Research Article

Artificial Intelligence and Machine Learning in Oncology: Historical Overview of Documents Indexed in the Web of Science Database

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Abstract

Objectives: Artificial Intelligence (AI) and Machine Learning (ML) are innovations contributing to the diagnosis and treatment of cancer. The aim is to present an overview of AI and ML application in oncology research.

Methods: Data was retrieved from the web of science. Bibliometrics and R packages and VOSviwer software was used for mapping and network analysis.

Results: 214 publications were retrieved written by 1161 authors and published in 133 journals from 1988 to 2021. There has been a steadily increasing trend of research over the past years. AI and ML in oncology research have attracted the interest of the scientific community and the readership. The first ranked documents received a 173 citations score. It covers hot topics related to common mistakes in diagnostic classification in clinical and the potential future opportunities for precision oncology using AI. Aneja S and Thompson RF from the USA are the most productive author. Frontiers in Oncology is the most productive Journal. The United States is leading the research effort on the topics, followed by Korea. The collaboration and network between countries in AL or ML in oncology research were documented.

Conclusion: AI and ML in oncology research have attracted the interest of of the scientific community and readership. The trend of research has been steadily increasing globally.

Keywords: Artificial Intelligence, bibliometric analysis, machine learning, oncology

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The scientific community's interest in Artificial Intelligence (AI) and machine learning (ML) has increased through the years, entering into a phase in which society's imagination has been captured and generating enthusiasm for the potential to improve human health.[1] Further studies suggest that AI can perform equally or better than humans at essential healthcare tasks, such as diagnosing disease, improving drug discovery, and upgrading. In

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the last decade, the exponential growth of AI and ML has supported optimal decision-making by super-intelligence through the number of massive data analyzed in record time.[2] These two domains have become a fundamental part and tools playing notable roles in a wide variety of aspects of medical research, such as general clinical oncology and cancer therapy, developed to tackle a variety of cancer-related challenges besides other healthcare to improve disease diagnosis and development of effective treatments.[3]

There is growing interest to offer the scientific community the landscape of the most promising work on AI in oncology within the area of cancer imaging, specifically digital pathology, radiographic imaging, and clinical photographs.[1,4] The progress in this field is due to the availability of electronic health records as big data that can provide phenotypic profiles of large cohorts of patients and use follow-up processing in radiation oncology and medicine to detect the disease and predict outcomes.[3]

Artificial Intelligence or machine learning in Oncology profoundly contributes to the medical society by pursuing material goals and aims. They may potentially be used to facilitate primary cancer prevention in the future, especially in the era of big data oncology.[1] Numerous investigations have been carried out to understand the development of AI and ML applications in oncology. However, despite this growing interest, AI and ML applications in oncology remains essential, and despite benefits for oncology, knowledge productivity to support the applications remain scarce. Much work remains to be done by the scientific community to determine the quality of research conducted in these domains and highlight the need for present and future research direction. Therefore, we employed bibliometric analysis using the Web of Science (WoS) online database, a repository for scientific documents across all disciplines to determine the prominent research fronts and output in AI and ML conceptualized on oncology. Our focus was to identify frontiers in research and topics over the past years, to assess research trends. This approach has been adopted in numerous scientific fields for mapping and thematic analysis.[5–9] The bibliometric analysis of scientific research productivity by authors, countries, and support funding agencies for research and collaboration networks, can provide helpful information for Oncology experts and channel future research directions.

Methods

Sources of Data and Searching Strategies

Data were retrieved from the Thomson Reuter Web of Science database (https://www.webofscience.com/wos). This database includes several bibliographic databases in the medical disciplines and covers the highest impact quality of publication and scientific journal that provides comprehensive metadata of the published work.

Search Strategy

The litearture search on the Web of Science was conducted on August 15, 2021. All publication was search form it first indexed up to August 15, 2021. The search approach is based on the query, which was uniquely developed with the aim at establishing the interest existing in the scientific literature on the field of Artificial Intelligence and Machine Learning in Oncology over the past 33 years by using the following terms: Title (Oncology* or neoplasms* or oncologys*) AND (artificial intelligence* or machine learning* or deep learning* or neural network* or logistic regression* or random forest* or support vector machine* or fuzzy logic* or computer vision* automatic programming* or speech understanding* or autonomous robots* or intelligent tutoring* or intelligent agents* or neural network* or voice recognition* or text mining*. Publication Indexes= Science Citation Index Expanded (SCI-expanded), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Conference Proceedings Citation Index- Science (CPCI-S), Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH), Emerging Sources Citation Index (ESCI), Current Chemical Reactions (CCR-Expanded), Index Chemicus (IC). Timespan=All years. This study analyzes all documents on this subject found in the WOS to assess the the overall contribution over the years in the field. The resulting samples comprise 214 papers, including (72 Articles, 64 abstracts, 45 reviews, 19 Editorial, 10 Proceedings, 4 early accesses, 4 letters, and 2 news). All publications identified were the English language—timespan: 1900 to August 15, 2021.

The bibliometric indicators, including research title, year of publications, affiliations, country or territories, institution, the productive journal in which authors have published research on AI and ML in oncology, keywords, authors, organizations and area of web of science research category in which the author has published. Research indexed, funding agencies, national and international collaboration were downloaded from the Web of Sciences database. Two authors (THM, IHM) dependably verified

the data collection and identify the top-cited documents. The validity of the search documents strategy was tested manually. All data were collected and downloaded in Excel CSV format or Plain TXT format for further analysis. Like other bibliometric studies, there was no need for ethical issues in the following research where the data was downloaded from public sources and didn't involve human or animal exposure.

A Bibliometric Analysis

Descriptive statistics was used to determine the frequency outcome of the study variables. The bibliometric indicators and results were presented in descending order using standard competition ranking (SCR). Bibliometrics and R package applied in R was used for comprehensive science mapping to obtain the mean of articles per author and article, and also average years from publication, and Collaboration Index between authors. Impact factors (IF) and h-Index were used to assess quality and quantity based on the number of publications and the influence of work premised on citations citations. Furthermore, the top 10 journals' impact factor was obtained from the journal citation report (JCR)© ranking: 2020.

Results

This study focuses on offering a brief overview of AI and ML application in oncology research. The descriptive analysis in Table 1 shows the basic statistics of the publication. The analysis indicates that this study included 214 documents published in 133 sources, contributed by 1161 authors. The mean of average years from publication was 2.65 and h_index 2. A total of 408 Keywords Plus was reported as a parameter for capturing the content and scientific concepts presented in articles published in Artificial Intelligence or Machine Learning in Oncology research. In addition to 276 Author's Keywords (DE) were reported representing their research interests in the area.

Figure 1 shows the development of the research productivity in Artificial Intelligence or machine learning in Oncology from its first published paper in 1988 until August 15, 2021.

The trend remained stable throughout the search period 1988 to 2014. Later there was an increase in the number of publications. The growth of publication indicates a steadily increasing trend of global documents from the year 2017 with 12 (5.61%) publications to 21(9.81%) publications in 2018 and 64 (29.91%) publications in 2020. Most research was published in 2020(64, 29.91%).

Table 1. Descriptive analysis of publications

| Description	Results
Timespan	1988:2021
Sources (Journals, Books, etc)	133
Documents	214
Average years from publication	2.65
H_index	2
Sum of times cited	1767
Sum of time cited without self-citations	
Average citations per document	8.257
Average citations per year per doc	2.215
References	5900
Document contents	
Keywords Plus (ID)	408
Author's Keywords (DE)	276
Authors	
Authors	1161
Author Appearances	1405
Authors of single-authored documents	21
Authors of multi-authored documents	1140
Authors Collaboration	
Single-authored documents	21
Documents per Author	0.184
Authors per Document	5.43
Co-Authors per Documents	6.57
Collaboration Index	5.91
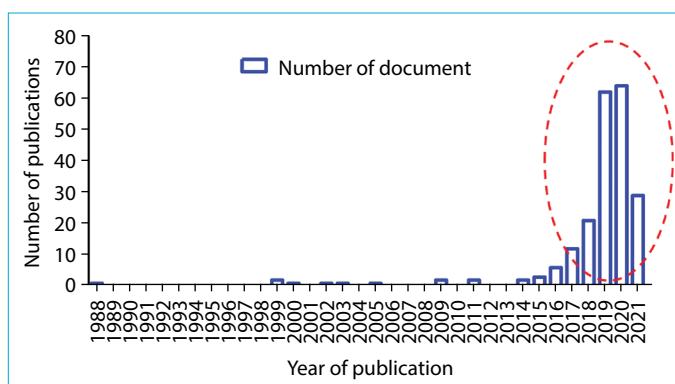
Figure 1. Annual trends of publications in Artificial Intelligence and Machine Learning in Oncology, from 1988 to August 15, 2021.

Top Most Cited Documents

Over the past years, AI or ML in oncology research productivity has shown broad interest among the scientific community and readership. The analysis in Table 2 shows the top 10 most cited documents retrieved from the Web of Sciences database. The first rank documents received a 173 citations score, where it covers the hot topics related to common mistakes in diagnostic classification in clinical when using ANNS.[10] The second-ranked article show that although precision

Table 2. Top 10 most top cited documents

SCR	Article title	TC
1	On the misuses of artificial neural networks for prognostic and diagnostic classification in oncology	173
2	artificial intelligence in digital pathology - new tools for diagnosis and precision oncology	140
3	Big Data and machine learning in radiation oncology: State of the art and future prospects	111
4	Automated quantitative tumor response assessment of MRI in neuro-oncology with artificial neural networks: a multicentre, retrospective study	84
5	Risk assessment in localized primary cutaneous melanoma - A Southwest Oncology Group study evaluating nine factors and a test of the Clark logistic regression prediction model	76
6	artificial intelligence in radiation oncology: A specialty-wide disruptive transformation?	71
7	Artificial neural networks for decision-making in urologic oncology	69
8	Radiomics and Artificial Intelligence for Biomarker and Prediction Model Development in Oncology	47
9	Investigating machine learning techniques for MRI-based classification of brain neoplasms	40
10	Emerging Applications of Artificial Intelligence in Neuro-Oncology	39

SCR: Standard competition ranking; TC: Total citations as update in August 15, 2021.

Table 3. Top 10 authors productive and influential authors with five documents and more

SCR	Authors	Author ffiliation	NP	TC	ACP	h_index
1	Aneja S	Yale University, Dept Therapeut Radiol, New Haven, CT, USA	6	108	18	4
2	Thompson RF	Oregon Hlth & Sci Univ, Dept Radiat Med, Portland, USA	6	95	15.83	4
3	Valdes G	Univ Calif San Francisco, San Francisco, USA	5	121	24.2	4
4	CHO BJ	Hallym Univ, Dept Ophthalmol, Coll Med, Chunchon, South Korea	6	46	7.67	4
5	Fuller CD	Univ Texas MD Anderson Canc Ctr, Houston, TX, USA	4	102	25.5	4
6	Takahashi S	Natl Canc Ctr, Div Mol Modificat & Canc Biol, Chuo Ku, 5-1-1 Tsukiji, Tokyo, Japan	5	24	4.8	2

SCR: Standard competition ranking; ACP: Average citations per item; TC: Total citations; NP: Number of publications.

oncology's provide potential future opportunities using AI are needed needed for well-curated validation datasets.[11]

Author's Performance Analysis

In total, 1161 authors with an average of 5.32 authors per document. The authors' information (H_index, Average citations per item, Total sources, number of publications, and number of citations reported without self-citations) was used to offer baseline information and identify the author with five or more documents as well as their institution. Aneja S from Yale University, Department of Therapeutic Radiology New Haven, CT, USA published the most research on Artificial Intelligence or machine learning in Oncology with six papers, followed by Thompson RF from Oregon Health & Science University, Dept Radiat Med, Portland, the USA with six articles (Table 3).

Three-Fields Plot Analysis

In the author's analysis, we identify the most active authors on Artificial Intelligence and Machine Learning in Oncology. At this stage, we further investigated these data records to see specific hot research areas, and we faced limitations in the capabilities of the Web of Science Analyse Results tool. We used the same data record to analyze further the

relationship between authors, affiliations, and keywords and how they are related through a Sankey diagram (Fig. 2).

Journal Analysis

The analysis of the journal sources contribution to published documents in Artificial Intelligence and Machine Learning in Oncology, which is especially important for deciding which journals to read when performing a literature review. During the analysis, we identified 133 published journal documents. According to the number of publications, Frontiers in Oncology, followed by International Journal of radiation oncology biology physics, JCO Clinical Cancer informatics, and Cancers (Table 4). The research domain of these journals was Oncology, Radiology, Nuclear Medicine, Medical Imaging, and biomedical informatics.

The Analysis of Top 10 Most Productive Countries and Regions

Twenty-four countries contributed in published 214 documents in Artificial Intelligence or machine learning in Oncology. According to the number of publications, The United States is leading the research effort on the topics of Artificial Intelligence or machine learning in Oncology with the most published papers (96, 44.85%), followed
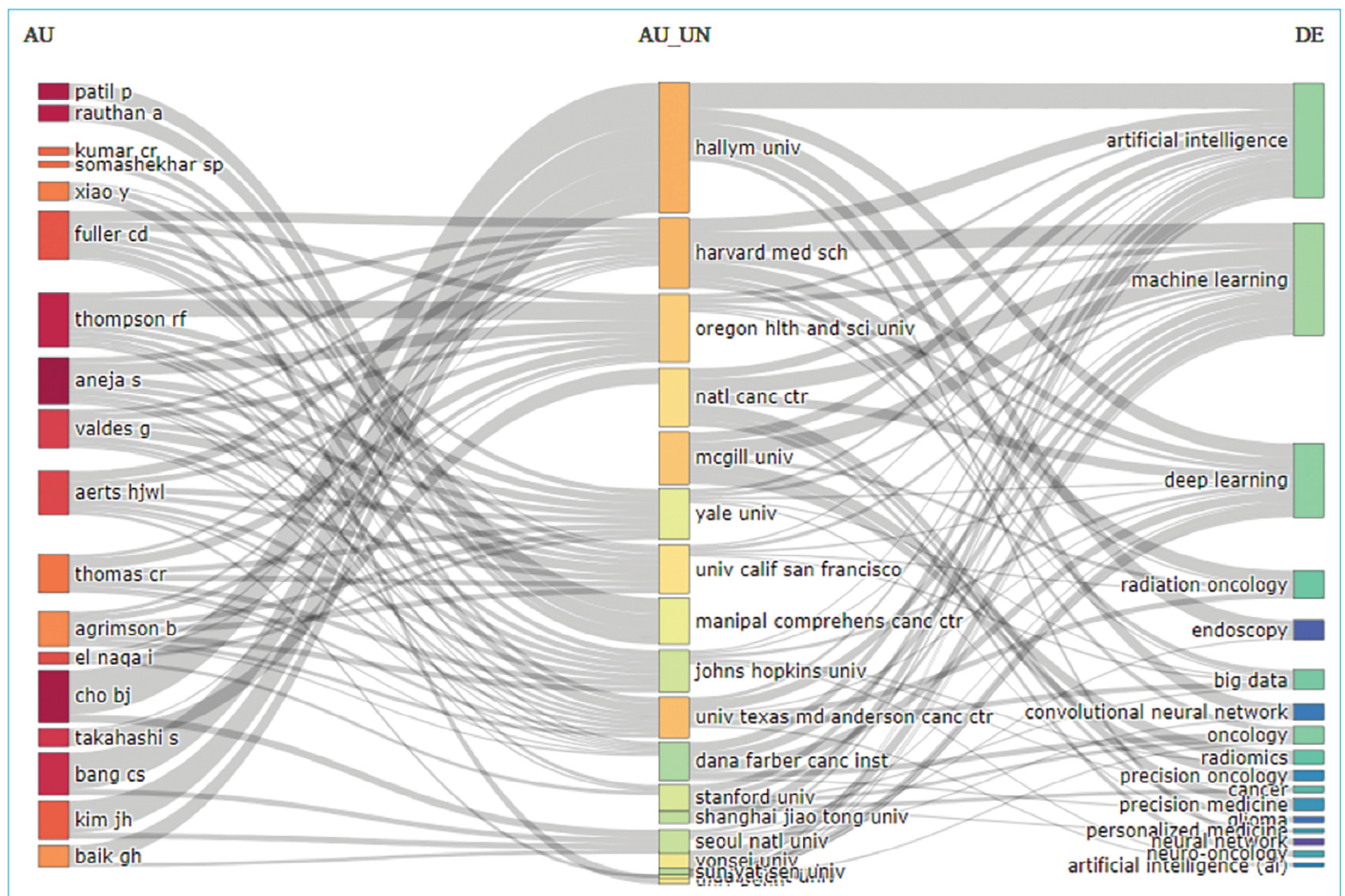
Figure 2. Three-Fields Plot: Affiliations-Middle, Author-Left, and Keywords- right field.

R	Element (n=133)	h_index	TC	NP	IF	Research domain
	Table 4. Top 10 journals in analysis					
1	Frontiers in Oncology	4	79	7	6.244	Oncology
2	International Journal of radiation oncology biology physics	4	32	4	7.038	Oncology
						Radiology, Nuclear Medicine & Medical Imaging
3	JCO Clinical Cancer informatics	2	9	4	NA	Biomedical informatics
4	Cancers	3	48	3	6.639	Oncology
5	Journal of Clinical Oncology	1	3	3	44.544	Oncology
6	Cancer Letters	2	134	2	8.679	Oncology
7	Computational And Structural Biotechnology Journal	2	53	2	7.271	Biochemistry & Molecular Biology
						Biotechnology & Applied Microbiology
8	Gastroenterology	2	4	2	22.682	Gastroenterology & Hepatolog
9	Journal of Biopharmaceutical Statistics	2	30	2	1.051	Pharmacology & Pharmacy
						Mathematics
10	Journal of Clinical Medicine	2	13	2	4.241	General & Internal Medicine

TC: Total citations; NP: Number of publications; IF: Impact factors; NA: Not Available.

by Korea (14, 6.54%), China, Italy, and United Kingdom with (8,3.73%) for each country (Table 5). The intrastate collaboration and network between these specific countries contributed to AI or ML in oncology are shown in Figure 3.

Keywords Analysis Trends

We identified 408 Keywords Plus during the study period. The annual distributions were showing that the theme changes in topic with time by years. Many research topics focus on machine learning, artificial intelligence, person-
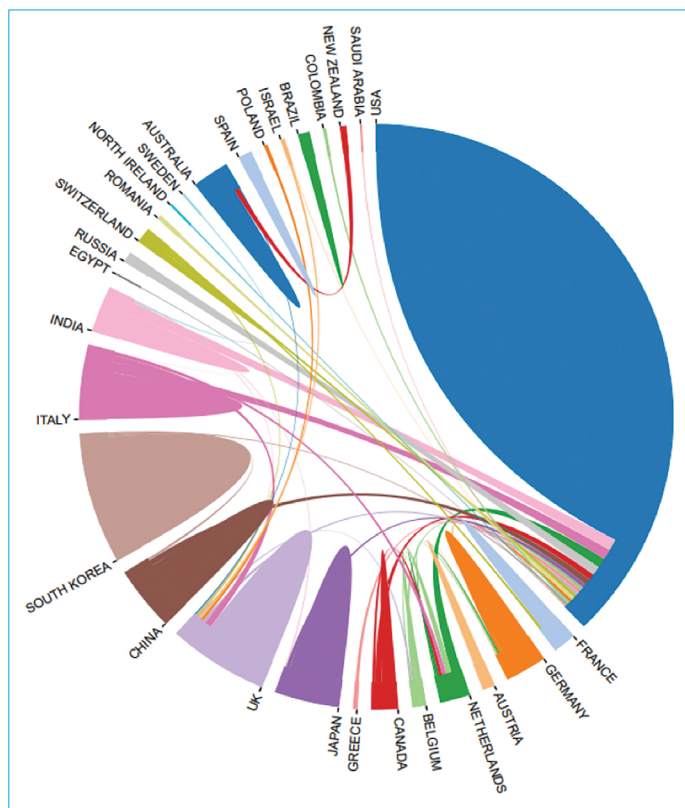
Figure 3. Mapping of Inter-state relations across 24 countries contributed to Artificial Intelligence or machine learning in Oncology.

alized machine, glioma, conventional neuronal network, and neuro-oncology. In the year 2020, research topics focused on machine learning, artificial intelligence, personalized machine, glioma (a type of tumor that occurs in the brain and spinal cord), cancer, precision medicine radiation oncology, and conventional neuronal network. Moreover, the annual evolutionary occurrences of research topics in the field of Artificial Intelligence or Machine Learning in Oncology base on the keyword Plus are presented in Figure 4.

Conceptual Structure Analysis for Keywords Plus and Title

In conceptual structure, using multiple correspondence analysis (MCA) was used to identify the related keywords and their synonyms and see how these are related to each other's (Fig. 5a) and between keyword and their synonyms in titles of the research (Fig. 5b). The analysis in overall figures shows how clusters develop from the correlations of the keywords over past years.

Funding Agencies and Most Frequency Web of Science Categories

In total, 161 funding agencies were acknowledging AI or ML in oncology. In addition, 30 research areas were identified
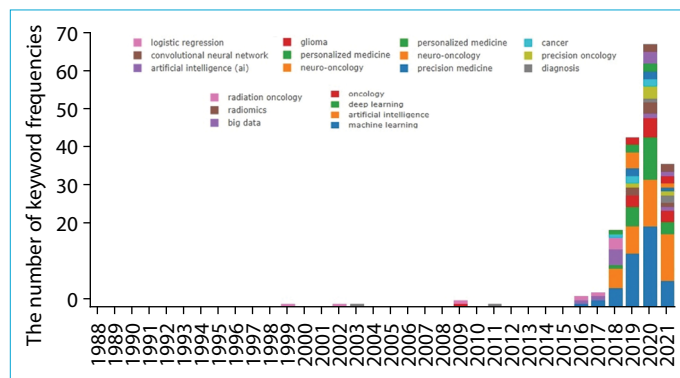

Figure 4. Annual evolutionary identification research topics in the field of Artificial Intelligence or Machine Learning in Oncology.

during the study period, the analysis of the top 10 leading research organizations, and the area where the documents in AI or ML and oncology are published across the study period. National Institutes of Health (NIH), USA, and United states department of health Human services are the top 2 organizations funding the research in AI or ML in oncology with the same output 26(12.15). Most of the documents are published in the field of oncology 100 (46.73%), followed by Radiology nuclear medicine and medical imaging 47 (21.96%), and Pathology 14 (6.54%). Making it the global research output published in specialized fields focused on oncology, radiology, and pathology (Table 6).

Discussion

Artificial intelligence (AI) and machine learning (ML) gradually strengthen their impact in everyday life. They are believed to have a dominant influence in digital health care for disease diagnosis and treatment soon.[2] Artificial intelligence (AI) uses mathematical algorithms to mimic human cognitive abilities and address difficult healthcare challenges, including complex biological abnormalities like cancer.[12] Cancer is a complex and multi-faced disorder with thousands of genetic and epigenetic variations.[13] The recent biomedical research is focused on bringing AI technology to the clinics safely and ethically. The present study found that articles published in Artificial Intelligence and Machine Learning in Oncology research have increased steadily over the past years. The first rank document received 173 citation scores, which covered the hot topics related to common mistakes in diagnostic classification in clinical when using ANNS.[10] Followed by second rank article that show that although the potential future opportunities for precision oncology by using AI are present, the use is needed for well- curated validation datasets.[11] A frontier in Oncology among others is the most productive Journal. Research domain of the journal was Oncology, Radiology,
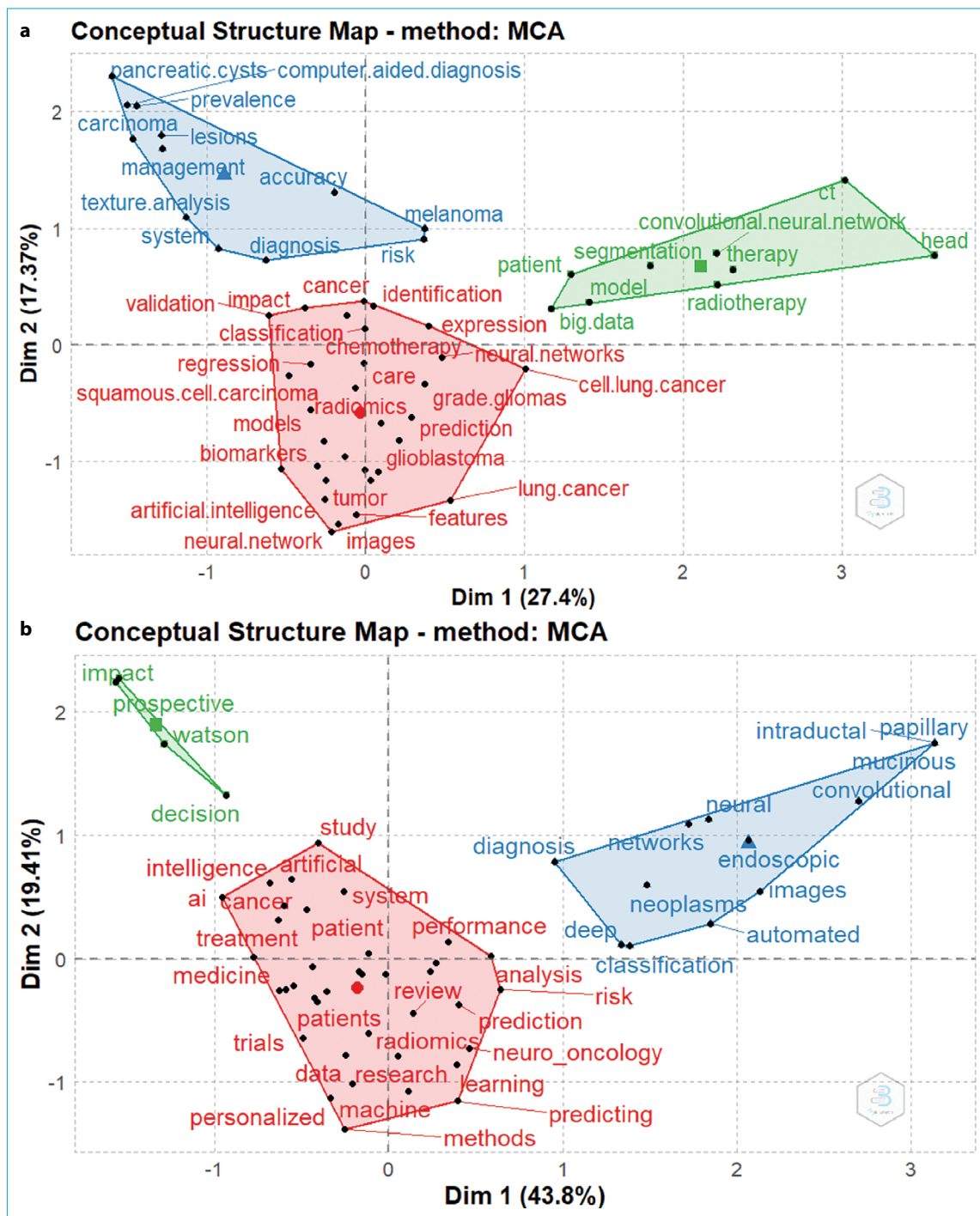
Figure 5. R Studio e factorial analysis, Conceptual structure Map Method Multiple Correspondence Analysis (MCA) of the 50 Keywords Plus **(a)**, title **(b)** organized in three clusters with different colors (Cluster 1: red, Cluster 2: blue and Cluster 3: light green).

Nuclear Medicine, Medical Imaging and biomedical informatics. The journal also has the highest impact factor and citation.

Approximately 24 countries have published articles in Artificial Intelligence or Machine Learning in Oncology. The United States leads the research, followed by Korea, Chi-

na, Italy, and the United Kingdom. Similarly, the National Institutes of Health (NIH), the USA, and the United States department of health Human services are the top organizations funding AI research or ML in oncology. Collaboration and network between these specific countries in AI or ML in oncology was documented in this study.

Table 5. Top 10 Countries and country collaborations analysis

SCR	Country (n=24)	Articles	TC	AAC	Freq	SCP	MCP	MCP_Ratio
1	USA	96	718	7.48	0.54545	77	19	0.198
2	Korea	14	56	4.00	0.07955	12	2	0.143
3	China	8	69	8.62	0.04545	7	1	0.125
4	Italy	8	71	8.88	0.04545	5	3	0.375
5	United Kingdom	8	58	7.25	0.04545	5	3	0.375
6	Canada	7	61	8.71	0.03977	7	0	0.000
7	Japan	7	94	13.43	0.03977	6	1	0.143
8	France	4	118	29.50	0.02273	3	1	0.250
9	Germany	4	263	65.75	0.02273	2	2	0.500
10	Switzerland	4	45	11.25	0.02273	2	2	0.500

SCR: Standard competition ranking; TC: Total citations; AAC: Average article citations; SCP: Single country publications (intra-country collaboration); MCP: Multiple country publications (Inter-country collaboration).

Table 6. Top 10 funding agencies and most frequencies web of science categories

SCR	Funding agencies (n=161)	N (%)	Web of Science Categories (n=30)	N (%)
1	National institutes of health NIH USA	26 (12.15)	Oncology	100 (46.73)
2	United states department of health Human services	26 (12.15)	Radiology nuclear medicine medical imaging	47 (21.96)
3	NIH National Cancer Institute NCI	10 (4.67)	Pathology	14 (6.54)
4	Japan Society For The Promotion of Science	6 (2.80)	Gastroenterology hematology	12 (5.61)
5	Ministry of Education Culture Sports Science and technology Japan MEXT	6 (2.80)	Health care sciences services	12 (5.61)
6	Grants in aid for Scientific Research kakenhi	5 (2.34)	Medical informatics	10 (4.67)
7	Korean government ministry of science and ICT MSIT	5(2.34)	Biochemistry molecular biology	9 (4.21)
8	National Science Foundation NSF	4 (1.87)	Pharmacology Pharmacy	8 (3.73)
9	Biomedical Technology Development Program of the National Research Foundation NRF	3 (1.40)	Medicine General Internal	6 (3.27)
10	Core research for evolutional Science and Technology Crest	3 (1.40)	Surgery	6 (3.27)

SCR: Standard competition ranking.

Cancer is a complex disease that needs interaction with multiple health care services. Its complexity can lead to inefficiency in exchanging information between medical professionals and laboratories to diagnose the condition, prescribe, and administer the required treatment regimen. [14,15] With the current evolution of cancer care management, new terrains are being discovered with the promise of leading to the effective management of care to avoid the cancer care system being headed for a crisis.[16,17] The direction for future research in using AI or ML in Oncology should be based on the premise that cancer care has always been "patient-centered." Efforts in research should be made to create an effective support system for the patients, their families, and the medical caregivers.[17–19] According to the National cancer policy forum workshop, there is a need for the Oncology community to embrace "cancer informatics" to improve the productivity of cancer research in bridging the gap between discovery and health.[20] Enhancing cancer care in oncology with the advantage of informatics includes the need to maximize quality data through (Natural language processing) NLP and ML. Cancer informatics will be helpful proof to improve the outcome of vulnerable cancer patients.[21]

Hereafter, the favorable outcome of oncology informatics is anticipated on using definitive scientific proof from biomedicine and behavioral science as supportive means to promote and improve cancer prevention and control.[21] The use of cases as a guide in attempts to have a deep understanding of cancer treatment remains a constant, which should be integrated into AI and ML. A human observer who understands the relevant information and uses it is pivotal for future research.[22]

Although it is the first bibliometric analysis based on the research productivity over pass years, the literature was not wholly sufficient. Second, although the study findings can help guide researchers in Artificial Intelligence or Machine Learning in Oncology. However, future studies should include articles that do not belong to the Web of Science to

provide an overview of the research productivity. Our analysis did not include articles published in other databases such as Scopus, Embase, PubMed, and Google scholar. Similarly, we only analyzed English published articles

Conclusions

Despite the uncertainties, the field of Oncology is mature in research with many potential research interests involving AI and ML. With the insights given from this study, we should be optimistic about the role that AI and ML can play in delivering quality health care to cancer patients. This article presents a bibliometric analysis of Artificial Intelligence or Machine Learning in Oncology research to determine the areas and the research direction over the past year. Most of the documents are published in oncology, radiology, nuclear medicine, medical imaging, and pathology in the present study. Whereas, annual evolutionary identification research topics analysis shows that the research topics focus on machine learning, artificial intelligence, personalized machine, glioma, conventional neuronal network, and neuro-oncology. Therefore, a conceptual structure using multiple correspondence analysis was used to identify the related keywords and synonyms and see how they are related. The analysis showed that different concepts are correlated in research studies.

Disclosures

Ethics Committee Approval: Ethics committee approval was not requested for this study.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – I.H.M., I.Z., T.H.M., M.O.; Design – T.Y.A., T.HM.; Supervision – T.H.M.; Materials – T.H.M., I.Z.; Data collection &/or processing – I.H.M.; Analysis and/ or interpretation – T.H.M. and T.Y.A.; Literature search – I.Z.; Writing – I.H.M., M.O., T.Y.A.; Critical review – T.H.M., T.Y.A.

References

1. Aminoshariae A, Kulild J, Nagendrababu V. Artificial Intelligence in dndodontics: current applications and future directions. JOE 2021;04:3–4.

2. Iqbal MJ, Javed Z, Sadia H, Qureshi IA, Irshad A, Ahmed R, et al. Clinical applications of artificial intelligence and machine learning in cancer diagnosis: looking into the future. Cancer Cell Int 2021;21:270. [CrossRef]

3. Chua IS, Gaziel-Yablowitz M, Korach ZT, Kehl KL, Levitan NA, Arriaga YE, et al. Artificial intelligence in oncology: Path to implementation. Cancer Med 2021;10:4138–49. [CrossRef]

4. Akintunde TY, Akintunde OD, Musa TH, Sayibu M, Tassang AE, Reed L, et al. Expanding telemedicine to reduce the burden on the healthcare systems and poverty in Africa for a post-coronavirus disease 2019 (COVID-19) pandemic reformation. Global Health Journal Jul 2021. Available at: https://reader.elsevier.com/reader/sd/pii/S2414644721000671?token=D414E7C7940A7207DF264C4DB52237370E3645547B7B0B043AE0B36A8C8DE81C8B008AE3A1E52E1F9D-CDAD0D8218E0AF&originRegion=eu-west-1&originCreation=20210922103512. Accessed Sep 22, 2021.

5. Akintunde TY, Musa TH, Musa HH, Chen S, Ibrahim E, Muhideen S, et al. Mapping the global research output on Ebola vaccine from research indexed in web of science and scopus: a comprehensive bibliometric analysis. Hum Vaccin Immunother 2021:1–13. [CrossRef]

6. Akintunde TY, Musa TH, Musa HH, Musa IH, Chen S, Ibrahim E, et al. Bibliometric analysis of global scientific literature on effects of COVID-19 pandemic on mental health. Asian J Psychiatr 2021;63:102753. [CrossRef]

7. Musa TH, Akintunde TY, Musa HH, Ghimire U, Gatasi G. Malnutrition research output: a bibliometric analysis for articles index in web of science between 1900 and 2020. Electron J Gen Med 2021;18:em293. [CrossRef]

8. Musa TH, Akintunde TY, Gatasi G, Ghimire U, Kawuki J, Musa HH. A bibliometric analysis of the 100 top-cited articles on global malnutrition indexed in Web of Science. J Public Health Emerg 2021. Available at: https://jphe.amegroups.com/article/view/7533/pdf. Accessed Sep 22, 2021. [CrossRef]

9. Musa, Hassan H, El-Sharief, Monsour, Musa, Idriss H, Musa TH, Akintunde TY. Global scientific research output on sickle cell disease : a comprehensive bibliometric analysis of web of science publication. Sci Afr 2021;12:e00774. [CrossRef]

10. Schwarzer G, Vach W, Schumacher M. On the misuses of artificial neural networks for prognostic and diagnostic classification in oncology. Stat Med 2000;19:541–61. [CrossRef]

11. Bera K, Schalper KA, Rimm DL, Velcheti V, Madabhushi A. Artificial intelligence in digital pathology - new tools for diagnosis and precision oncology. Nat Rev Clin Oncol 2019;16:703–715.

12. Patel SK, George B, Rai V. Artificial intelligence to decode cancer mechanism: beyond patient stratification for precision oncology. Front Pharmacol 2020;11:1177. [CrossRef]

13. Kosvyra A, Maramis C, Chouvarda I. Developing an integrated genomic profile for cancer patients with the use of NGS data. Emerg Sci J 2019;3:157–67. [CrossRef]

14. American Cancer Society. Cancer Facts & Figures 2014. Available at: https://www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/cancer-facts-figures-2014.html. Accessed Sep 22, 2021.

15. National Cancer Policy Forum; Board on health care services; institute of medicine. delivering affordable cancer care in the

21st century: workshop summary. Washington (DC): National Academies Press (US); 2013 May 20.

16. Hesse BW, Ahern DK, Beckjord E. Introduction. Oncology Informatics. Cambridge, Massachusetts: Academic Press; 2016.

17. Levit L, Balogh E, Nass S, Ganz PA. Delivering high-quality cancer care: charting a new course for a system in crisis. committee on improving the quality of cancer care: addressing the challenges of an aging population. Board on Health Care Services, Institute of Medicine. Washington DC: National Academies Press; 2013.

18. James B. Quality improvement opportunities in health care. making it easy to do it right. J Manag Care Pharm 2002;8:394–9. [CrossRef]

19. Reid PP, Compton WD, Grossman JH FG. Building a better delivery system: a new engineering/health care partnership. In: Reid PP, Compton WD, Grossman JH, Fanjiang G, editors. Washington, DC: National Academy of Engineering Institute of Medicine; 2005. p. 262.

20. Nass SJ, Wizemann TM. Informatics needs and challenges in cancer research: workshop summary. In: Washington DNAP, editor. Washington, DC: National Academies Press; 2012. p. 129. [CrossRef]

21. Hirsch B, Abernethy AP. Informatics support across the cancer continuum. Oncology Informatics. Cambridge, Massachusetts: Academic Press; 2016. p. 145–57. [CrossRef]

22. Horowitz TS, Rensink RA. Extended Vision for Oncology. Cambridge, Massachusetts: Oncology Informatics. Academic Press; 2016. p. 287–303. [CrossRef]