and publication times, flawed peer-review processes, higher withdrawal and retraction rates [33], increased preprints [34, 35] and corrections, and frequent omission of reference to ethics committee's approval and informed consent [36] have been shown. Furthermore, there were fewer randomized controlled trials and more editorial, opinion, and single- or multi-case-based articles [36], which contrasts with

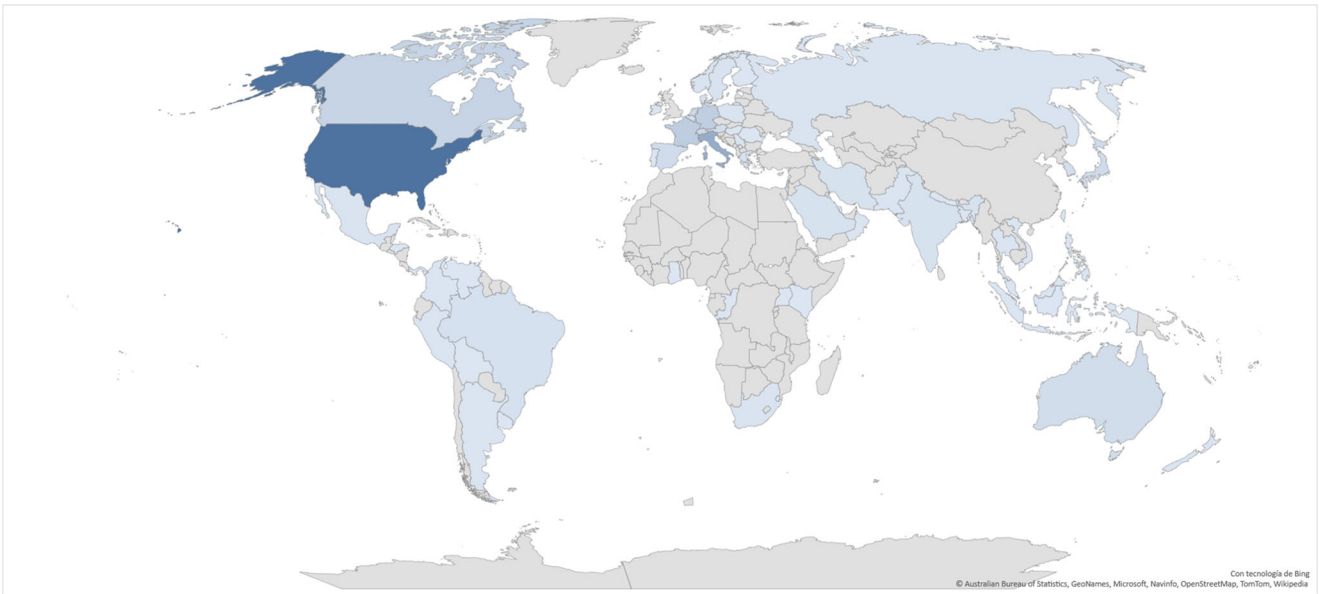

Fig. 6 Map chart showing the countries with the highest number of authors in the articles of the co-citation network

Table 5 Most cited documents by communities. The three most cited documents from each of the seven communities shown in Figure 2a are presented

Community	Topic (key words)	Reference	Times cited	Degree
1	Consensus, COVID-19 Testing, Follow-Up Studies, Severity of Illness Index, Tomography, X-Ray Computed / methods	ai t, 2020, radiology, v296, pe32, https://doi.org/10.1148/radiol.2020200642	509	8060
		pan f, 2020, radiology, v295, p715, https://doi.org/10.1148/radiol.2020200370	253	4559
		rubin gd, 2020, radiology, v296, p172, https://doi.org/10.1148/radiol.2020201365	224	3943
2	Coronavirus Infections/ epidemiology, Intensive Care Units/ statistics & numerical data, Clinical Laboratory Techniques, Tomography, X-Ray Computed	Huang cl, 2020, lancet, v395, p497, https://doi.org/10.1016/s0140-6736(20)30183-5	413	6138
		fang yc, 2020, radiology, v296, pe115, https://doi.org/10.1148/radiol.2020200432	323	5305
		chung ms, 2020, eur radiol, v30, p2182, https://doi.org/10.1148/radiol.2020200230	304	5149
3	Betacoronavirus/ isolation & purification, Coronavirus Infections/ virology, Sensitivity and Specificity Tomography, X-Ray Computed/ methods, Viral Load	shi hs, 2020, lancet infect dis, v20, p425, https://doi.org/10.1016/s1473-3099(20)30086-4	262	4686
		zou lr, 2020, new engl j med, v382, p1177, https://doi.org/10.1056/nejmc2001737	235	4174
		bai hx, 2020, radiology, v296, pe46, https://doi.org/10.1148/radiol.2020200823	181	3783
4	Blood Coagulation, Cardiovascular Diseases/ complications, Coronavirus Infections/ complications, Disseminated Intravascular Coagulation/ virology, Prognosis	zhou f, 2020, lancet, v395, p1054, https://doi.org/10.1016/s0140-6736(20)30566-3	180	2536
		tang n, 2020, j thromb haemost, v18, p844, https://doi.org/10.1111/jth.14768	95	1539
		klok fa, 2020, thromb res, v191, p145, https://doi.org/10.1016/j.thromres.2020.04.013	107	1530
5	Communicable Disease Control, Coronavirus Infections/ epidemiology, Positron Emission Tomography Computed Tomography, Radiology Department, Hospital/ standards	wu zy, 2020, jama-j am med assoc, v323, p1239, https://doi.org/10.1001/jama.2020.2648	123	2011
		kooraki s, 2020, j am coll radiol, v17, p447, https://doi.org/10.1016/j.jacr.2020.02.008	96	1402
		qin cx, 2020, eur j nucl med mol i, v47, p1281, https://doi.org/10.1007/s00259-020-04734-w	102	1265
6	Coronavirus Infections/ diagnostic imaging, Lung/ diagnostic imaging, Radiography, Thoracic, Tomography, X-Ray Computed, Ultrasonography	peng qy, 2020, intens care med, v46, p849, https://doi.org/10.1007/s00134-020-05996-6	95	1558
		soldati g, 2020, j ultras med, v39, p1459, https://doi.org/10.1002/jum.15284	77	1379
		lomoro p, 2020, eur j radiol open, v7, https://doi.org/10.1016/j.ejro.2020.100231	58	1345
7	COVID-19/ therapy, Dexamethasone/ therapeutic use, Respiration, Artificial, Survival Analysis, X-Ray Therapy / methods	horby p, 2021, new engl j med, v384, p693, https://doi.org/10.1056/nejmoa2021436	33	371
		calabrese edward j., 2013, yale journal of biology and medicine, v86, p555	49	341
		guan wj, 2020, eur respir j, v55, https://doi.org/10.1183/13993003.00597-2020	14	275

Each color in the table corresponds to the color shown in the graphical representation of the co-citation network

the usual practice in many radiological journals, where original articles and reviews had been predominant [32, 37, 38].

As for funding which ranged from 21.6 to 47.7% in radiology research according to previous studies [27, 39], a decrease in its mean frequency (17.88%) was observed, only surpassed by China (45.38%). Lastly, international collaborations between authors, which result in a positive impact on citation [40], have been described as heterogeneous and insufficient to provide a coordinated response in a context of a global emergency [40].

As limitations of the study, many journals and documents are not indexed in the WoS Core Collection, possibly because this database is likely biased in its inclusion of high-impact literature, neglecting lower-impact documents. Another limitation is that the co-citation analysis focuses only on highly cited publications, ignoring recent publications or those belonging to a niche far from the most common thematic clusters. Regarding possible lines of research emerging from our study, and since co-citation analysis allows for the assessment of the past in a specific field of research, a bibliographic

coupling and co-word analysis would be necessary to prepare a review more focused on the present and future, respectively.

In conclusion, the rapid growth of radiology publications related to COVID-19 in the toughest years of the pandemic clearly shows the relevance of the radiologist in the early diagnosis of the disease. This topic has greatly attracted the attention of researchers to radiology publications. Furthermore, the diverse origin of the most co-cited documents indicates that the research required global cooperation between various authors, organizations, and countries to progress.

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Statistics and biometry One of the authors has significant statistical expertise.

Informed consent This is a bibliometric study. Written informed consent was not required for this study because it is describing research without an intervention (observational study) and we didn't use identifiable data.

Ethical approval Institutional Review Board approval wasn't necessary.

Methodology
- retrospective
- observational
- multicentre study

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