




## NARRATIVE REVIEW

# Bibliometric analysis of the use of artificial intelligence in COVID-19 based on scientific studies

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## Abstract

**Background and Aims:** One such strategy is citation analysis used by researchers for research planning an article referred to by another article receives a “citation.” By using bibliometric analysis, the development of research areas and authors’ influence can be investigated. The current study aimed to identify and analyze the characteristics of 100 highly cited articles on the use of artificial intelligence concerning COVID-19.

**Methods:** On July 27, 2022, this database was searched using the keywords “artificial intelligence” and “COVID-19” in the topic. After extensive searching, all retrieved articles were sorted by the number of citations, and 100 highly cited articles were included based on the number of citations. The following data were extracted: year of publication, type of study, name of journal, country, number of citations, language, and keywords.

**Results:** The average number of citations for 100 highly cited articles was 138.54. The top three cited articles with 745, 596, and 549 citations. The top 100 articles were all in English and were published in 2020 and 2021. China was the most prolific country with 19 articles, followed by the United States with 15 articles and India with 10 articles.

**Conclusion:** The current bibliometric analysis demonstrated the significant growth of the use of artificial intelligence for COVID-19. Using these results, research priorities are more clearly defined, and researchers can focus on hot topics.

## KEYWORDS

artificial intelligence, bibliometric analysis, citations, COVID-19

## 1 | INTRODUCTION

The coronavirus disease (COVID-19) was detected in December 2019, and its rapid spread in most countries caused global concerns.<sup>1</sup> It is transmitted through face-to-face contact, mainly via respiratory droplets and contaminated surfaces. In patients with COVID-19,

clinical symptoms including fever, dry coughs, dyspnea, nausea, vomiting, diarrhea, headache, weakness, loss of sense of taste or smell, and so on are very common.<sup>2</sup> As of August 26, 2020, more than 6 million deaths due to COVID-19 have been recorded worldwide.<sup>3</sup> The COVID-19 pandemic has disrupted essential health services in most countries.<sup>4</sup>

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Artificial intelligence (AI) has reduced the burden on healthcare systems by identifying and diagnosing COVID-19 more quickly and has helped predict the future of such pandemics to provide adequate healthcare preparedness. Therefore, it can be used as an effective tool to reduce the burden of healthcare systems such as planning, diagnosing, and treating patients. AI can help promote the speed and accuracy of identifying COVID-19 cases to effectively deal with the current health crisis.<sup>5</sup> AI entails algorithm-grounded programs that can simulate the internal and intellectual conditioning of humans and enable machines to solve problems with knowledge. AI is widely employed in medication and health and can promote treatment styles, optimize case care pathways, and thus reduce medical errors.<sup>6</sup> Using AI, patients with critical COVID-19 outcomes can be identified using an inexpensive and accessible point-of-care test.<sup>7</sup> Totally AI-based techniques have enabled the follow-up and monitoring of affected people, rapid diagnosis, severity assessment, and early analysis prediction in controlling affected people at different stages of the COVID-19 pandemic. Even though obstacles and demanding situations exist, with the preparation of totally AI-based structures, lives can be saved and public health can be improved.<sup>8</sup>

Today, different indicators are utilized to examine the quality of studies.<sup>9</sup> One such strategy is citation analysis used by researchers for research planning an article referred to by another article receives a "citation."<sup>10</sup> One of the ways to check the impact of an article and compare between disciplines is to check the number of citations.<sup>11</sup> By using bibliometric analysis, the development of research areas and authors' influence can be investigated.<sup>12</sup> Numerous bibliometric studies have been conducted in various medical fields such as dentistry,<sup>13</sup> cancer,<sup>14</sup> osteoporosis,<sup>15</sup> aortic dissection,<sup>16</sup> care simulation,<sup>17</sup> and so on. To the best of our knowledge, there is no study that bibliometrically analyzes high-cited articles in the field of AI application in COVID-19. Considering the importance of the application of AI and the spread of the COVID-19 pandemic and the importance of highly cited articles, we analyzed the highly cited articles in this field so that researchers can adjust their research interests by using the results and help them in the process of research and better use of articles. The current study aimed to identify and analyze the characteristics of 100 highly cited articles on the use of AI concerning COVID-19.

## 2 | METHODS

### 2.1 | Search strategy

The Web of Science database is a leading and authoritative source for citation analysis.<sup>18</sup> On July 27, 2022, this database was searched using the keywords "AI" and "COVID-19" in the topic without restrictions on study type, and abstract availability. Due to the outbreak of COVID-19 in 2019, the articles were retrieved without any time limitation.

### 2.2 | Inclusion criteria

To select the articles, the following inclusion criteria were defined: (1) Articles focused on the use of AI concerning COVID-19 and (2) Included studies were limited to those written in the English language, (3) articles published in the form of reviews and editorial papers, reports, letters to editors, short briefs, and commentaries.

### 2.3 | Exclusion criteria

Articles with at least one of these exclusion criteria were excluded: (1) The title, abstract, or full text of the article was not related to the use of AI concerning COVID-19, (2) articles not written in English, (3) full text was not available.

### 2.4 | Data extraction

After an extensive search in the Web of Science database, inclusion and exclusion criteria were applied. All retrieved articles were sorted by the number of citations, and 100 highly cited articles were included based on the number of citations. Three researchers extracted the findings of the included studies and organized them in a table. One of the authors independently reviewed the extracted data and resolved any discrepancies. The following data were extracted: year of publication, type of study, name of journal, country, number of citations, language, and keywords. The data were tabulated and analyzed in Microsoft Excel 2016. Descriptive statistics were used to analyze the data. VOSviewer software, a common tool for bibliometric analysis and visualization, was employed for keyword analysis.

The authors confirm the availability of all selected studies and details of the references and citations of the retrieved articles are provided in the results section.

## 3 | RESULTS

In the initial search, 2633 articles were retrieved. Two thousand thirty-three articles were reviewed after applying inclusion and exclusion criteria, and finally 100 highly cited articles were selected and analyzed.

### 3.1 | Citations

The average number of citations for 100 highly cited articles was 138.54. The top three cited articles with 745, 596, and 549 citations were "Automated detection of COVID-19 cases using deep neural networks with X-ray images" published in *Computers in Biology and Medicine* journal in 2020, "Using AI to Detect COVID-19 and Community-acquired Pneumonia Based on Pulmonary CT: Evaluation of the Diagnostic Accuracy" published in *Radiology* journal in 2020,

and "Modified SEIR and AI prediction of the epidemics trend of COVID-19 in China under public health interventions" published in the *Journal of Thoracic Disease* in 2020, respectively.

### 3.2 | Language and year of publication

The top 100 articles were all in English and were published in 2020 and 2021. The majority ( $n = 77$ ) of the articles were published in 2020 (Figure 1; Tables 1–3).

### 3.3 | Countries of origin

China was the most prolific country with 19 articles, followed by the United States with 15 articles and India with 10 articles. Figure 2 depicts a map of the most prolific countries.

### 3.4 | Journals

The journal with the highest number of articles was *IEEE Access* ( $n = 6$ ), followed by *Chaos, Solitons & Fractals* ( $n = 5$ ), and *Medical Internet Research* ( $n = 4$ ).

### 3.5 | Article type

Table 4 summarizes the types of articles in the 100 most-cited articles. Out of 100, 48 articles were original research, and the remaining were reviews/systematic reviews ( $n = 43$ ), commentaries, news, editorials, short communications, and perspective papers.

## 3.6 | Co-occurrences and author keywords

A widely used indicator in bibliometric analysis is keyword analysis. The minimum number of occurrences of a keyword was fixed at five. Keywords were classified into three clusters: COVID-19, deep learning, and AI. Cluster 1 (COVID-19) included 13 links, 68 occurrences, and an average citation of 130.44; cluster 2 (deep learning) included 11 links, 23 occurrences, and an average citation of 162.14; and cluster 3 (AI) included 12 links, 35 occurrences, and the average citation of 135.23 (Figure 3A). Figure 3B illustrates the distribution of keywords based on their citation rate. Keywords in blue have fewer citations, and those in yellow have more citations. Figure 3C shows the density map in which the keywords are ranked based on the number of occurrences in the articles. When the occurrence of the words increases, the yellow color around the words will be darker.

## 4 | DISCUSSION

Bibliometric analysis studies are critical tools for evaluating research activities and researchers.<sup>119</sup> The number of citations of an article indicates its importance and influence in a specific research field.<sup>120</sup> The bibliometric analysis performed in this study is an attempt to provide relatively comprehensive data on scientific activities in the field of AI application in the COVID-19 pandemic, thereby providing researchers with easier access to relevant research trends. In this study, we identified 100 highly cited articles on the application of AI in the field of COVID-19 and analyzed the bibliometric indices, types of studies, and relevant keywords. To investigate the research trends and topics, the strategic method is bibliometric analysis of the literature. The

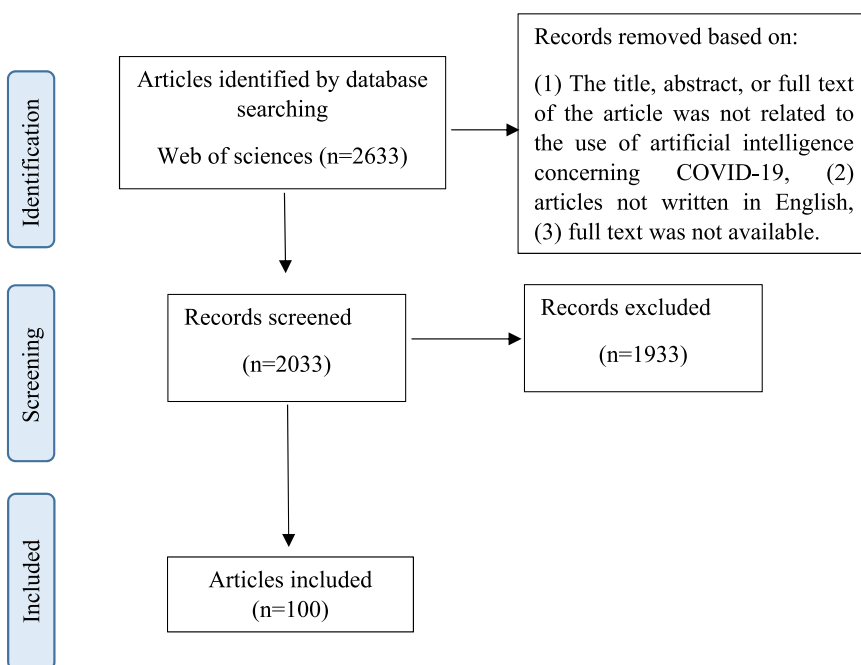


FIGURE 1 Flow chart of selecting articles.

TABLE 1 Top 100 most cited articles.

Authors	Year	Citations		Authors	Year	Citations	
		No.	Rank			No.	Rank
Ozturk et al. <sup>19</sup>	2020	745	1	Murphy <sup>20</sup>	2020	93	54
Li et al. <sup>21</sup>	2020	596	2	Morselli Gysi et al. <sup>22</sup>	2021	90	55
Yang et al. <sup>23</sup>	2020	549	3	Albahri et al. <sup>24</sup>	2020	90	56
Wang et al. <sup>25</sup>	2021	491	4	O'Dowd et al. <sup>26</sup>	2020	89	57
Shi et al. <sup>27</sup>	2021	431	5	Hassantabar et al. <sup>28</sup>	2020	88	58
Haug et al. <sup>29</sup>	2020	375	6	Maghded et al. <sup>30</sup>	2020	85	59
Mei et al. <sup>31</sup>	2020	369	7	Ko et al. <sup>32</sup>	2020	84	60
Vaishya et al. <sup>33</sup>	2020	321	8	Loey et al. <sup>34</sup>	2020	83	61
Chamola et al. <sup>35</sup>	2020	300	9	Nayak <sup>36</sup>	2021	82	62
Chowdhury et al. <sup>37</sup>	2020	289	10	Kaushik et al. <sup>38</sup>	2020	81	63
Ardakani et al. <sup>39</sup>	2020	262	11	Ke et al. <sup>40</sup>	2020	81	64
Jiang and Wen <sup>41</sup>	2020	248	12	Aslan et al. <sup>42</sup>	2021	80	65
Oh et al. <sup>43</sup>	2020	238	13	Albahri et al. <sup>44</sup>	2020	80	66
Lalmuanawma et al. <sup>45</sup>	2020	222	14	Zheng et al. <sup>46</sup>	2020	80	67
Dwivedi et al. <sup>47</sup>	2020	210	15	Kwekha-Rashid et al. <sup>48</sup>	2021	79	68
Togacar et al. <sup>49</sup>	2020	184	16	He et al. <sup>50</sup>	2021	78	69
Alimadadi et al. <sup>51</sup>	2020	177	17	Kummitha <sup>52</sup>	2020	78	70
Harmon et al. <sup>53</sup>	2020	174	18	Izquierdo et al. <sup>54</sup>	2021	77	71
Zeng et al. <sup>55</sup>	2020	174	19	Golinelli et al. <sup>56</sup>	2020	77	72
Jiang et al. <sup>57</sup>	2020	171	20	Wang et al. <sup>58</sup>	2021	76	73
Brunese et al. <sup>59</sup>	2020	162	21	Xie et al. <sup>60</sup>	2021	76	74
Loey et al. <sup>61</sup>	2020	159	22	Hassounah et al. <sup>62</sup>	2020	74	75
Cui and Zhou <sup>63</sup>	2020	148	23	Kumar et al. <sup>64</sup>	2021	73	76
Jamshidi et al. <sup>65</sup>	2020	143	24	Neri et al. <sup>66</sup>	2020	73	77
McCall <sup>67</sup>	2020	140	25	Saba and Elsheikh <sup>68</sup>	2020	69	78
Allam and Jones <sup>69</sup>	2020	140	26	Shuja et al. <sup>70</sup>	2021	68	79
Zhou et al. <sup>71</sup>	2020	139	27	Cohen et al. <sup>72</sup>	2020	68	80
Iwendi et al. <sup>73</sup>	2020	139	28	Tayarani <sup>74</sup>	2021	66	81
Bai et al. <sup>75</sup>	2020	137	29	Islam et al. <sup>76</sup>	2021	64	82
Rao and Vazquez. <sup>77</sup>	2020	134	30	Li et al. <sup>78</sup>	2021	63	83
Bhattacharya et al. <sup>79</sup>	2021	133	31	Alakus and Turkoglu <sup>80</sup>	2020	63	84
Stebbing et al. <sup>81</sup>	2020	125	32	Boskoski et al. <sup>82</sup>	2020	63	85
Shan et al. <sup>83</sup>	2020	122	33	Zhou et al. <sup>84</sup>	2020	63	86
Cosic et al. <sup>85</sup>	2020	120	34	Keshavarzi Arshadi et al. <sup>86</sup>	2020	63	87
Santosh <sup>87</sup>	2020	119	35	Nguyen et al. <sup>88</sup>	2020	63	88
Dong et al. <sup>89</sup>	2021	117	36	Jain et al. <sup>90</sup>	2021	61	89
Naude <sup>91</sup>	2020	115	37	Dotolo et al. <sup>92</sup>	2021	60	90
Jin et al. <sup>93</sup>	2020	113	38	Hung et al. <sup>94</sup>	2020	60	91

TABLE 1 (Continued)

Authors	Year	Citations		Authors	Year	Citations	
		No.	Rank			No.	Rank
Wu et al. <sup>95</sup>	2020	113	39	Agbehadji et al. <sup>96</sup>	2020	60	92
Liu et al. <sup>97</sup>	2020	113	40	Gupta et al. <sup>98</sup>	2020	60	93
Wang et al. <sup>99</sup>	2021	108	41	Vaid et al. <sup>100</sup>	2020	60	94
Kim et al. <sup>101</sup>	2021	108	42	Pham et al. <sup>102</sup>	2020	59	95
Bragazzi et al. <sup>103</sup>	2020	108	43	Ameen et al. <sup>104</sup>	2021	58	96
Bullock et al. <sup>105</sup>	2020	107	44	Ouchichaa et al. <sup>106</sup>	2020	58	97
Ardabili et al. <sup>107</sup>	2020	106	45	Civit-Masot et al. <sup>108</sup>	2020	58	98
Laguarta et al. <sup>109</sup>	2020	103	46	Di Vaio et al. <sup>110</sup>	2020	58	99
Elavarasan and Pugazhendhi <sup>111</sup>	2020	102	47	Acharya et al. <sup>112</sup>	2020	57	100
Ciotti et al. <sup>113</sup>	2020	101	48				
Boukhris et al. <sup>114</sup>	2020	101	49				
Mohamadou et al. <sup>115</sup>	2020	99	50				
Kumar et al. <sup>116</sup>	2020	96	51				
Pirouz et al. <sup>117</sup>	2020	96	52				
Wang et al. <sup>118</sup>	2021	93	53				

TABLE 2 Number of articles produced by countries.

Country	No. of articles
China	19
USA	15
India	10
UK, Italy	8
Canada	5
Turkey	4
Korea, Egypt	3
Iran, Malaysia, Iraq, Spain, Saudi Arabia	2
Austria, Qatar, Czech Republic, Mauritius, Croatia, Germany, Cameroon, Netherlands, Ireland, Taiwan, Pakistan, Vietnam, South Africa, Morocco, Hong Kong	1

results of this bibliometric study can help researchers, planners, and healthcare policy-makers. The current citation analysis shows the basic progress in recent studies, which indicates the improvement of the quality of research and the increase in the number of articles. The analysis also identified the most influential authors, countries, and journals on the application of AI to the COVID-19 pandemic. The obtained points about research priorities can help researchers to gain more mastery over the research area and be useful for future research activities.

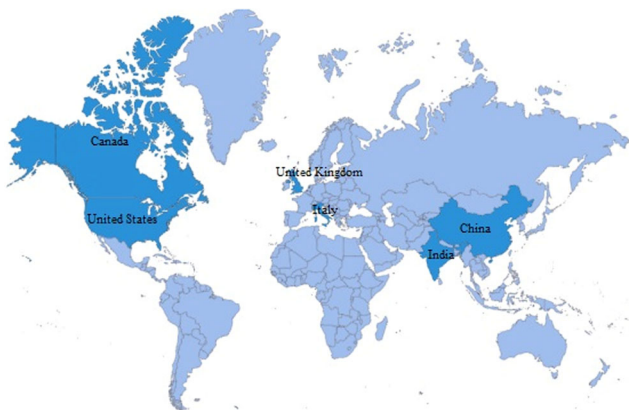
In recent years, COVID-19 has been recognized as one of the most important research fields in the world. AI has widely been used to prevent, identify, and treat this disease. Research shows that AI has a high performance in diagnosing and predicting COVID-19.<sup>121,122</sup> The most cited article is “automated detection of COVID-19 cases using deep neural networks with X-ray images”<sup>19</sup> with 745 citations, published in 2020. The country of origin of this article was Turkey. The research field of this article was “providing a deep learning model for the diagnosis of COVID-19.” The next most-cited article is “Using AI to Detect COVID-19 and Community-acquired Pneumonia Based on Pulmonary CT: Evaluation of the Diagnostic Accuracy”<sup>21</sup> with 596 citations, published in 2020. Its country of origin is China, which is the target of the article “development of a fully automated framework for the diagnosis of COVID-19 using chest CT”. Article citations depend on various factors, such as the impact factor of journals, the period of publication, and the accessibility of articles.<sup>123</sup>

China has the largest number of publications in this field, followed by the United States. The fact that the spread of the coronavirus started in China has probably been effective in conducting articles in this country. This shows that China and the United States are still at the forefront of AI and studies on COVID-19.

The analysis of journals allows researchers to detect journals related to the application of AI in COVID-19 and helps with journal evaluation and selection. Most articles in this field have been published in *IEEE Access* with an impact factor of 3.476, and

**TABLE 3** The top publishing journals in the field of using artificial intelligence in COVID-19.

Rank	Journal	Impact factor (IF)	No. articles
1	IEEE Access	3.476	6
2	Chaos, Solitons & Fractals	9.922	5
3	Journal of Medical Internet Research	7.08	4
4	Computers in Biology and Medicine	6.698	3
4	Radiology	29.146	3
5	IEEE Reviews in Biomedical Engineering	7.073	2
5	Diabetes & Metabolic Syndrome: Clinical Research & Reviews	-	2
5	IEEE Transactions on Medical Imaging	11.037	2
5	International Journal of Information Management	18.958	2
5	Nature Communications	17.694	2
5	Biosensors and Bioelectronics	12.545	2
5	The Lancet Digital Health	36.615	2
5	Journal of Medical Systems	4.92	2
5	International Journal of Environmental Research and Public Health	4.614	2
5	Applied Intelligence	5.019	2
5	Sustainability	3.889	2
5	Applied Soft Computing	8.263	2

**FIGURE 2** The map of the most prolific countries.

*Computers in Biology and Medicine* has the most cited articles in this field with an impact factor of 6.698. The next most-cited article was published in *Radiology* with an impact factor of 29.146. Based on the evidence, journals with a high impact factor

**TABLE 4** The types of articles in the 100 most cited articles.

Type of study	No. of articles	Mean (No. Citations)
Experimental	31	144.61
Commentary	1	174
News	1	140
Editorial	2	155.5
Short Communication	1	73
Perspective	4	227.75
Observational study	17	168.41
Review	40	111.025
Systematic review	3	82.33

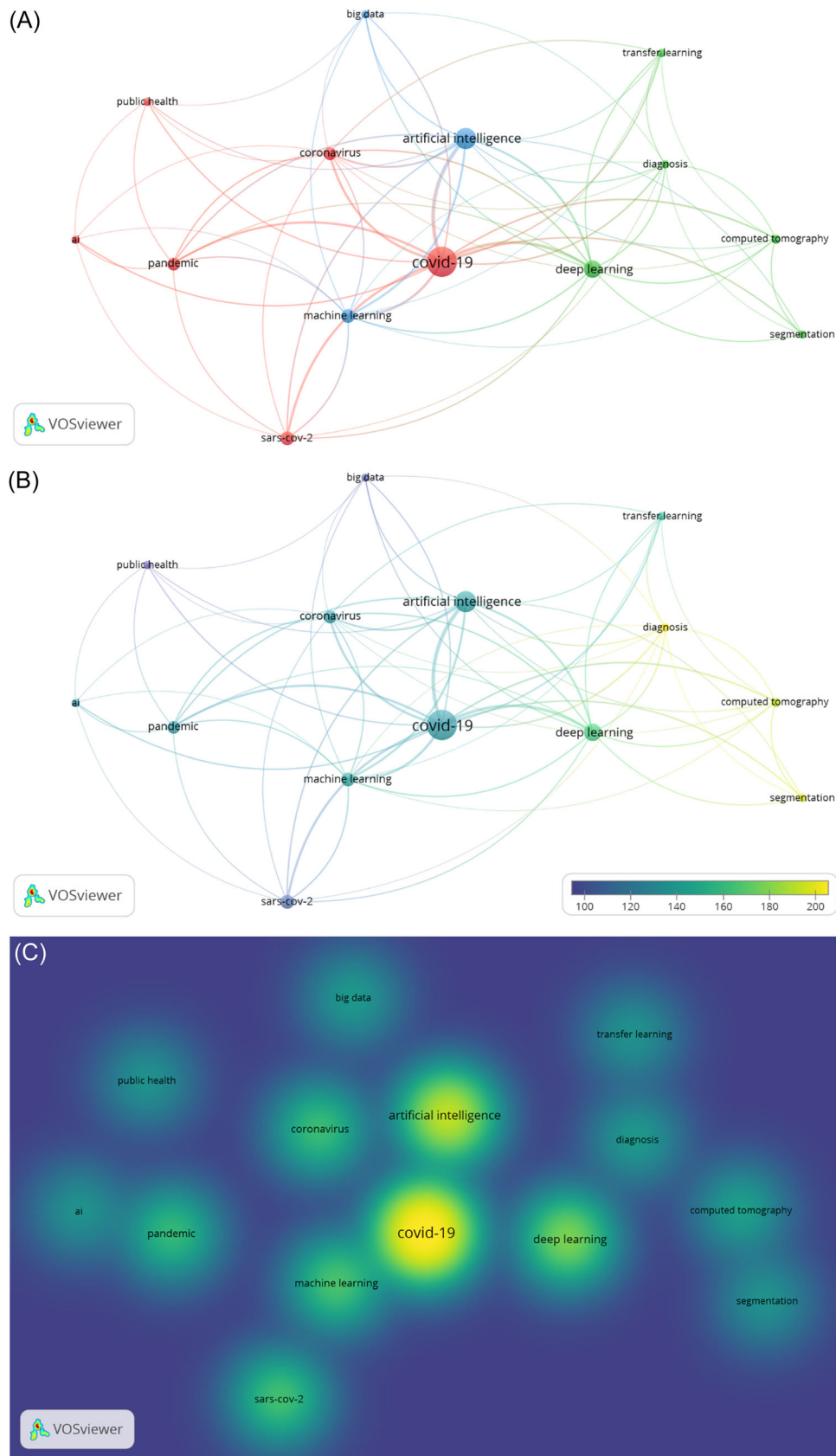
have a high scientific impact and attract more high-quality articles.<sup>124</sup>

All 100 reviewed articles were published in English, and 43% of them were reviews/systematic reviews. However, the highest number of citations belonged to experimental articles that often used COVID-19 data for modeling with different AI methods. Due to the large volume of COVID-19 data in recent years, various prediction and diagnosis models may have been performed on such data, and the results of these studies must be very valuable for researchers and readers. All this increases the number of citations to these articles.

The VOSviewer, which is a popular software for visualization, was employed to analyze the keywords and determine the relationship between the keywords. The most frequently used key terms “COVID-19” and “AI” were in research fields, indicating hot topics in these fields. The clusters of COVID-19, AI, and deep learning were the three main clusters that had the highest number of occurrences. In most articles, the deep learning method was adopted to model the prediction of COVID-19, demonstrating that it is a novel and exciting field with great potential.<sup>125</sup> Through cluster analysis, we find that AI techniques in the design of various studies are hot topics in this field.

#### 4.1 | Limitations

One of the limitations of the article was the use of a single database (Web of Science) to review highly cited articles, and we only reviewed the citations based on this database; meanwhile, the review of other databases might change the number of citations and the results. In addition, articles published a long time ago receive more citations; still, due to the spread of COVID-19 since 2019, studies had been published within 1 or 2 years and may not have received many citations. Finally, the keyword search in this study might not have covered all articles.



**FIGURE 3** Network visualization map of author keywords of the 100 most-cited articles in the field of artificial intelligence in COVID-19. (A) Author keywords visualization mapping. (B) Overlay visualization by citation. (Network map in which nodes and clusters are colored based on citation). (C) Density visualization.

## 5 | CONCLUSION

This study reviewed and examined the bibliometric analysis of articles on the use of AI in COVID-19. Although the number of citations of an article does not indicate its high quality,<sup>13</sup> it can provide a framework for future research opportunities. This study provides the possibility of identifying relevant details to provide scientific mapping in the field of AI applications in connection with the COVID-19 pandemic. Scientific analysis can draw the research of authors and institutions considering different aspects. Also, it allows us to identify the most cited authors, institutions and articles. The findings of this research emphasize the following points: (1) Based on this bibliometric analysis, attention in the field of using AI for the COVID-19 pandemic is still increasing. (2) Citation analysis does not indicate the scientific quality of articles, but the number of citations an article receives after several years indicates the status of the impact of scientific research in that field. (3) China has been one of the leading countries in publishing articles related to the use of AI in the COVID-19 pandemic. (4) Most of the published articles were original and review. Using these results, research priorities are more clearly defined, and researchers can focus on hot topics. Future research can address different aspects of AI in a variety of diseases.

### AUTHOR CONTRIBUTIONS

**Zahra Karbasi:** Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing—original draft; writing—review and editing. **Sadrieh H. Gohari:** Data curation; formal analysis; methodology; writing—review and editing. **Azam Sabahi:** Data curation; formal analysis; methodology; writing—review and editing.

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### CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

### DATA AVAILABILITY STATEMENT

All data and material collected are presented in the study. Clarification on any matter can be made through the corresponding author.

### ETHICS STATEMENT

No human subjects were included.

### TRANSPARENCY STATEMENT

The lead author Zahra Karbasi affirms that this manuscript is an honest, accurate, and transparent account of the study being

reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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