Machine Learning Technology and Application in the Health Sector: Bibliometric Analysis Mapping and Trends

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ABSTRACT

Recently, machine learning is rapidly transforming the healthcare sector, offering innovative solutions to a wide range of medical challenges. This article presents a comprehensive bibliometric analysis of research on machine learning (ML) applications in healthcare, mapping the growth and trends from 2019 to 2024. Two keywords were used to search in the Scopus database, which were "machine learning" and "healthcare". The search included title, abstract, and keywords, refining results to focus on the health sector's application of ML. The results revealed that there is a sharp increase in research output, with the number of publications rising from 56 in 2019 to 2210 in 2023, and 2014 articles already published by September 2024. The 20 most published authors had between 69 and 34 documents. The countries dominating in research are the United States and India, each with over 1800 publications, followed by China, the United Kingdom, and Saudi Arabia. Other related keywords that emerged were "artificial intelligence", "deep learning", and "healthcare", which suggested a strong focus on the application of ML in improving medical services, quality of life, and gender-specific health issues. The study highlights that ML technologies have great potential to improve clinical decision-making, enhance operational efficiency, provide more personalized treatment options, and improve the overall health services delivery.

Keywords: Machine learning in healthcare, Bibliometric analysis, Predictive analytics, Medical imaging, Personalized medicine

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Introduction

Machine learning (ML) involves computer systems processes where machines and other technological devices use data and algorithms to perform tasks with improved accuracy without being explicitly programmed. Through the study of algorithms and datasets, ML allows technological devices and computers to improve through experience to become independent and automatic.[1] For instance, the study by Jasti et al.[2] asserts that by processing large quantities of historical data and identification patterns, machine models in healthcare can learn to predict and diagnose cancer from X-ray image datasets. The health sector is constantly evolving and the use of new technology in diagnosis and treatment is being developed every time. The incorporation of ML in healthcare plays a significant role in various healthcare processes including patient monitoring tools, diagnostic support systems, and risk assessment tools.[3] Often, ML algorithms help healthcare professionals make sense of the vast amount of data generated every day through prediction of the likelihood of disease development, and analysing risk factors associated with diseases among other processes.

There is a growing importance of ML in various industries, particularly in the healthcare industry. The high rate of patient data collected in the healthcare industry continues to increase the importance of ML technologies in healthcare systems. According to[4], ML continues to develop its importance in the identification and diagnosis of diseases. Ailments considered tough to identify, such as cancer and other genetic ailments, have in the past been identified through the integration of cognitive computing with genome tumour sequencing.[5] Often, the natural human language can be complex and can lack uniformity, and therefore, the increased use of ML capabilities plays a critical role in other healthcare sector processes including the automation of medical billing, the development of clinical practice guidelines within the healthcare systems and helping in clinical decision support.

The increased number of ML applications also plays a critical role in the transformation of the healthcare sector. Various ML-based applications are often used in healthcare processes. The study by[6] articulates that ML algorithms can utilize medical imaging analysis to diagnose abnormalities that could otherwise not be detected by human radiologists. Using the medical imaging datasets including X-rays, CT scans, and MRIs could help ML applications to detect early signs of tumours and cancers. Also, ML applications in healthcare can be used in predictive modelling.[7] asserts that through predictive analytics ML applications can use patient data to determine whether a hypertension patient is at risk of heart disease. Similarly, ML algorithms can analyse patient data to determine personalized treatment, by analysing genetic information, and lifestyle factors and identifying the individual's health outcomes.

Over the past decade, there has been an increase in the body of research focused on ML in healthcare.[8] Articulate that the increased focus in research focusing on ML results from the need for health researchers to understand the strengths and limitations of ML technologies. There are already several research articles suggesting that ML technologies can perform with better precision in diagnosis and treatment compared to humans.[9] observe that there are various incidences where ML algorithms have outperformed healthcare professionals such as radiologists in the diagnosis of malignant tumours; however, it is believed that technology is yet to replace humans in healthcare. Bibliometric analysis in the research focusing on ML in healthcare is thus critical in enabling researchers to identify patterns and trends in the ML capabilities to help identify dominant themes and help curb possible limitations of the technologies.

Based on the above review, the primary purpose of this study is to conduct a comprehensive bibliometric analysis to explore the evolution and impact of ML applications in the healthcare sector. This bibliometric study aims to systematically review and quantify the development of ML in healthcare, providing a data-driven perspective on how the research landscape has evolved over time. The objectives were (1) to identify the key research trends, (2) to identify the influential authors and publications, (3) to map collaboration networks, and (4) to evaluate geographical distributions. By achieving these objectives, this study will provide a holistic overview of the ML research landscape in healthcare, offering valuable insights for researchers, practitioners, and policymakers interested in the intersection of technology and health.

Literature Review

The development and application of ML technologies in the health sector present various opportunities and limitations in healthcare processes. Various studies on ML technologies in healthcare highlight the evolution, application, challenges and limitations and the current and future trends of the technologies in the healthcare system.

Evolution of Machine Learning in Healthcare

The incorporation of ML in healthcare has evolved over the last ten to five decades.[10] observe that ML applications in healthcare can be dated back to the 1980s when computer systems were allowed to learn from datasets to improve their performance. For instance, the earliest use of ML algorithms in healthcare involved the analysis of medical images used in disease diagnosis in the late 1980s.[11] The development of diagnostic systems through ML paved the way for more advancements in healthcare systems including the development of electronic health records (EHRs) and data mining technology in the 2000s. During the early 2000s era, the health sector used predictive analytics based on data mining to identify potential health risks. Also, the EHRs helped the healthcare management to manage data effectively promoting individualized treatment of patients.[12] In the period after 2010, ML technologies involved the use of deep learning. The ML algorithms from this period utilized the vast available patient data to learn health trends as well as image analysis to detect serious ailments such as cancer and other tumours.[13] Similarly, through deep learning, ML technologies helped develop individualized medicine that was critical in tailored treatment based on individual patient data.

Current Application of ML in Health Services

The current period of ML in healthcare is characterized by wearable devices that use continuous monitoring algorithms to continuously determine health and predictive analytics. According to.[14] the current use of ML in healthcare focuses on enabling the detection of patterns and connections that are not easy to identify and can be used in health outcome predictions. For instance, the use of smart devices such as smartwatches and other wearable devices helps in the effective management of patient conditions in healthcare facilities. Also,[15] articulate that the current ML technologies in healthcare use deep learning to enhance predictive analytics. Predictive analytics are critical in the early diagnosis of ailments and help in developing early treatment plans. Predictive analytics in healthcare diagnosis involve the use of past patient data to determine the cause of health trends and is critical in preventing possible costly diagnoses through enhanced accuracy. The evolution of ML in healthcare is ongoing and the other current trends include drug discovery critical in personalized medicine.[16] Through the analysis of patient reactions to particular treatment plans, ML technologies can develop personalized medicine towards the treatment of individual patients' ailments.

Challenges and Limitations of ML Application

Similar to challenges in technology adoption in other sectors, the application of ML technologies in healthcare is often faced with various challenges and limitations.[17] assert that the common challenge in the application of ML in healthcare involves the lack of training data. Unlike artificial intelligence (AI), which requires programming, ML requires data information that is used to train the technology. Often, rare ailments such as cancer lack enough data that can be used as an example in ML-based algorithm training. The other limitation in the application of ML in healthcare involves the lack of interpretability of the algorithm models.[18] Often, the ML algorithms give outcomes based on datasets used in training, and this may lack interpretation to healthcare professionals. Lack of interpretation of results leads to a lack of trust, critical among healthcare professionals. Similarly,[19] observe that regulatory and ethical considerations can be a limiting factor in the application of ML technologies in healthcare. Healthcare regulatory bodies such as the HIPAA require patient consent to the use of technologies, which might limit their use in the healthcare setting. Other ethical issues limiting the use of ML applications include implicit patient data exploitation, algorithmic bias, and algorithmic fairness among other ethical issues.

Trends and Future Directions

Various research exists on the ML technology trends and future directions. The current trends in ML in healthcare include precision medicine and personalization of treatment. Predictive analytics play a critical role in the determination of accurate diagnoses using patient data and the development of personalized treatment plans. The other trend in ML technologies includes analysing imaging. According to[20] ML has made strides in the analysis of radiology and pathology images which is critical in the quick and accurate classification of images leading to early diagnosis and disease prevention. With the increasing developments in ML and AI, the future of ML technologies is likely

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to be more complex.[21] believe that ML technologies are likely to be used in real-time diagnosis during clinical examinations. The ability to make real-time diagnoses will help in improving patient treatment outcomes.

Methodology

Design and Data Sources

This research adopted a qualitative research design, where the data collected was analysed using non-statistical techniques. The bibliometric analysis was conducted using data retrieved from Scopus, one of the most comprehensive academic databases for peer-reviewed literature. The search was performed to obtain data between the years 2019 and 2024, a period of six years, since the ML technology is quite new. The dataset comprises a collection of research articles, review articles, conference proceedings, and book chapters.

Inclusion and Exclusion Criteria

To capture the appropriate data, there was an exclusion and inclusion criteria observed. For the inclusion criteria, the study used publications that directly focus on ML applications in healthcare, especially in areas such as medical diagnostics, predictive modelling, personalized treatment, and healthcare management. For the exclusion criteria, the studies that do not apply ML in the healthcare context, non-English publications, and papers lacking full-text availability in Scopus were excluded.

Search Strategy

To search for the articles, two major keywords were used in a search in the Scopus database. These are "ML" and "healthcare". The search included title, abstract, and keywords, refining results to focus on the health sector's application of ML. Filters such as document type, subject area, and publication year were applied to narrow down the relevant studies.

Bibliometric Analysis Techniques

To conduct the bibliometric analysis, the VOSviewer software was adopted. The software was used to build and visualize networks and connections regarding previous studies in the area of study interest. VOSviewer was selected because of its capability of conducting various analyses, including citation analysis, co-authorship analysis, keyword occurrence analysis, and co-citation analysis.

In the analysis, the VOSviewer tool was adopted to create visual maps that provide an intuitive understanding of the relationships and trends within the dataset, revealing hidden patterns and emerging areas of research. The analysis that was conducted included the trend analysis to observe the publication trends in the area over time. Citation analysis was conducted in terms of the most cited papers and authors. Co-authorship was conducted to identify global collaboration patterns. Keyword co-occurrence was conducted to identify frequently occurring keywords related to ML applications in healthcare, such as "deep learning", "medical imaging", and "predictive analytics".

Data Analysis and Findings

Trend of Publication over Time

The first analysis that was conducted was the analysis of the trend. The trend evaluated the number of publications related to the application of ML in the healthcare sector over a period of six years (2019–2024). The results are summarized in Figure 1. The study shows that there is an increase in publications from 2019 to 2024. For the year 2019, there were very little publications of 56 publications. For the year 2020, the publications increased to 759 publications. The year 2023 was the year with the highest publication of 2210. As of September 2024, there were 2014 publications, which was quite high. This implies that at the end of the year 2024, there will be a high number of publications made.

Publications per Country

In this analysis, a ranking was done for the first 20 countries that had published a lot regarding the application of ML in healthcare. The results indicated that the United States had the highest number of publications of 1887 documents, as well as the highest number of citations of 31,500. This could be attributed to

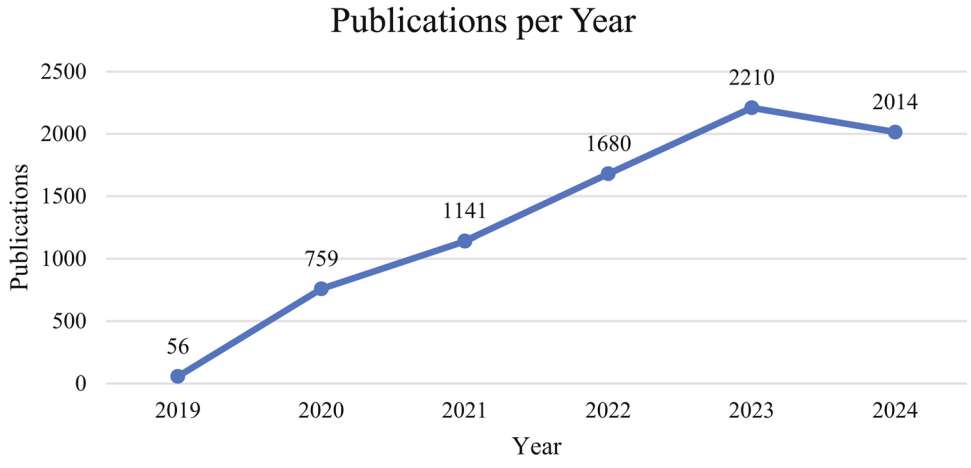

Fig 1 | Trend of publication over time

Table 1 | Publications per country

Country	Documents	Citations	Total Link Strength
United States	1887	31500	1518
India	1853	25073	1137
China	873	14785	780
United Kingdom	774	19741	1240
Saudi Arabia	765	11514	1243
Pakistan	401	9256	801
Canada	399	7333	555
Australia	370	7635	550
South Korea	363	7240	520
Italy	358	5050	494
Germany	290	5375	533
Malaysia	240	3921	411
Spain	240	3893	411
Egypt	207	4206	336
United Arab Emirates	193	4280	395
Taiwan	191	3219	247
Turkey	176	2095	239
France	169	4058	371
Iran	166	2342	220

the advanced healthcare facilities, technologies, and policies in the US healthcare system. As a result, many researchers have conducted investigations into the associated and relevant technologies. The second in rank was India, which was very close to the United States and had 1853 publications and 25,073 citations. The high publications in India could be linked to the highly technologically developed healthcare system in India.[22] As a result, the sector has attracted a wide range of researchers on the application of ML technology in healthcare. The third country was China with a way low number of documents published of 873, followed by the United Kingdom with 774 documents published, and then Saudi Arabia with 765 documents published, closing the list of the first five countries. These findings are summarized in Table 1 and an overlay network visualization in Figure 2. The visualization shows the United States having the largest circle node, then followed by India and China.

A further analysis of the VOSviewer network diagram revealed that the United States was linked to other countries, with 66 links and 1518 total link strengths. Additionally, India had 66 links with 1137 total link strengths. This implies that the researchers and authors from the two countries were well-referenced and connected to researchers in other countries (Figure 2). In addition to the above publications per country, a chi-squared test was conducted to investigate whether the distribution of publication counts across the listed countries deviates significantly from a uniform distribution. From the results, the chi-squared statistic was 9364.04 and p-value was 0.000. The results indicated a highly significant difference in publication counts among countries. This means the distribution of publications is not uniform, and certain countries contribute disproportionately to the total publications. For example, the United States and India have much higher publication counts compared to others. This showed the varying efforts of researchers in different countries towards the concept of ML technology in healthcare.

Co-authorship Major Researcher

The other aspect that was evaluated was the researchers who had published a lot in the area of application of ML technology in healthcare. Considering the ranking by the documents published, authors Li, Y. had the highest publication (69 in number) followed by Wang, Y. with a total of 60 in number. Then there is Zhang, Y.

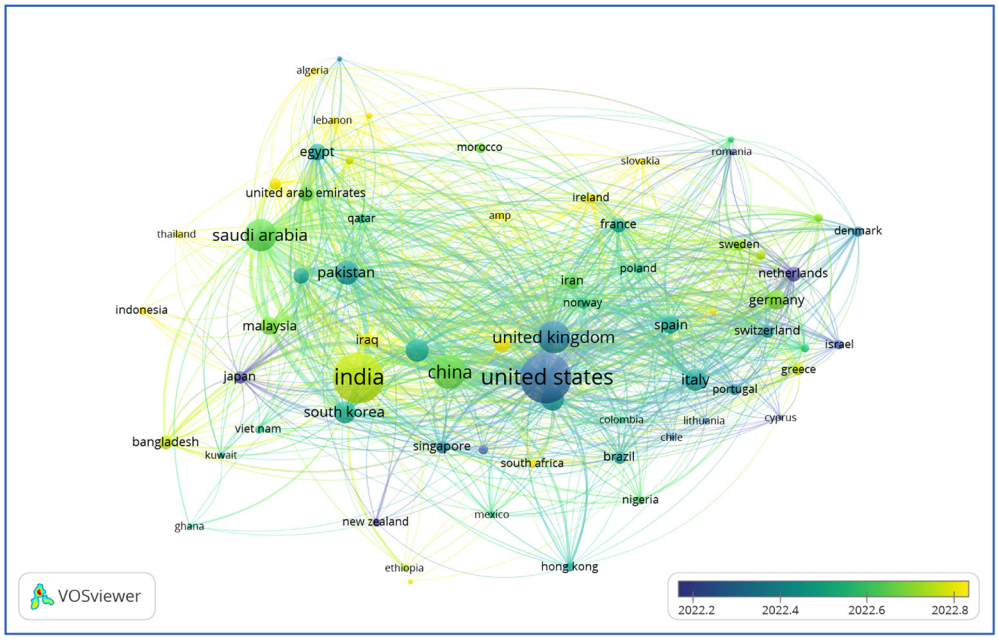

Fig 2 | Publications per country

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with 56 publications, then Li, J with 54 publications, and closing the first five is Liu, Y with 52 publications (Table 2).

For the case of ranking by citations, Li, W has the highest number of citations – 1506 in total, followed by Khan, Ma with 1444 in number, and then Zhou Y with 1334 citations. The fourth in rank is Zhang Z with 1257 citations and the fifth is Wang J with 1229 citations. The network of the citations is presented in Figure 3.

In addition to co-authorship ranking by document and citations, an additional analysis was conducted to evaluate the advanced network metrics such as centrality, clustering coefficients, and collaboration strengths based on the ranking of the first ten authors with many documents. As demonstrated in Table 3, it is observed that Li, Y. remains a prominent figure in both documents published and citations, with a high degree of centrality, reflecting their extensive collaboration. However, Wang, Y. and Zhang, Z. demonstrate strong clustering coefficients, indicating they form close-knit research groups. Authors such as Li, W. and Khan, Ma with high citations are strategically positioned as connectors in the network, displaying notable betweenness centrality.

Analysis of Keywords Co-occurrence

The other analysis that was conducted was the analysis of keywords co-occurrence. The analysis evaluated the most occurring keywords in terms of the links with other keywords related to the study area. The results are presented in Figure 4.

The analysis showed that the most common keyword was "ML" with a total link strength of 59,270 links and occurrences of 5863 and links of 230. The next keyword that was second in occurrence was "human" which had

Table 2 | Co-authorship major researcher

Ranking by Documents			Ranking by Citations		
Author	Documents	Citations	Author	Documents	Citations
Li, Y	69	1036	Li, W	14	1506
Wang, Y	60	767	Khan, Ma	41	1444
Zhang, Y	56	586	Zhou, Y	23	1334
Li, J	54	405	Zhang, Z	45	1257
Liu, Y	52	300	Wang, J	44	1129
Zhang, Z	45	1257	Ali, A	16	1101
Wang, J	44	1129	Li, Y	69	1036
Li, X	43	567	Gadekallu, Tr	10	1019
Khan, Ma	41	1444	Srivastava, G	16	948
Wang, H	40	858	Chen, Y	36	898
Zhang, J	40	466	Wang, H	40	858
Kumar, S	37	515	Khan, A	19	843
Zhang, X	37	143	Wang, Y	60	767
Chen, Y	36	898	Chen, X	27	722
Kumar, A	35	296	Chakraborty, C	12	715
Wang, X	35	221	Chen, J	34	698
Zhang, L	35	189	Wang, T	16	697
Chen, J	34	698	Rehman, A	23	682
Wang, Z	34	421	Wang, M	13	675

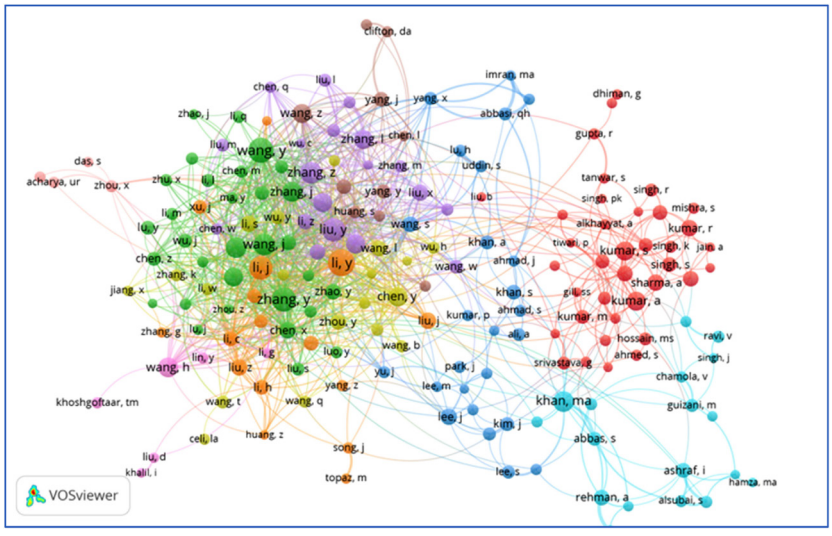

Fig 3 | Co-authorship major researcher

Table 3 | Advanced network metrics

Author	Documents	Citations	Degree Centrality	Betweenness Centrality	Clustering Coefficient	Collaboration Strength
Li, Y	69	1036	High	Medium	Low	Strong (with Wang, Y, Zhang, Y)
Wang, Y	60	767	High	Low	High	Strong (with Li, Y, Zhang, Y)
Zhang, Y	56	586	Medium	Medium	High	Moderate (with Li, Y, Wang, Y)
Li, J	54	405	Medium	Low	Low	Moderate (with Zhang, Y)
Liu, Y	52	300	Low	Low	Low	Moderate (with Zhang, Y)
Zhang, Z	45	1257	Medium	High	High	Strong (with Khan, Ma)
Wang, J	44	1129	Medium	Medium	Low	Moderate (with Zhang, Z)
Khan, Ma	41	1444	High	High	Low	Strong (with Zhang, Z, Wang, Y)
Wang, H	40	858	Low	Low	Low	Weak (with Zhang, Y)
Zhang, J	40	466	Low	Low	Low	Weak (with Zhang, Y)

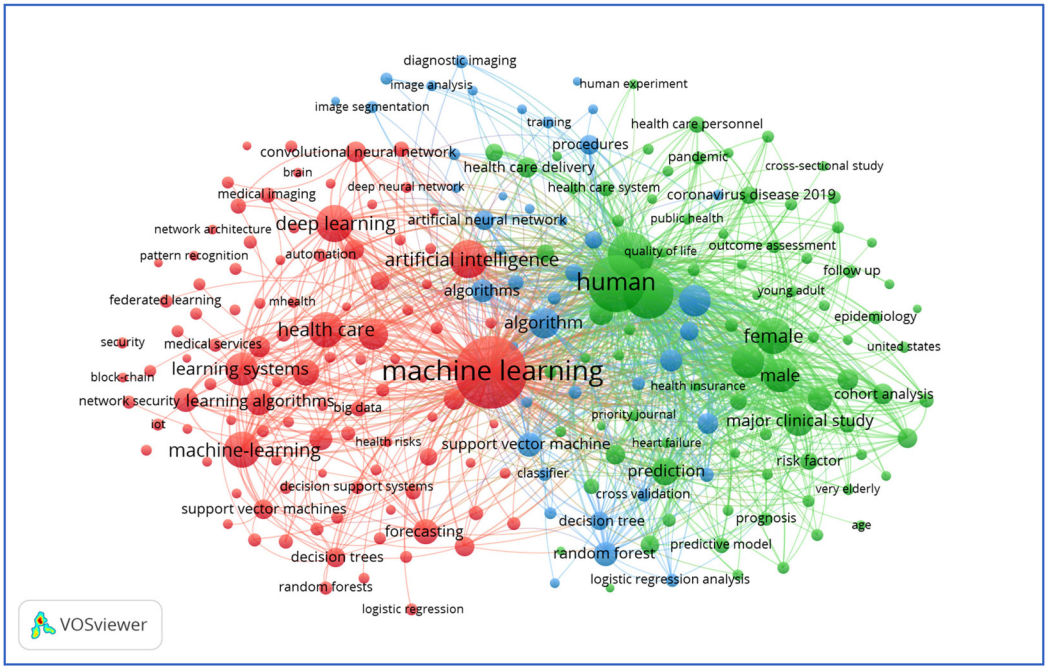

Fig 4 | Analysis of keywords co-occurrence

a total link strength of 50,568 links and occurrences of 3579 and links of 230. The results also show that "health care" has a strong link with other keywords, with a total link strength of 14,593 links and occurrences of 1393 and a link of 230. "AI" was another important keyword, with a total link strength of 17,528 links and occurrences of 1661 and a link of 230.

Discussion of Results

Similar to previous studies, the findings of this study indicate that the application of advanced technology to solve healthcare issues has increased significantly in the recent past.[17,3,23] This study shows a sharp increase in the research on the application of ML technologies in the global healthcare sector, over the last six years (2019–2024). In the year 2019, there were only 56 published articles while in the year 2023, there were 2210 published articles. In September 2024, there were already 2014 published articles. This shows the significance and contribution of ML technology in solving health issues. Several reasons could be attributed to this explosive growth in publications. First, it highlights the increasing recognition of ML as a transformative tool in healthcare, driving innovation in areas such as disease diagnosis, predictive analytics, personalized medicine, and healthcare management.[24,25] It also suggests the urgency and relevance of ML technology in addressing contemporary healthcare challenges. Researchers and practitioners are leveraging ML to enhance diagnostic accuracy, optimize treatment plans, and manage large-scale healthcare data efficiently. The increase in the last six years could also be attributed to the global response to the COVID-19 pandemic, which has catalysed further interest in ML technologies, as evidenced by several studies focusing on its role in predicting infection trends, optimizing resource allocation, and improving treatment strategies.[26]

Another interesting finding is that the United States and India had the highest publications in this area, with 1887 and 1885 respectively. Other countries were China, the United Kingdom, and Saudi Arabia, with much lower publications of 873, 774, and 765 respectively. This disparity highlights the varying levels of

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engagement with ML technologies in healthcare across different regions.

The prominence of the United States in ML healthcare research can be attributed to several factors, including its well-established academic institutions, robust healthcare infrastructure, and significant funding for AI research from both government and private sectors. Major institutions such as Stanford University, MIT, and Harvard Medical School have been key players in advancing ML research in healthcare.[24] India's significant contribution is a reflection of the country's growing investment in AI and healthcare technology in recent years. India has a vast population and diverse healthcare needs, and increasing access to healthcare data have fuelled interest in applying ML for telemedicine, remote diagnostics, and predictive healthcare analytics.[27] It is also important to note the increasing influence of other countries such as China and the United Kingdom in this space. This study finds that the observed variation in research is attributed to various aspects such as healthcare infrastructure, government policies, and availability of funding for AI research.

An interesting observation was made, that there were no dominant researchers in this area. The highest researcher (Li, Y) had only 69 documents published, while the second (Wang, Y) had 60 documents. The first 20 researchers had published documents between 34 and 69 each. This shows that even to researchers, the application of ML in healthcare is a new and rapidly evolving field that has yet to see the emergence of a concentrated group of experts who dominate the landscape. The absence of dominant individual researchers could be explained by the collaborative nature of the work in this domain. The successful application of ML in healthcare often involves partnerships between clinicians, computer scientists, biostatisticians, and data engineers.[28] As a result, research output is typically dispersed across teams, rather than concentrated in the hands of a few leading individuals.

In examining the most common keywords in this research domain, "ML" dominated. Other significant keywords were "human", "AI", "healthcare", "deep learning", "female", "medical services", and "quality of life". These keywords give significant insights in terms of applications and themes that define the research landscape of ML in healthcare. The prominence of terms such as ML, AI, and deep learning indicates the centrality of these technologies in advancing medical research and services.

Theoretical and Managerial Implications

The theoretical implications of this study are that, first, it contributes to the existing body of knowledge of ML applications in healthcare by providing a comprehensive bibliometric analysis that maps the research landscape and identifies key trends and emerging areas. It demonstrates the increasing importance of ML technology integration in healthcare systems to solve and address diverse medical challenges. Secondly, the analysis of keywords, co-authorship networks, and citation patterns reveals how the field is still in its exploratory phase. It is characterized by dispersed authorship, and integration with other technologies such as AI with clinical decision-making, bioinformatics, and public health.

Several managerial implications are suggested giving valuable insights for healthcare managers, policymakers, and technology developers who are looking to integrate ML into clinical practices. The increasing importance demonstrates the relevance of ML in solving real-world health issues and could be considered vital for improving diagnostic accuracy, optimizing healthcare delivery, and enhancing patient outcomes. For health organizations, adopting and integrating ML technologies in the in-house systems would help them manage large datasets, deliver personalized care, and streamline hospital operations. Lastly, this study foresees an explored area for policymakers to create regulatory frameworks that ensure the ethical deployment of ML technologies in healthcare settings.

Conclusions

ML technology has played a critical role in revolutionizing healthcare in the recent past. It is being applied in the development of health devices such as wearable fitness trackers and smartwatches that monitor vital signs like heart rate and blood pressure. These technologies, powered by ML algorithms, can detect abnormal patterns and predict potential health issues. They are also applied in application in medical imaging, predictive analytics, and clinical decision support systems enabling faster and more accurate diagnoses, optimizing treatment plans, and enhancing overall healthcare efficiency.

This study conducted a comprehensive bibliometric analysis of research on the application of ML in the healthcare sector, offering insights into the field's evolution, the distribution of research across countries, and the most influential authors and topics.

The findings showed that there is a rapid growth in publications, especially between 2019 and 2024. This shows the increasing relevance of ML technologies in addressing critical healthcare challenges. The leading contributors—the United States, India, China, the United Kingdom, and Saudi Arabia. Though there is a global perspective, the United States and India demonstrate a significant advancement in healthcare technology compared to the rest.

The keywords analysis demonstrates that ML is adopted and applied in solving various healthcare issues, including predictive modelling, medical imaging, quality of life, and gender-specific health issues. The study also found that there are no dominant researchers, indicating that the field is still in a phase of exploration and discovery. This research therefore points out that the application of ML in healthcare systems is both evolving and promising. It has great potential to improve clinical decision-making, enhance operational efficiency, and provide more personalized treatment options.

This study has several recommendations for future research. Researchers should consider exploring the ethical and regulatory framework around the application of ML in healthcare. It is a critical area as there is a need for ethical frameworks that ensure the responsible use of these technologies. Additionally, a focus on real-world implementations and case studies in clinical settings would help assess their effectiveness in improving patient outcomes and operational efficiency.

References

1 Li Y, Shan B, Li B, Liu X, Pu Y. Literature review on the applications of machine learning and Blockchain Technology in smart healthcare industry: a bibliometric analysis. J Healthc Eng. 2021;2021(1):9739219.

2 Jasti VDP, Zamani AS, Arumugam K, Naved M, Pallathadka H, Sammy F, et al. Computational technique based on machine learning and image processing for medical image analysis of breast cancer diagnosis. Secur Commun Netw. 2022;2022(1):1918379.

3 Javaid M, Haleem A, Singh RP, Suman R, Rab S. Significance of machine learning in healthcare: features, pillars and applications. Int J Intell Netw. 2022;3:58–73.

4 Jia Y, McDermid J, Lawton T, Habli I. The role of explainability in assuring safety of machine learning in healthcare. IEEE Trans Emerg Top Comput. 10(4):1746–60.

5 Kothuru SK, Komperla RCA, Shah MK, Sundararajan V, Paramasivan P, Regin R. Advancing healthcare outcomes through machine learning innovations. Cross-Industry AI Appl. 2024;2024:245–61.

6 Houssein EH, Emam MM, Ali AA, Suganthan PN. Deep and machine learning techniques for medical imaging-based breast cancer: A comprehensive review. Expert Syst Appl. 2021;167:114161.

7 Aggarwal R, Sounderajah V, Martin G, Ting DS, Karthikesalingam A, King D, et al. Diagnostic accuracy of deep learning in medical imaging: a systematic review and meta-analysis. NPJ Digit Med. 2021;4(1):65.

8 Cho H, She J, De Marchi D, El-Zaatari H, Barnes EL, Kahkoska AR, et al. Machine learning and health science research: tutorial. J Med Internet Res. 2024;26:e50890.

9 Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. Future Healthc J. 2019;6(2):94–8.

10 Alowais SA, Alghamdi SS, Alsuhebany N, Alqahtani T, Alshaya AI, Almohareb SN. Revolutionizing healthcare: the role of artificial intelligence in clinical practice. BMC Med Educ. 2023;23(1):689.

11 Kononenko I. Machine learning for medical diagnosis: history, state of the art and perspective. Artif Intell Med. 2001;23(1):89–109.

12 Sanchez Zuleta CC, Giraldo Marín LM, Vélez Gómez JF, Sanguino Cotte D, Vargas López CA, Jaimes Barragán FA. Evolution of the data mining and machine learning techniques used in health care: a scoping review. Trends Appl Inf Syst Technol. 2021;2(9):151–60.

13 Das S, Nayak SP, Sahoo B, Nayak SC. Machine learning in healthcare analytics: a state-of-the-art review. Arch Comput Methods Eng. 2024;31:1–40.

14 Badawy M, Ramadan N, Hefny HA. Healthcare predictive analytics using machine learning and deep learning techniques: a survey. J Electr Syst Inf Technol. 2023:10(1):40.

15 Nithya B Ilango V. Predictive analytics in health care using machine learning tools and techniques. 2017 International Conference on Intelligent Computing and Control Systems (ICICCS). 2017;492–9.

16 Vamathevan J, Clark D, Czodrowski P, Dunham I, Ferran E, Lee G, et al. Applications of machine learning in drug discovery and development. Nat Rev Drug Discov. 2019;18(6):463–77.

17 Nayyar A, Gadhavi L, Zaman N. Machine learning in healthcare: Review, opportunities and challenges. In Machine Learning and the Internet of Medical Things in Healthcare. 2021;(pp. 23–45). Academic Press.

18 An Q, Rahman S, Zhou J, Kang JJ. A comprehensive review on machine learning in healthcare industry: classification, restrictions, opportunities and challenges. Sensors. 2023;23(9):4178.

19 Ramudu K, Mohan VM, Jyothirmai D, Prasad DVSSSV, Agrawal R, Boopathi S. Machine learning and artificial intelligence in disease prediction: applications, challenges, limitations, case studies, and future directions. In Contemporary Applications of Data Fusion for Advanced Healthcare Informatics. 2023;(pp. 297–318). IGI Global.

20 Ramírez JGC, Islam MM, Even AIH. Machine learning applications in healthcare: current trends and future prospects. J Artif Intell Gen Sci (JAIGS). 2024;1(1):ISSN: 3006–4023.

21 Nti IK, Adekoya AF, Weyori BA, Keyeremeh F. A bibliometric analysis of technology in sustainable healthcare: emerging trends and future directions. Decis Anal J. 2023;8:100292.

22 Gupta P, Choudhury R, Kotwal A. Achieving health equity through healthcare technology: perspective from India. J Fam Med Primary Care. 2023;12(9):1814–7.

23 Usmani UA Jaafar J. Machine learning in healthcare: current trends and the future. In International Conference on Artificial Intelligence for Smart Community: AISC 2020, 17–18 December, Universiti Teknologi Petronas, Malaysia. 2022;(pp. 659–75). Singapore: Springer Nature Singapore.

24 Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44–56.

25 Rieke N, Jonny H, Wenqi L, Fausto M, Roth HR, Shadi A, et al. The future of digital health with federated learning. NPJ Digit Med. 2020;3(1):1–7.

26 Vaid A, Somani S, Russak AJ, De Freitas JK, Chaudhry FF, Paranjpe I, et al. Machine learning to predict mortality and critical events in COVID-19 positive New York city patients. J Med Internet Res. 2020;22(11):e24018.

27 NITI Aayog. *National Strategy for Artificial Intelligence.* Government of India. 2018. Available from: https://www.niti.gov.in/national-strategy-artificial-intelligence

28 Esteva A, Kuprel B, Novoa RA, Ko J, Swetter SM, Blau HM, et al. Dermatologist-level classification of skin cancer with deep neural networks. Nature. 2017;542(7639):115–8.