SYSTEMATIC REVIEW

The 100 most influential papers in medical artificial intelligence; a bibliometric analysis

Fatima Zahoor[1], Muhammad Abdullah[2], Muhammad Waleed Tahir[3], Asif Islam[4]

Abstract

Objective: To assess the current trends in the field of artificial intelligence in medicine by analysing 100 most cited original articles relevant to the field.

Methods: The bibliometric analysis was conducted in September 2022, and comprised literature search on Scopus database for original articles only. Google and Medical Subject Headings databases were used as resources to extract key words. In order to cover a broad range of articles, original studies comprising human as well as non-human subjects, studies without abstract and studies in languages other than English were part of the inclusion criteria. There was no specific time period applied to the search and no specific selection was done regarding the journals in the database. The screening was done using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to extract the top 100 most cited articles in the field of artificial intelligence usage in medicine. Data was analysed using SPSS 23.

Results: Of the 11,571 studies identified, 100(0.86%) were analysed in detail. The studies were published between 1986 and 2021, with a median of 43 citations (IQR 53) per article. The journal 'Artificial Intelligence in Medicine' accounted for the highest number 9(9%)) of articles, and the United States was the country of origin for most of the articles 36(36%).

Conclusion: The trends, development and shortcomings in field of artificial intelligence usage in medicine need to be understood to conduct an effective research in areas that still need attention, and to guide the authorities to direct their funding accordingly.

Key Words: Artificial intelligence, Machine learning, Computer reasoning, Machine intelligence.

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Introduction

Evidence-based approach is important in revolutionising the field of medicine and research. It guides the need to make changes in old practices and bring forth new methods that could benefit science and humanity. In this era of evidence-based medicine (EBM), bibliometric analysis has become an important tool that guides researchers and funding agencies about the progress made in a particular field to date and identifies the areas for future research prospects.[1] Therefore, there is growing interest in bibliometric analysis to find the most significant and impactful papers, their authors, countries of origin and affiliations.

Bibliometric analysis is a tool which focuses on extracting data from published scientific literature to see research progress and trends in a specific field [2] and provide physicians with the most impactful data in a particular field. It is useful not only for the researchers, but also guides funding agencies and the government that finance the researchers to allocate their funding in the most useful way.

Artificial intelligence (AI) is rapidly making its place in the field of medicine. AI means the use of machines and computers to accomplish the task that usually requires human intelligence. There has been a rise in interest in AI since the 1950s. [3] The advocates of AI believe that it could help in diagnosing patients, prescribing drugs and determining the prognosis. It could also help to reduce the workload in hospitals and can help in precision medicine.[4] A huge body of literature is available on the subject of AI in medicine with variations in quality. Therefore, there is a need to identify the current trends in the field that would help to guide those who have limited knowledge of this field. The current systematic review was planned to analyse the top 100 most cited original articles across the full range of specialities related to AI in medicine.

Materials and Methods

The bibliometric analysis was conducted in September 2022, and comprised literature search on Scopus [5] database for original articles only. Google and Medical

Subject Headings (MeSH) databases were used as resources to extract key words (Table 1). The search was conducted by two reviewers independently. Approval from ethics review committee was not needed as the review was limited to a bibliometric analysis of data that was already published.

In order to cover a broad range of articles, original studies comprising human as well as non-human subjects, studies without abstract and studies in languages other than English were part of the inclusion criteria. There was no specific time period applied to the search and no specific selection was done regarding the journals in the database. The screening was done using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[6]to extract the top 100 most cited articles in the field of artificial intelligence usage in medicine.

Abstracts of all the retrieved articles were reviewed to assess their relevance to the topic. The top 100 most cited articles were then organised, and included with consensus of the reviewers.

Scopus and manual screening were used side by side to do citation analysis of the selected articles. The data extracted included number of citations, name of the journal, number of authors, year of publication, funding sources for research, country of origin and domains of research of the selected articles. To find the impact factor of journals containing the selected articles using the Thomson Reuters' Journal Citation Reports[7].

Data was analysed using SPSS 23, and Microsoft Excel and Word were used to express the data in the shape of charts and tables. Mean and median values were calculated for the number of citations and citations per year. The correlation between the journal impact factor and the number of papers of that journal was determined. P<0.05 was considered significant.

Results

Of the 11,571 studies identified, 100(0.86%) were analysed in detail (Figure 1). The studies were published between 1986 and 2021, with a median of 43 citations (IQR 53) per article (Table 2). The total number of citations was 9538, and the number of citations per year ranged from 10 to 151.57, with median and mean citations per year being 14 (IQR 22) and 23.25 (SD 25.92), respectively.

A rapid increase was seen starting from 1998 and it peaked in 2015 after which it declined with minor fluctuations (Figure 2). The number of publications in each 5-year phase was the highest in the 2015-20 period (Figure 3).

Table-1: Primary key words used in the search strategy.

Artificial Intelligence
Machine Learning
Computational Intelligence
Computer Reasoning
AI (Artificial Intelligence)
Robotics
Machine Intelligence
Neural Networks
Expert System
Knowledge Engineering
Intelligent Retrieval
Deep learning
Natural Language Processing
Data Mining
Fuzzy
Medical
Medicine
Surgical
Surgery
Healthcare

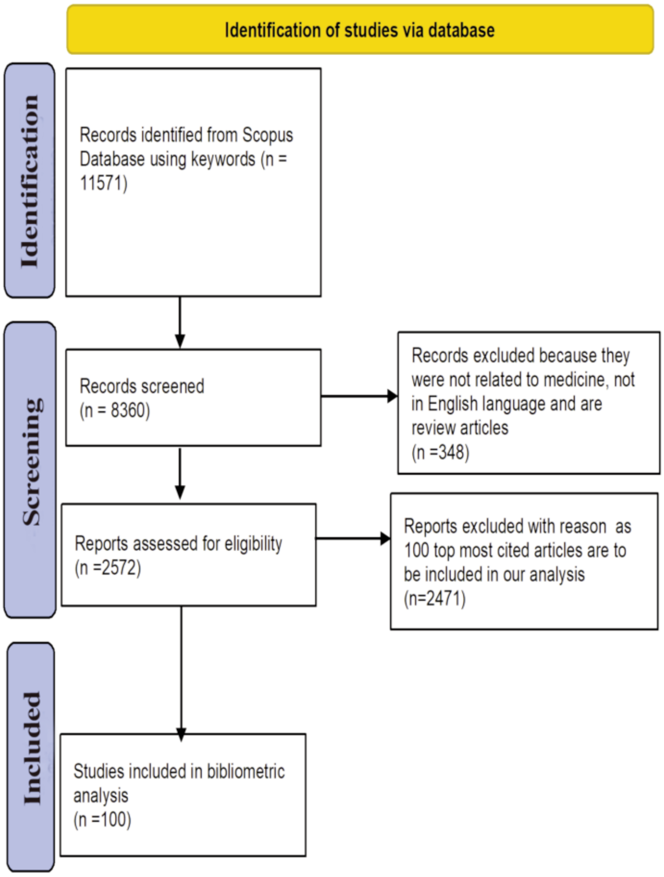

Figure-1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

Table 2: Top 100 articles, their citations, and citations per year.

Rank	Article	Citations	Citations per year
1	Deo RC. Machine Learning in Medicine. Circulation. 2015;132:1920-30.	1061	151.57
2	Kononenko I. Machine learning for medical diagnosis: history, state of the art and perspective. Artif Intell Med. 2001;23:89-109.	902	42.95
3	Hamet P, Tremblay J. Artificial intelligence in medicine. Metabolism. 2017;69S:S36-S40	530	106
4	Abràmoff MD, Lavin PT, Birch M, Shah N, Folk JC. Pivotal trial of an autonomous AI-based diagnostic system for detection of diabetic retinopathy in primary care offices. NPJ Digit Med. 2018;1:39.	450	112.5
5	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.	337	112.33
6	Menden MP, Iorio F, Garnett M, McDermott U, Benes CH, Ballester PJ, et al: Machine learning prediction of cancer cell sensitivity to drugs based on genomic and chemical properties. PLoS One. 2013;8:e61318.	292	32.44
7	Patel VL, Shortliffe EH, Stefanelli M, Szolovits P, Berthold MR, Bellazzi R, et al: The coming of age of artificial intelligence in medicine. Artif Intell Med. 2009;46:5-17	283	21.77
8	Longoni C, Bonezzi A, Morewedge C.K. Resistance to Medical Artificial Intelligence. J Consum Res. 2019;43:629-650.	253	84.33
9	Giger ML. Machine Learning in Medical Imaging. J Am Coll Radiol. 2018;15(3 Pt B):512-520.	246	61.5
10	Horie Y, Yoshio T, Aoyama K, Yoshimizu S, Horiuchi Y, Ishiyama A, et al: Diagnostic outcomes of esophageal cancer by artificial intelligence using convolutional neural networks. Gastrointest Endosc. 2019;89:25-32.	205	68.33
11	Dilsizian SE, Siegel EL. Artificial intelligence in medicine and cardiac imaging: harnessing big data and advanced computing to provide personalized medical diagnosis and treatment. Curr Cardiol Rep. 2014;16:441.	198	24.75
12	Long E, Lin H, Liu Z, Wu X, Wang L, Jiang J, et al: An artificial intelligence platform for the multihospital collaborative management of congenital cataracts. Nat Biomed Eng. 2017;1:	193	38.6
13	Bennett CC, Hauser K. Artificial intelligence framework for simulating clinical decision-making: a Markov decision process approach. Artif Intell Med. 2013;57:9-19	173	19.22
14	London AJ. Artificial Intelligence and Black-Box Medical Decisions: Accuracy versus Explainability. Hastings Cent Rep. 2019;49:15-21.	171	57
15	Vayena E, Blasimme A, Cohen IG. Machine learning in medicine: Addressing ethical challenges. PLoS Med. 2018;15:e1002689.	171	42.75
16	Pinto Dos Santos D, Giese D, Brodehl S, Chon SH, Staab W, Kleinert R, et al. Medical students' attitude towards artificial intelligence: a multicentre survey. Eur Radiol. 2019;29:1640-1646.	132	44
17	Ahuja AS. The impact of artificial intelligence in medicine on the future role of the physician. PeerJ. 2019;7:e7702	127	42.33
18	Lamy JB, Sekar B, Guezennec G, Bouaud J, Séroussi B. Explainable artificial intelligence for breast cancer: A visual case-based reasoning approach. Artif Intell Med. 2019;94:42-53	117	39
19	Ke YY, Peng TT, Yeh TK, Huang WZ, Chang SE, Wu SH, et al. Artificial intelligence approach fighting COVID-19 with repurposing drugs. Biomed J. 2020;43:355-362	115	57.5
20	Amann J, Blasimme A, Vayena E, Frey D, Madai VI; Precise4Q consortium. Explainability for artificial intelligence in healthcare: a multidisciplinary perspective. BMC Med Inform Decis Mak. 2020;20:310.	106	53
21	Fiske A, Henningsen P, Buyx A. Your Robot Therapist Will See You Now: Ethical Implications of Embodied Artificial Intelligence in Psychiatry, Psychology, and Psychotherapy. J Med Internet Res. 2019;21:e13216.	102	34
22	Mintz Y, Brodie R. Introduction to artificial intelligence in medicine. Minim Invasive Ther Allied Technol. 2019;28:73-81.	96	32
23	Catto JW, Linkens DA, Abbod MF, Chen M, Burton JL, Feeley KM, et al. Artificial intelligence in predicting bladder cancer outcome: a comparison of neuro-fuzzy modeling and artificial neural networks. Clin Cancer Res. 2003;9:4172-7.	96	5.05
24	Zupan B, Demsar J, Kattan MW, Beck JR, Bratko I. Machine learning for survival analysis: a case study on recurrence of prostate cancer. Artif Intell Med. 2000;20:59-75	84	3.82
25	Briganti G, Le Moine O. Artificial Intelligence in Medicine: Today and Tomorrow. Front Med (Lausanne). 2020;7:27.	80	40

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26	Lauritsen SM, Kristensen M, Olsen MV, Larsen MS, Lauritsen KM, Jørgensen MJ et al. Explainable artificial intelligence model to predict acute critical illness from electronic health records. Nat Commun. 2020;11:3852	79	39.5
27	Gil D., Girela J.L., De Juan J., Jose Gomez-Torres M., Johnsson, M. Predicting Seminal Quality with Artificial Intelligence Method. Expert Syst Appl. 2012;39:12564-12573.	79	7.9
28	Goldberg V, Manduca A, Ewert DL, Gisvold JJ, Greenleaf JF. Improvement in specificity of ultrasonography for diagnosis of breast tumors by means of artificial intelligence. Med Phys. 1992;19:1475-81.	78	2.6
29	Deepa S.N., Devi A.B. A survey on artificial intelligence approaches for medical image classification. Indian J Sci Technol. 2011;4:1583-1595.	72	6.55
30	Luxton DD. Recommendations for the ethical use and design of artificial intelligent care providers. Artif Intell Med. 2014;62:1-10.	71	8.88
31	Zhou LQ, Wang JY, Yu SY, Wu GG, Wei Q, Deng YB, et al. Artificial intelligence in medical imaging of the liver. World J Gastroenterol. 2019;25:672-682.	70	23.33
32	Porumb M, Stranges S, Pescapè A, Pecchia L. Precision Medicine and Artificial Intelligence: A Pilot Study on Deep Learning for Hypoglycemic Events Detection based on ECG. Sci Rep. 2020;10:170.	65	32.5
33	Makino M, Yoshimoto R, Ono M, Itoko T, Katsuki T, Koseki A, et al. Artificial intelligence predicts the progression of diabetic kidney disease using big data machine learning. Sci Rep. 2019;9:11862	64	21.33
34	McDougall RJ. Computer knows best? The need for value-flexibility in medical AI. J Med Ethics. 2019;15:156-160	64	21.33
35	Oh S, Kim JH, Choi SW, Lee HJ, Hong J, Kwon SH. Physician Confidence in Artificial Intelligence: An Online Mobile Survey. J Med Internet Res.2019;21:e12422.	62	20.67
36	Winkler-Schwartz A, Bissonnette V, Mirchi N, Ponnudurai N, Yilmaz R, Ledwos N, et al. Artificial Intelligence in Medical Education: Best Practices Using Machine Learning to Assess Surgical Expertise in Virtual Reality Simulation. J Surg Educ. 2019;76:1681-1690.	59	19.67
37	Ferroni P, Zanzotto FM, Riondino S, Scarpato N, Guadagni F, Roselli M. Breast Cancer Prognosis Using a Machine Learning Approach. Cancers (Basel). 2019;11:328.	59	19.67
38	Faes L, Liu X, Wagner SK, Fu DJ, Balaskas K, Sim DA, et al. A Clinician's Guide to Artificial Intelligence: How to Critically Appraise Machine Learning Studies. Transl Vis Sci Technol. 2020;9:7.	57	28.5
39	Escudero J, Ifeachor E, Zajicek JP, Green C, Shearer J, Pearson S; Alzheimer's Disease Neuroimaging Initiative. Machine learning-based method for personalized and cost-effective detection of Alzheimer's disease. IEEE Trans Biomed Eng. 2013;60:164-8.	57	6.33
40	Stewart J, Sprivulis P, Dwivedi G. Artificial intelligence and machine learning in emergency medicine. Emerg Med Australas. 20128;30, 870-874.	56	14
41	Topalovic M, Das N, Burgel PR, Daenen M, Derom E, Haenebalcke C, et al. Artificial intelligence outperforms pulmonologists in the interpretation of pulmonary function tests. Eur Respir J. 2019;53:1801660	55	18.33
42	Stefanelli M. The socio-organizational age of artificial intelligence in medicine. Artif Intell Med. 2001;23:25-47	54	2.57
43	Ulrich R, Kalkuhl A, Deschl U, Baumgärtner W. Machine learning approach identifies new pathways associated with demyelination in a viral model of multiple sclerosis. J Cell Mol Med. 2010;14:434-48.	51	4.25
44	Carter SM, Rogers W, Win KT, Frazer H, Richards B, Houssami N. The ethical, legal and social implications of using artificial intelligence systems in breast cancer care. Breast. 2020;49:25-32.	50	25
45	Nelson CA, Pérez-Chada LM, Creadore A, Li SJ, Lo K, Manjaly P, et al. Patient Perspectives on the Use of Artificial Intelligence for Skin Cancer Screening: A Qualitative Study. JAMA Dermatol. 2020;156:501-512.	49	24.5
46	Weiss JC, Natarajan S, Peissig PL, McCarty CA, Page D. Machine Learning for Personalized Medicine: Predicting Primary Myocardial Infarction from Electronic Health Records. AI Magazine, 2012;33, 33.	49	4.9
47	Shimizu H, Nakayama KI. Artificial intelligence in oncology. Cancer Sci. 2020;111:1452-1460.	48	24
48	Speight PM, Elliott AE, Jullien JA, Downer MC, Zakzrewska JM. The use of artificial intelligence to identify people at risk of oral cancer and precancer. Br Dent J. 1995;179:382-7	48	1.78
49	Miller PL. The evaluation of artificial intelligence systems in medicine. Comput Methods Programs Biomed. 1986;22:5-11.	46	1.28
50	Masters K. Artificial intelligence in medical education. Med Teach. 2019;41:976-980	44	14.67
51	Niel O, Bastard P. Artificial Intelligence in Nephrology: Core Concepts, Clinical Applications, and Perspectives. Am J Kidney Dis. 2019;74:803-810.	42	14
52	Nensa F, Demircioglu A, Rischpler C. Artificial Intelligence in Nuclear Medicine. J Nucl Med. 2019 Sep;60(Suppl 2):29S-37S	42	14

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53	Arimura H, Soufi M, Kamezawa H, Ninomiya K, Yamada M. Radiomics with artificial intelligence for precision medicine in radiation therapy. J Radiat Res. 2019;60:150-157.	42	14
54	Yoo TK, Kim SK, Kim DW, Choi JY, Lee WH, Oh E, et al. Osteoporosis risk prediction for bone mineral density assessment of postmenopausal women using machine learning. Yonsei Med J. 2013;54:1321-30.	42	4.67
55	Horn W. AI in medicine on its way from knowledge-intensive to data-intensive systems. Artif Intell Med. 2001;23:5-12.	40	1.91
56	Ilhan B, Lin K, Guneri P, Wilder-Smith P. Improving Oral Cancer Outcomes with Imaging and Artificial Intelligence. J Dent Res. 2020;99:241-248.	39	19.5
57	Rahmatizadeh S., Valizadeh-Haghi S., Dabbagh A. The role of artificial intelligence in management of critical COVID-19 patients. J Cell Mol Anesth. 2020;5:16-22.	39	19.5
58	Bhaskar S, Bradley S, Sakhamuri S, Moguilner S, Chattu VK, Pandya S, et al. Designing Futuristic Telemedicine Using Artificial Intelligence and Robotics in the COVID-19 Era. Front Public Health. 2020;8:556789.	38	19
59	Harmon SA, Tuncer S, Sanford T, Choyke PL, Türkbey B. Artificial intelligence at the intersection of pathology and radiology in prostate cancer. Diagn Interv Radiol. 2019;25:183-188.	37	12.33
60	Masud M, Sikder N, Nahid AA, Bairagi AK, AlZain MA. A Machine Learning Approach to Diagnosing Lung and Colon Cancer Using a Deep Learning-Based Classification Framework. Sensors (Basel). 2021;21:748.	34	34
61	Ahammed Muneer K V, Rajendran VR, K PJ. Glioma Tumor Grade Identification Using Artificial Intelligent Techniques. J Med Syst. 2019;43:113.	34	11.33
62	Yadav K, Sarioglu E, Smith M, Choi HA. Automated outcome classification of emergency department computed tomography imaging reports. Acad Emerg Med. 2013;20:848-54.	34	1.42
63	Prosperi MC, Marinho S, Simpson A, Custovic A, Buchan IE. Predicting phenotypes of asthma and eczema with machine learning. BMC Med Genomics. 2014;7 Suppl 1(Suppl 1):S7.	33	4.13
64	Kundu S. AI in medicine must be explainable. Nat Med. 2021;27:1328.	32	32
65	Enshaei A, Robson CN, Edmondson RJ. Artificial Intelligence Systems as Prognostic and Predictive Tools in Ovarian Cancer. Ann Surg Oncol. 2015;22:3970-5.	31	4.43
66	Bickman L. Improving Mental Health Services: A 50-Year Journey from Randomized Experiments to Artificial Intelligence and Precision Mental Health. Adm Policy Ment Health. 2020;47:795-843.	30	15
67	Powell J. Trust Me, I'm a Chatbot: How Artificial Intelligence in Health Care Fails the Turing Test. J Med Internet Res. 2019;21:e16222	30	10
68	Bjerring, J.C., Busch, J. Artificial Intelligence and Patient-Centered Decision-Making. Philos. Technol. 2020 Jan; 34: 349–371.	29	29
69	Kearney V, Chan JW, Valdes G, Solberg TD, Yom SS. The application of artificial intelligence in the IMRT planning process for head and neck cancer. Oral Oncol. 2018;87:111-116.	29	7.25
70	Lillehaug SI, Lajoie SP. AI in medical education—another grand challenge for medical informatics. Artif Intell Med. 1998;12:197-225.	29	1.21
71	Burton RJ, Albur M, Eberl M, Cuff SM. Using artificial intelligence to reduce diagnostic workload without compromising detection of urinary tract infections. BMC Med Inform Decis Mak. 2019;19:171.	28	9.33
72	Kulikowski CA. Beginnings of Artificial Intelligence in Medicine (AIM): Computational Artifice Assisting Scientific Inquiry and Clinical Art - with Reflections on Present AIM Challenges. Yearb Med Inform. 2019;28:249-256.	28	9.33
73	Peng S, Liu Y, Lv W, Liu L, Zhou Q, Yang H, et al. Deep learning-based artificial intelligence model to assist thyroid nodule diagnosis and management: a multicentre diagnostic study. Lancet Digit Health. 2021;3:e250-e259.	28	27
74	Mekov E, Miravitlles M, Petkov R. Artificial intelligence and machine learning in respiratory medicine. Expert Rev Respir Med. 2020;14:559-564.	27	13.5
75	Goldstein CA, Berry RB, Kent DT, Kristo DA, Seixas AA, Redline S, et al. Artificial intelligence in sleep medicine: background and implications for clinicians. J Clin Sleep Med. 2020;16:609-618.	27	13.5
76	Diprose WK, Buist N, Hua N, Thurier Q, Shand G, Robinson R. Physician understanding, explainability, and trust in a hypothetical machine learning risk calculator. J Am Med Inform Assoc. 2020;27:592-600.	27	13.5

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77	Perk T, Bradshaw T, Chen S, Im HJ, Cho S, Perlman S, et al. Automated classification of benign and malignant lesions in ^{18}F-NaF PET/CT images using machine learning. Phys Med Biol. 2018;63:225019.	27	6.75
78	Azencott CA. Machine learning and genomics: precision medicine versus patient privacy. Philos Trans A Math Phys Eng Sci. 2018;376:20170350.	27	6.75
79	Tay B, Hyun JK, Oh S. A machine learning approach for specification of spinal cord injuries using fractional anisotropy values obtained from diffusion tensor images. Comput Math Methods Med. 2014;2014:276589.	27	3.38
80	Abadir AP, Ali MF, Karnes W, Samarasena JB. Artificial Intelligence in Gastrointestinal Endoscopy. Clin Endosc. 2020;53:132-141.	27	13
81	Celi LA, Hinske LC, Alterovitz G, Szolovits P. An artificial intelligence tool to predict fluid requirement in the intensive care unit: a proof-of-concept study. Crit Care. 2008;12:R151.	26	1.86
82	Braun M, Hummel P, Beck S, Dabrock P. Primer on an ethics of AI-based decision support systems in the clinic. J Med Ethics. 2020;47:e3.	26	25
83	Khemasuwan D, Sorensen JS, Colt HG. Artificial intelligence in pulmonary medicine: computer vision, predictive model and COVID-19. Eur Respir Rev. 2020;29:200181.	25	12.5
84	Jutzi TB, Krieghoff-Henning EI, Holland-Letz T, Utikal JS, Hauschild A, Schadendorf D, et al. Artificial Intelligence in Skin Cancer Diagnostics: The Patients' Perspective. Front Med (Lausanne). 2020;7:233.	25	12.5
85	Guan J. Artificial Intelligence in Healthcare and Medicine: Promises, Ethical Challenges and Governance. Chin Med Sci J. 2019;34:76-83.	25	8.33
86	Shahid O, Nasajpour M, Pouriyeh S, Parizi RM, Han M, Valero M, et al. Machine learning research towards combating COVID-19: Virus detection, spread prevention, and medical assistance. J Biomed Inform. 2021;117:103751.	25	24
87	Rubeis G. The disruptive power of Artificial Intelligence. Ethical aspects of gerontechnology in elderly care. Arch Gerontol Geriatr. 2020;91:104186	24	12
88	Silva MA, Patel J, Kavouridis V, Gallerani T, Beers A, Chang K, et al. Machine Learning Models can Detect Aneurysm Rupture and Identify Clinical Features Associated with Rupture. World Neurosurg. 2019;131:e46-e51.	24	8
89	Chin-Yee B, Upshur R. Three Problems with Big Data and Artificial Intelligence in Medicine. Perspect Biol Med. 2019;62:237-256.	24	8
90	Mori Y, Neumann H, Misawa M, Kudo SE, Bretthauer M. Artificial intelligence in colonoscopy - Now on the market. What's next? J Gastroenterol Hepatol. 2021;36:7-11.	24	23
91	Yuan KC, Tsai LW, Lee KH, Cheng YW, Hsu SC, Lo YS, et al. The development an artificial intelligence algorithm for early sepsis diagnosis in the intensive care unit. Int J Med Inform. 2020;141:104176.	23	11.5
92	Hainc N, Federau C, Stieltjes B, Blatow M, Bink A, Stippich C. The Bright, Artificial Intelligence-Augmented Future of Neuroimaging Reading. Front Neurol. 2017;8:489.	23	4.6
93	Hopkins BS, Mazmudar A, Driscoll C, Svet M, Goergen J, Kelsten M, et al. Using artificial intelligence (AI) to predict postoperative surgical site infection: A retrospective cohort of 4046 posterior spinal fusions. Clin Neurol Neurosurg. 2020 ;192:105718.	21	10.5
94	Dikici E, Bigelow M, Prevedello LM, White RD, Erdal BS. Integrating AI into radiology workflow: levels of research, production, and feedback maturity. J Med Imaging (Bellingham). 2020;7:016502.	21	10.5
95	Vellido A, Ribas V, Morales C, Ruiz Sanmartín A, Ruiz Rodríguez JC. Machine learning in critical care: state-of-the-art and a sepsis case study. Biomed Eng Online. 2018;17(Suppl 1):135.	21	5.25
96	Diprose W, Buist N. Artificial intelligence in medicine: humans need not apply? N Z Med J. 2016;129:73-6. PMID: 27349266.	21	3.5
97	Sun LM, Chiu HW, Chuang CY, Liu L. A prediction model based on an artificial intelligence system for moderate to severe obstructive sleep apnea. Sleep Breath. 2011;15:317-23.	21	1.91

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98	Scheetz J, Rothschild P, McGuinness M, Hadoux X, Soyer HP, Janda M, et al. A survey of clinicians on the use of artificial intelligence in ophthalmology, dermatology, radiology and radiation oncology. Sci Rep. 2021;11:5193.	20	20
99	Castagno S, Khalifa M. Perceptions of Artificial Intelligence Among Healthcare Staff: A Qualitative Survey Study. Front Artif Intell. 2020;3:578983.	20	10
100	Kim KJ, Tagkopoulos I. Application of machine learning in rheumatic disease research. Korean J Intern Med. 2019;34:708-722.	20	6.67

Table-3: Top 5 journals in terms of highest number of cited articles.

No of Journal	No. of Articles	Impact Factor of Journal s
1. Artificial Intelligence in	9	7.011
2. Scientific Reports	4	4.996
3. Digital Medicine	2	15.36
4. Frontiers in Medicine	2	5.091
5. Journal of Medical Ethics	2	2.021

The journal 'Artificial Intelligence in Medicine' accounted for the highest number 9(9%) of articles. The impact factor of these journals ranged from 87.241 to 0.941. The impact factor of the 5 journals which contributed most of the articles to our bibliometric analysis ranged from 2.021 to 15.36 (Table 3).

The 100 top-cited articles originated from 37 different countries, with the highest number of articles originating from the United States 36(36%), followed by the United Kingdom 13(13%) and Germany 12(12%). Of the total, 2(2%) studies had unidentified origin (Figure 4).

The institutions affiliated with the selected articles were Harvard Medical School and its affiliated institutes, Brigham and Women's Hospital and Massachusetts General Hospital, which accounted for 11(11%) articles, followed by Univerza v Ljubljani 4(4%), University of California, Irvine, Yale School of Medicine, University of California, San Francisco 3(3%) publications each.

The articles were funded by some organisations, with the National Institute of Health (NIH) funding of most of the articles 8(8%), followed by other organisations (Figure 5).

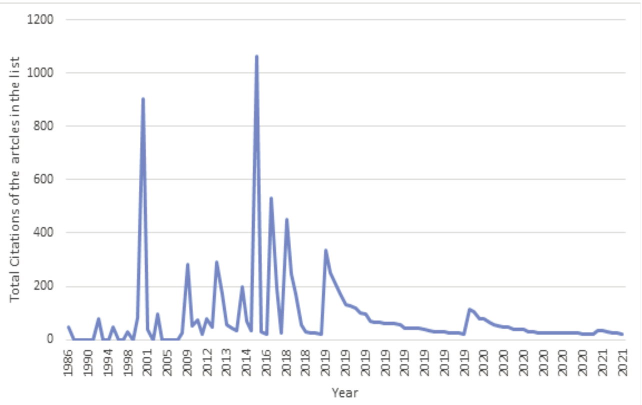

Figure-2: Total citations of the articles in the top-100 list every year.

Table-4: Publication distribution by research domains.

Rank	Research Domain	Output
1.	Medicine	45%
2.	Computer Science	11%
3.	Others	11%
4.	Biochemistry	10%
5.	Engineering	4%
6.	Social Sciences	4%
7.	Arts and Humanity	3%
8.	Nursing	3%
9.	Multidisciplinary	3%
10.	Health Profession	3%
11.	Physics and Astronomy	3%

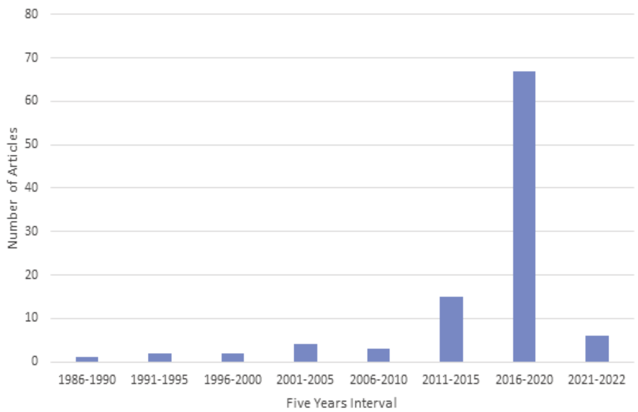

Figure-3: Number of Publications in each 5-year period.

The biggest part of the contribution was from the field of Medicine, followed by Computer Science (Table 4).

Discussion

The 100 most cited articles (Table 2) showed the extent of research and the evolving trends in the field of AI in medicine. The articles were published between 1986 and 2021, but most of the articles (n=65) were published between 2015 and 2020, which signifies a marked increase in research on the subject in recent years that is accompanied by its widespread use in the medical field and the development of the field of AI in recent times. Compared to bibliometric studies in other fields of medical practice, like General Surgery [8], Orthopaedics [9]

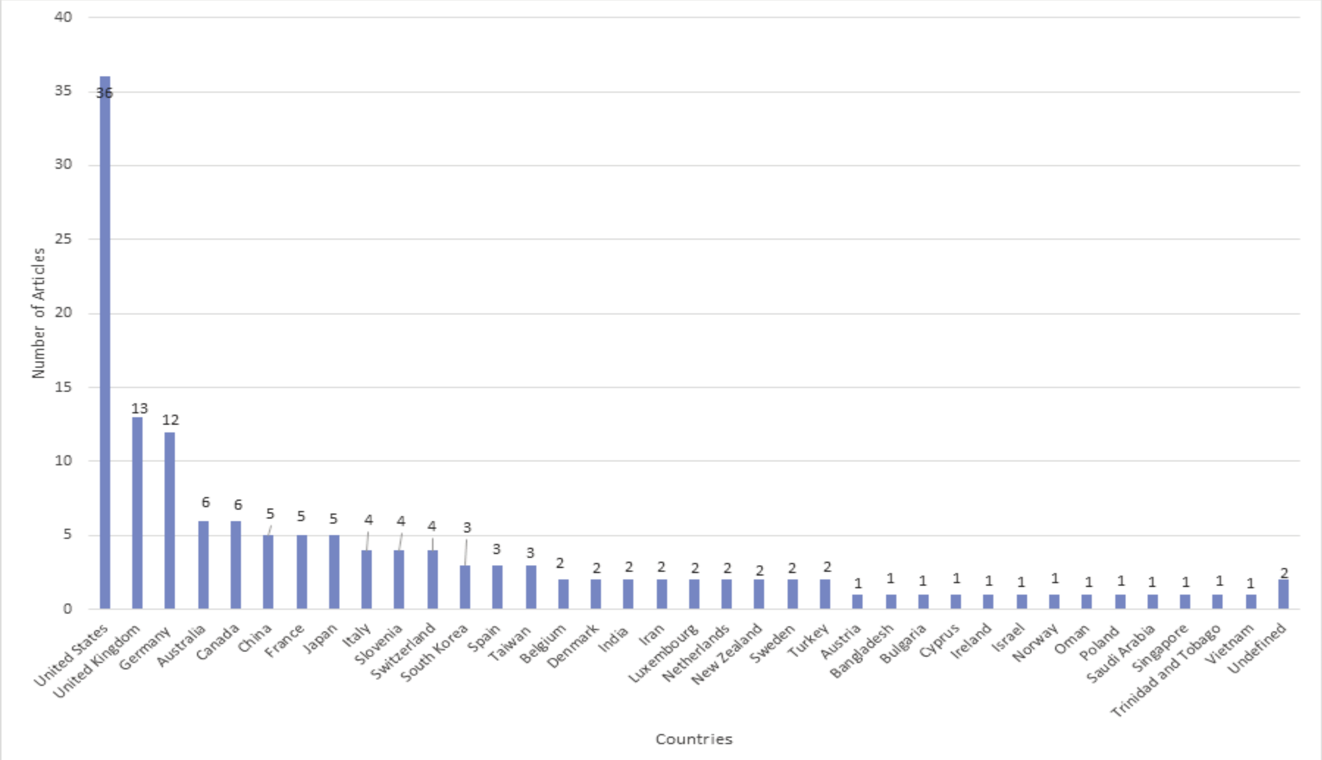

Figure-4: Number of articles originating from each country.

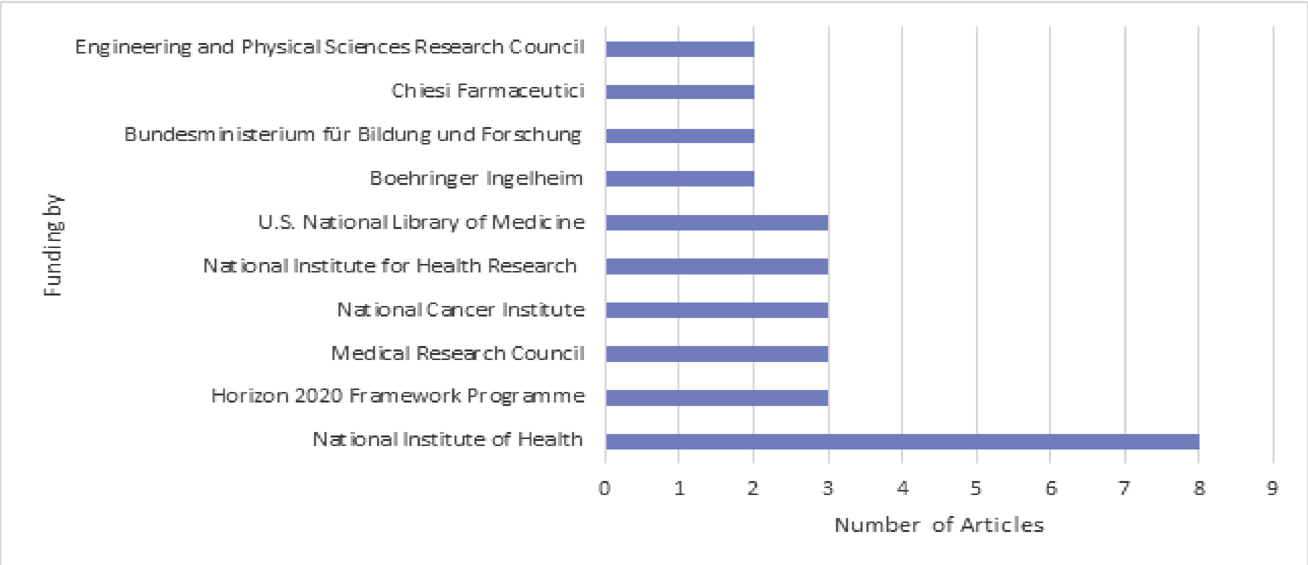

Figure-5: Top-10 funding sources of the articles.

and Neurosurgery [10] that have published their highly influential articles before the 1980s, there is a great rise in research trends in the field of AI in medicine in recent years. However, the study of some other fields, like cardiovascular magnetic resonance [11] and diabetes mellitus [12] have their most impactful research done in recent years, like that of AI. The phenomenon of obliteration-by-incorporation [13] suggests that some classic and highly impactful articles may not be cited as frequently as before because the information extracted from them has become so widespread in use in the field of medicine that researchers do not specifically cite them in their studies. Moreover, the trend of bibliometrics towards citing recently published papers that show the rapidly changing medical practices with the passing of time may lead to the exclusion of some important research papers [14]. The absence of articles published before 1986 in the current bibliometric analysis highlights that old articles are not relevant anymore as research trends have changed with time. The number of citations of an article reflects the overall impact of an article, but the current influence of an article cannot be perceived by just looking at this number alone.

To have an idea of the impact of an article in a particular year, the element of 'citations per year' (Table 2) was used. The article, 'Machine learning in medicine', had the most number of citations and citations per year, which, in part, was due to its old publication year (2015) and it was also funded by institutes, like the NIH and the National Heart, Lung and Blood Institute. Moreover, it incorporated many research domains, like Medicine and Computer Science, and was published in a high impact factor journal. All these factors contributed to the high citation score.

The highest number of articles (n=9) were published in the journal, 'Artificial Intelligence in Medicine'. Other articles were published in a broad variety of journals encompassing various fields, like Medicine, Biochemistry, Computer Science, Engineering, Social Sciences and Nursing. The top most cited articles were published in high impact factor journals with high citation index which showed the growing interest of research in the field of AI in medicine.

In the current bibliometric analysis of the 100 most cited articles on AI in medicine, the greatest number of articles on the list (n=36) originated from the US, which is probably attributed to the funding support provided by the NIH and various other platforms that promote research. Several European countries, like the United Kingdom and Germany followed, but there were only a few articles contributed from Asian countries, which can be attributed to the lack of research programmes, lack of motivation to do research, unwillingness to spend funds on research purposes, and an almost non-existent development of research institutes in these countries.

The current review has its limitations. It is reported that Scopus is likely to miss old citations prior to the 1980s, which could have resulted in the exclusion of the articles from the past [14,15]. Also, self-citations could lead to bias in the bibliometric analysis, which was expected as many of the authors had collaborated on many studies. Besides, some highly impactful articles published recently may not have made to the list of top 100 most-cited articles as citations number builds up over some period of time,[16] and the articles published long ago have a greater number of citations which is because of the increased number of citations over time.

Despite the limitations, the current review provided a thorough understanding of the most frequently cited and impactful articles relating to AI usage in medicine.

Conclusion

The review identified the current trends in the field of AI in medicine using studies indexed with the Scopus database. These studies were carefully selected from medical literature and will serve the researchers in the use of this emerging topic to transform the field of medicine. The analysis showed the growth of healthcare-related AI publications in the last decade because of their adoption in the field of medicine to transform healthcare, and also helped in the identification of countries and institutions that have made the most contribution. This will help future researchers in identifying the emerging patterns, and the need to explore the domain further.

Disclaimer: Out of 16 references, only four are from the last 05 years as more recent references could not be found.

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References

1. Abramo G, D'Angelo CA. Evaluating research: from informed peer review to bibliometrics. Scientometrics 2011;87:499-51. DOI: 10.1007/s11192-011-0352-7
2. Mejia C, Wu M , Zhang Y, Kajikawa Y. Exploring topics in bibliometric research through citation networks and semantic analysis. Front Res Metr Anal 2021 14:6:675071.doi: 10.3389/frma.2021.675071. eCollection 2021.
3. Schwartz WB, Patil RS, Szolovits P. Artificial intelligence in medicine. N Engl J Med 1987;31.
4. Basu K, Sinha R, Ong A, Basu T. Artificial Intelligence: How is It Changing Medical Sciences and Its Future? Indian J Dermatol. 2020;65(5):365-70. doi: 10.4103/ijd.IJD_421_20.
5. Yoon DY, Yun EJ, Ku YJ, Baek S, Lim KJ, Seo YL, et al. Citation classics in radiology journals: the 100 top-cited articles, 1945–2012. AJR Am J Roentgenol 2013;201:471-81. doi: 10.2214/AJR.12.10489.
6. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.
7. Journal Citations Reports JCR [Internet]. Clarivate. [online] [cited 2024 Jan 2]. Available from:URL: http://thomsonreuters.com /journal-citation-reports/?subsector= 18127
8. Paladugu R, Schein M, Gardezi S, Wise L. One hundred citation classics in general surgical journals. World J Surg. 2002;26:1099–105. doi: 10.1007/s00268-002-6376-7. Epub 2002 Jun 25.
9. Lefaivre KA, Shadgan B, O'Brien PJ. 100 most cited articles in orthopaedic surgery. Clin Orthop Relat Res. 2011;469:1487–97.

DOI:10.1007/s11999-010-1604-1
10. Ponce FA, Lozano AM. Highly cited works in neurosurgery. Part I: the 100 top-cited papers in neurosurgical journals. J Neurosurg. 2010;112:223–32. doi: 10.3171/2009.12.JNS091599.
11. Shuaib W, Costa JL. Anatomy of success: 100 most cited articles in diabetes research. Ther Adv Endocrinol Metab. 2015;6:163– 73. doi: 10.1177/2042018815580254.
12. Sztompka P. Society in action: The theory of social becoming. Chicago: University of Chicago Press; 1991.
13. Seglen PO. Citation rates and journal impact factors are not suitable for evaluation of research. Acta Orthop Scand. 1998;69: 224–9. doi: 10.3109/17453679809000920.
14. Falagas ME, Pitsouni EI, Malietzis GA, Pappas G. Comparison of PubMed, Scopus, web of science, and Google scholar: strengths and weaknesses. FASEB J. 2008;22:338– 42. doi: 10.1096/fj.07-9492LSF. Epub 2007 Sep 20.
15. Bakkalbasi N, Bauer K, Glover J, Wang L. Three options for citation tracking: Google Scholar, Scopus and Web of Science. Biomed Digit Libr. ;3:7. doi: 10.1186/1742-5581-3-7.
16. Brookes BC. Bradford's law and the bibliography of science. Nature. 1969;224: 953–6. doi: 10.1038/224953a0

Authors' Contributions

FZ: Data collection, tables and figures design, writing.
MA: Writing and referencing.
MWT: Data collection, tables design, writing.
AI: Writing.
All authors approved the final version.