Mathematical Biosciences and Engineering

MBE, 20 (6): 11367–11378.
DOI: 10.3934/mbe.2023504
Received: 06 March 2023
Revised: 05 April 2023
Accepted: 10 April 2023
Published: 27 April 2023

http://www.aimspress.com/journal/MBE

Research article

Artificial intelligence in acupuncture: A bibliometric study

Qiongyang Zhou[1,#], Tianyu Zhao[2,#], Kaidi Feng[3], Rui Gong[3], Yuhui Wang[3] and Huijun Yang[4,*]

[1] Department of Acupuncture and Moxibustion, The First People's Hospital of Wenling, Wenling 317500, China
[2] Hospital of Chengdu University of Traditional Chinese Medicine, Chengdu 610032, China
[3] Tianjin University of Traditional Chinese Medicine, Tianjin 301617, China
[4] Gansu Provincial Hospital of TCM, Lanzhou 730050, China

*** Correspondence:** Email: yhjtcm16999@163.com.

[#] The authors contributed equally to this work.

Abstract: This study aimed to provide a panorama of artificial intelligence (AI) in acupuncture by characterizing and visualizing the knowledge structure, hotspots and trends in global scientific publications. Publications were extracted from the Web of Science. Analyses on the number of publications, countries, institutions, authors, co-authorship, co-citation and co-occurrence were conducted. The USA had the highest volume of publications. Harvard University had the most publications among institutions. Dey P was the most productive author, while lczkowski KA was the most referenced author. The *Journal of Alternative and Complementary Medicine* was the most active journal. The primary topics in this field concerned the use of AI in various aspects of acupuncture. "Machine learning" and "deep learning" were speculated to be potential hotspots in acupuncture-related AI research. In conclusion, research on AI in acupuncture has advanced significantly over the last two decades. The USA and China both contribute significantly to this field. Current research efforts are concentrated on the application of AI in acupuncture. Our findings imply that the use of deep learning and machine learning in acupuncture will remain a focus of research in the coming years.

Keywords: acupuncture; artificial intelligence; publications; hotspots; trends

1. Introduction

Artificial intelligence (AI) is defined as technology that mimics human behavior with the goal of sensing how the human brain functions and incorporating human working mechanisms into the technology [1]. With the update and progress of AI, AI technologies have been used widely in various fields such as education, communication, transportation and healthcare [2,3]. The use of sophisticated simulation algorithms by AI has revolutionized various fields of healthcare, including medical imaging diagnostics, biomarker identification and drug development [4]. Most importantly, AI has given researchers and clinicians a crucial reference point for disease detection, prognosis and treatment [5].

As an integral part of traditional Chinese medicine (TCM), acupuncture is gradually being appreciated in the world [6,7]. In cases where conventional treatments are ineffective, patients often seek acupuncture treatment [8]. With the rapid development of modern scientific research, acupuncture has evolved in tandem with many advanced scientific techniques, including AI [9]. Notably, there has been a dramatic rise in the number of research works and publications on the application of AI in acupuncture. To guide future work and advance high-quality research, a bibliometric analysis of the literature on the application of AI in acupuncture may offer insight into the current state of this field [10,11]. This study aimed to reveal the fundamental status, research hotspots and research trends of AI in acupuncture based on the global literature.

2. Materials and methods

2.1. Data source

The Web of Science database is considered to be the best option for bibliometric research because it is the most thorough, transparent and extensive compared to other databases. The literature search was performed on 25 February 2023 with the following search query: TS = (acupuncture OR acupotomy OR acupotomies OR pharmacoacupuncture OR pharmacopuncture OR body-acupuncture OR electroacupuncture OR electro-acupuncture OR auricular acupuncture OR needle OR needling OR warm needle) AND TS = (artificial intelligence OR computational intelligence OR AI). The document type was restricted to “article”. Works published between 1985 and 2022 were included.

2.2. Data analyses

Data analyses were performed by Microsoft Excel 2019, R software (4.0.2), VOSviewer (1.6.18), and CiteSpace (6.1.R3). The number of annual publications and their trends, national publications, institutional publications, author publications, number of journal publications and data related to cited references were analyzed and described using Microsoft Excel 2019. Collaborative networks among countries, institutions and authors were constructed with R-package (http://www.bibliometrix.org). Analyses of co-cited references and co-occurrence keywords were performed using VOSviewer. Finally, the timeline of co-occurrence analyses of the keywords and burst keywords was built using CiteSpace.

3. Results

3.1. Analysis of publications

A total of 417 documents were identified and included in the present study. The number of publications in this field showed an increasing trend year by year (Figure 1A). The number of publications increases yearly in an exponential fashion, as shown by the data fitting (R^2 = 0.7046) (Figure 1B). These findings imply that research on AI in acupuncture is a hot topic and is moving quickly forward.

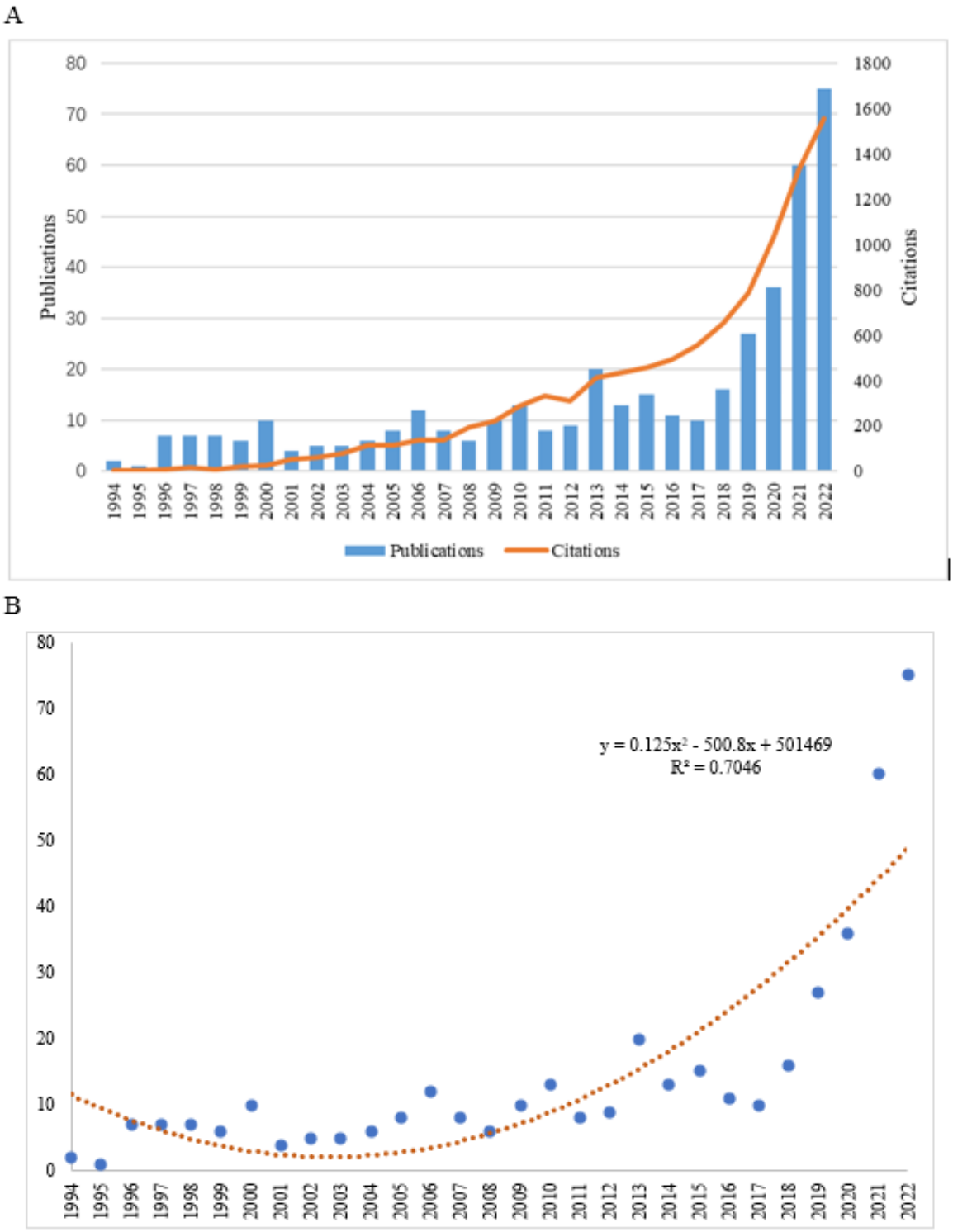


Figure 1. (A) Times cited and publications over time. (B) Curve fitting of the of the annual growth trend of publications.

3.2. Analysis of countries/regions

The top ten countries/regions with the highest frequency are summarized in Table 1. The USA was the most prolific country with 154 publications, accounting for 36.93% of published articles, and had the highest overall citations (n = 7020). With 85 and 38 publications, respectively, China and Japan came in second and third. Furthermore, France had the highest average number of citations (n = 56.69). In addition, the USA and United Kingdom showed the most active international partnerships in this field (Figure 2).

Table 1. The top 10 productive countries/regions.

Ranking	Country/Region	Publications	% of (417)	Total citations	Average citations
1	USA	154	36.93	5773	37.49
2	China	85	20.38	1316	15.48
3	Japan	38	9.11	699	18.39
4	Germany	31	7.43	1238	39.94
5	United Kingdom	27	6.47	1231	45.59
6	Italy	24	5.76	851	35.46
7	Korea	24	5.76	426	17.75
8	Canada	22	5.28	1041	47.32
9	France	13	3.12	737	56.69
10	Spain	13	3.12	255	19.62

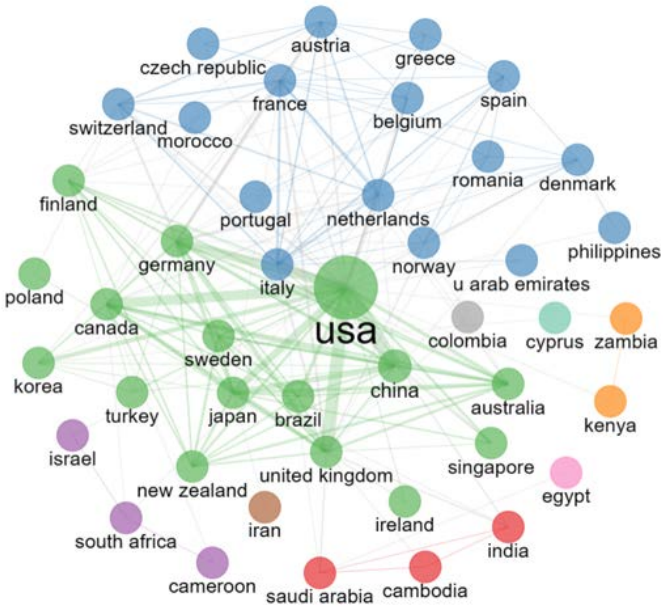


Figure 2. International collaboration between countries/regions.

3.3. Analysis of affiliations

The top ten affiliations with the highest frequency are summarized in Table 2. Harvard University was the most prolific affiliation with 15 publications. With 11 and 10 publications, respectively, the

University of California System and Harvard Medical School came in second and third. It was worth noting that the University of California System also had the highest the highest total citations (n = 705) and average citations (n = 64.09). In addition, Seoul National University and Duke University showed a complex network of cooperation in this field (Figure 3).

Table 2. The top 10 productive affiliations.

Ranking	Affiliation	Country	Publications	Total citations	Average citations
1	Harvard University	USA	15	627	41.80
2	University of California System	USA	11	705	64.09
3	Harvard Medical School	USA	10	382	38.20
4	Seoul National University	Korea	10	219	21.90
5	Chinese Academy of Sciences	China	9	189	21.00
6	Pennsylvania Commonwealth System of Higher Education	USA	9	233	25.89
7	Duke University	USA	8	334	41.75
8	Johns Hopkins University	USA	8	483	60.38
9	University of Pennsylvania	USA	8	349	43.63
10	University of Texas System	USA	8	255	31.88

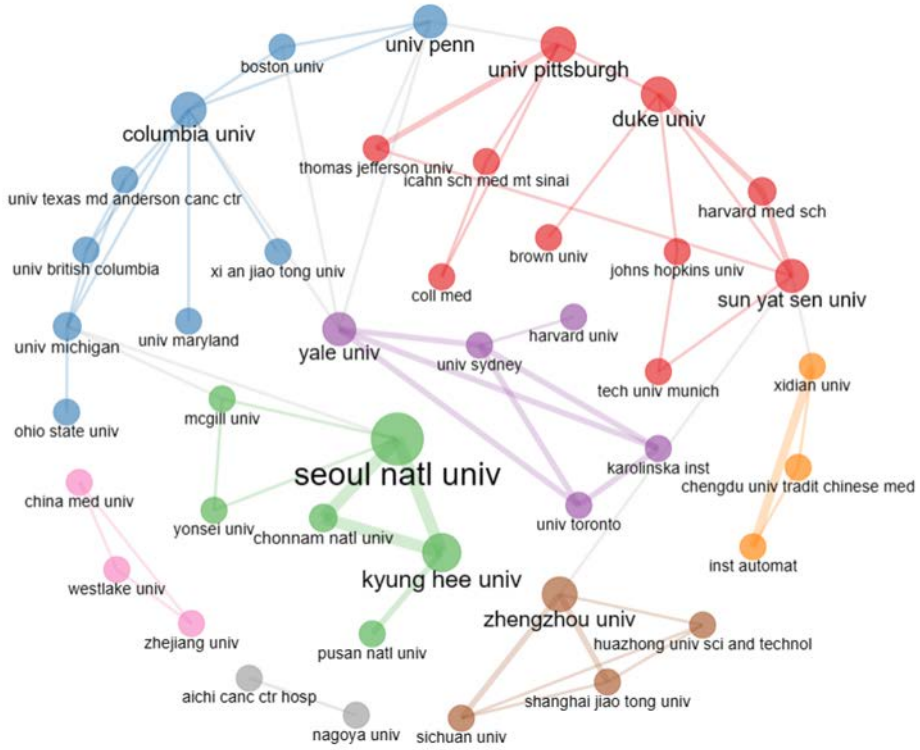


Figure 3. Collaboration between affiliations.

3.4. Analysis of authors

The top ten authors with the highest frequency are summarized in Table 3. Dey P was the most prolific author with six publications. With five and four publications, respectively, Wang J and Beitz

AJ came in second and third. It was worth noting that lczkowski KA had the highest total citations (n = 357) and average citations (n = 89.25). Interestingly, the H-indexes of all authors were comparable. In addition, Egevad L, Kim HW and Liu Z showed a complex network of cooperation in this field (Figure 4).

Table 3. The top 10 productive authors.

Ranking	Author	Country	Publications	Total citations	Average citations	H-index
1	Dey P	India	6	70	11.67	4
2	Wang J	China	5	264	52.8	4
3	Beitz AJ	Korea	4	130	32.50	4
4	Egevad L	Sweden	4	223	55.75	3
5	Han HJ	Korea	4	130	32.50	4
6	Lczkowski KA	US	4	357	89.25	4
7	Kim HW	Korea	4	130	32.50	4
8	Kwon YB	Korea	4	130	32.50	4
9	Lee HJ	Korea	4	130	32.50	4
10	Lee JH	Korea	4	130	32.50	4

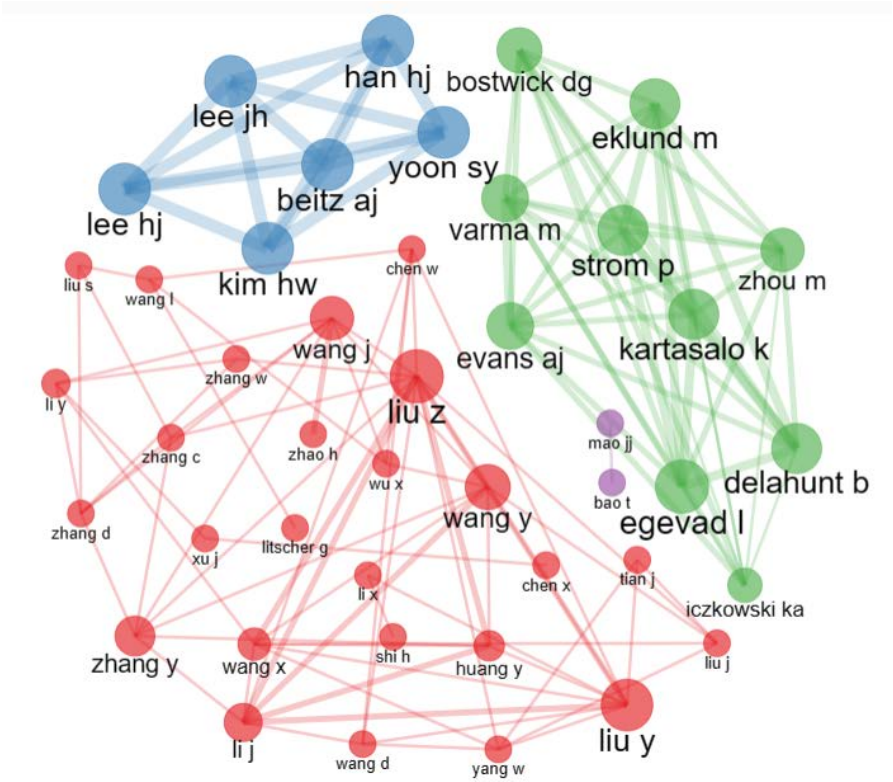


Figure 4. Collaboration between authors.

3.5. Analysis of journals

The top ten journals with the highest frequency are summarized in Table 4. The *Journal of Alternative and Complementary Medicine* was the most prolific journal with ten publications. With seven and six publications, respectively, *Diagnostic Cytopathology* and *Diagnostics* came in second

and third. It was worth noting that the *Journal of Alternative and Complementary Medicine* also had the highest total citations (n = 294) and average citations (n = 29.40). *European Radiology* was the journal in this field with the highest impact factor (IF) (7.034). In the last five years, the number of annual publications from the top five most active journals steadily increased (Figure 5).

Table 4. The top 10 most active journals.

Ranking	Journal	Publications	Total citations	Average citations	2021 IF
1	*Journal of Alternative and Complementary Medicine*	10	294	29.40	2.381
2	*Diagnostic Cytopathology*	7	130	18.57	1.390
3	*Diagnostics*	6	25	4.17	3.992
4	*Evidence-Based Complementary and Alternative Medicine*	6	5	0.83	2.650
5	*IEEE Robotics and Automation Letters*	6	44	7.33	4.321
6	*European Radiology*	5	127	25.40	7.034
7	*Acupuncture in Medicine*	4	74	18.50	1.976
8	*Cancer Cytopathology*	4	43	10.75	4.354
9	*Cytopathology*	4	23	5.75	1.286
10	*Materials Science and Engineering A-Structural Materials Properties Microstructure and Processing*	4	97	24.25	6.044

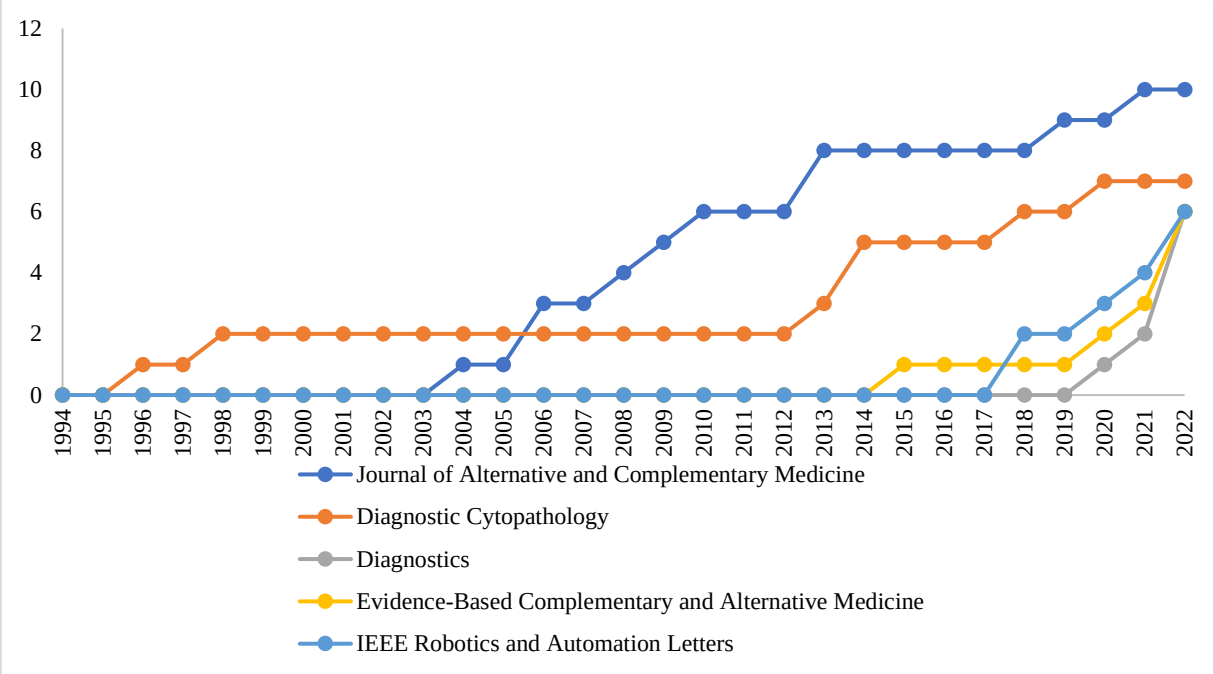


Figure 5. Publications of the top 5 most active journals over time.

3.6. Analysis of co-cited references

The included articles contained a total of 13,791 references. Of these references, 63 publications

with more than 5 co-citations were used to construct a literature co-citation network to reflect the research base in this field. After VOSviewer clustering, these references were divided into four clusters corresponding to the common technologies of AI (cluster 1 in red) and the application of AI in healthcare (cluster 2 in green, cluster 3 in blue and cluster 4 in yellow) (Figure 6).

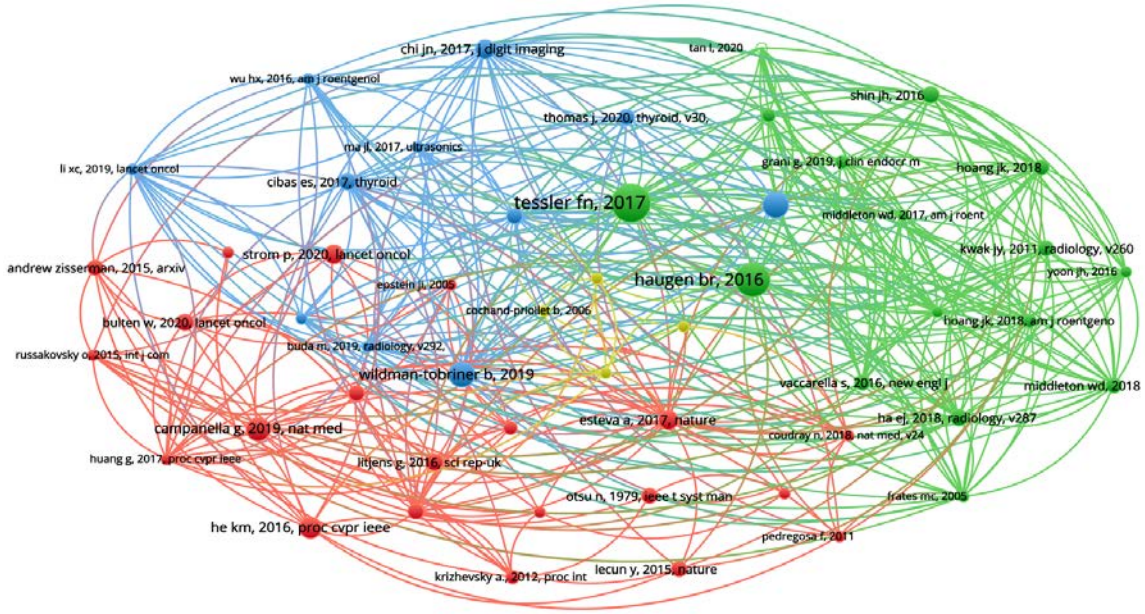
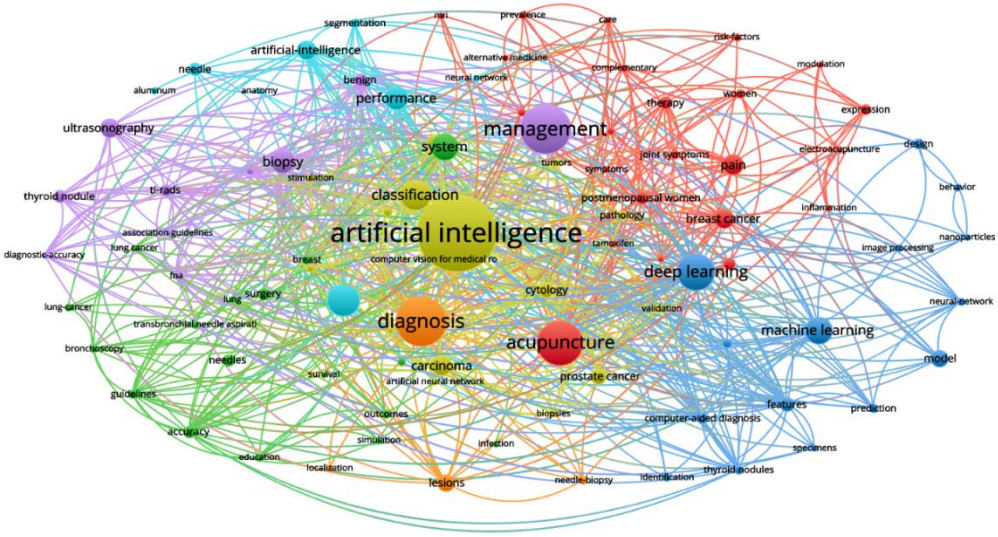


Figure 6. Network map of co-cited references.

3.7. Analysis of hotspots and trends in research

After VOSviewer clustering, keywords of authors were divided into seven clusters corresponding to the common diseases treated by acupuncture (cluster 1 in red), the implementation of acupuncture treatment (cluster 2 in green), the application of common AI technologies in acupuncture (cluster 3 in blue), the diagnosis and prognosis of disease (cluster 4 in yellow and cluster 7 in orange), and the mechanism of action of acupuncture (cluster 5 in purple and cluster 6 in light blue) (Figure 7A). The keywords that recently surfaced were "machine learning" and "deep learning" (Figure 7B).

A



B

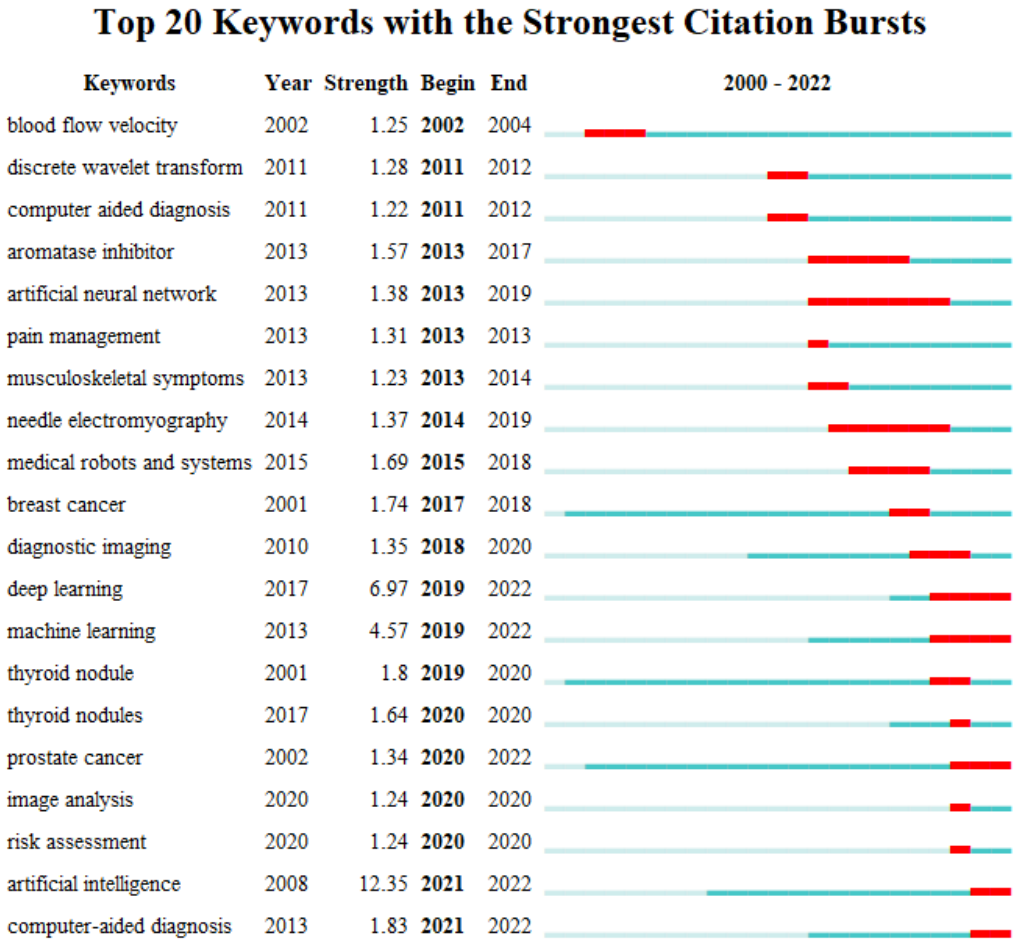


Figure 7. (A) Network map of keywords on AI in acupuncture. (B) Trends of keywords over time.

4. Discussion

From 1994 to 2022, 417 research articles on the application of AI in acupuncture were published. As AI technology has continued to advance since 2018, so too has the number of papers that have been published. Additionally, the USA and China demonstrated close cooperation, indicating their leadership in this field. In general, the research carried out in the USA and France was of high quality, and the most articles in this field were published in the *Journal of Alternative and Complementary Medicine*. The common technologies of AI and the application of AI in healthcare formed the basis of research in this field. The specific application of AI in various aspects of acupuncture, including diagnosis, treatment, acupoint combination and mechanism exploration, was the hot research topic in this field. Advanced techniques of AI, including machine learning and deep learning, may be the research trend in this field.

Acupuncture has been widely used in China for thousands of years. Today, it is a popular alternative therapy worldwide for treating chronic illnesses like functional gastrointestinal disorders, stroke, dementia and primary headaches [12–16]. One of the most important and fundamental components of acupuncture treatment is the combination of acupoints. Acupuncture point combinations are frequently designed based on the acupuncturist's experience, and experience with

acupuncture point combinations used varies greatly between acupuncturists, even when they treat the same disease. Each acupuncture point has multiple functions, according to TCM theory. For many diseases, there are still no widely accepted protocols for choosing acupuncture points. As a result, the transmission of acupuncture experience has long been challenged. In addition, the standardization, quantification and objectification of acupuncture, as well as the implementation of individualized clinical treatment, are pressing issues in acupuncture research.

AI is a novel, developing field with novel concepts, theories and technologies. Currently, the main areas of AI include artificial neural networks, intelligent decision systems, automatic programming, pattern recognition, machine learning and expert systems. A new surge in machine learning and deep learning-based AI has been particularly noticeable in recent years [17]. With the rapid development of TCM research and AI, acupuncture research has benefited as a result. With the application of AI in acupuncture, data mining methods based on AI can efficiently explore the law of acupoint combination, reveal effective acupoint combination and form effective acupuncture treatment options [18]. Machine learning methods, such as clustering algorithms and association rules, are the main tools being used in these fields, greatly improving the efficiency of identifying hidden knowledge about acupuncture point selection and prescription [19]. In addition, models using self-organizing neural network feature maps can be used to automatically and objectively identify the acupuncturist's techniques, enhancing the standardization, quantification and objectification of acupuncture operations [20]. Recently, it was reported that neuroimaging-based machine learning can learn a function based on the efficacy of acupuncture and clinical characteristics of patients, and this function can assist physicians in predicting the efficacy of acupuncture treatment [21]. In addition, methods through AI technologies have been reported to help reveal the mechanism of action of acupuncture from a neural network perspective [22,23]. In generally, the application of AI in acupuncture is a promising field in the future. As found in this study, the application of AI in various aspects of acupuncture is a current hot topic, and research based on the latest AI technologies, such as machine learning and deep learning, will be the research trend in this field.

Limitations should be acknowledged. Articles indexed in other databases that could have been included were missed because data were only taken from Web of Science. Additionally, we might have overlooked some pertinent publications because we focused our search on articles where specific keywords appeared in the title, abstract and keywords.

5. Conclusions

Research on AI in acupuncture has advanced significantly over the last two decades. The USA and China both contribute significantly to this field. Current research efforts are concentrated on the application of AI in acupuncture. Our findings imply that the use of deep learning and machine learning in acupuncture will remain a focus of research in the coming years.

Acknowledgments

This work was supported by the Science and Technology Program of Lanzhou, China (2022-ZD-73); Administration of Traditional Chinese Medicine of Gansu Province, China (GZKP-2022-17); the Project of Director of Gansu Famous Doctors Studio, China (No. [2022]50); Influence of different acupoint combinations "Li Zhongyu Pestle needle Therapy" on insomnia (2022CP0992).

Conflict of interest

The author declares there is no conflict of interest.

References

1. A. J. Hamilton, A. T. Strauss, D. A. Martine, J. S. Hinson, S. Levin, G. Lin, et al., Machine learning and artificial intelligence: Applications in healthcare epidemiology, *Antimicrob. Steward. Healthc. Epidemiol.*, **1** (2021), e28. https://doi.org/10.1017/ash.2021.192
2. M. Greco, P. F. Caruso, M. Cecconi, Artificial Intelligence in the Intensive Care Unit, *Semin. Respir. Crit. Care Med*., **42** (2021), 2–9. https://doi.org/10.1055/s-0040-1719037
3. R. A. Miller, Medical diagnostic decision support systems–past, present, and future: A threaded bibliography and brief commentary, *J. Am. Med. Inform. Assoc.*, **1** (1994), 8–27. https://doi.org/10.1136/jamia.1994.95236141
4. P. Hamet, J. Tremblay, Artificial intelligence in medicine, *Metabolism*, **69S** (2017), S36–S40. https://doi.org/10.1016/j.metabol.2017.01.011
5. K. H. Yu, A. L. Beam, I. S. Kohane, Artificial intelligence in healthcare, *Nat. Biomed. Eng*., **2** (2018), 719–731. https://doi.org/10.1038/s41551-018-0305-z
6. B. Y. Liu, B. Chen, Y. Guo, L. X. Tian, Acupuncture – a national heritage of China to the world: International clinical research advances from the past decade, *Acupunct. Herb. Med*., **1** (2021), 65–73. https://doi.org/10.1097/HM9.0000000000000017
7. Y. Guo, Y. M. Li, T. L. Xu, M. X. Zhu, Z. F. Xu, B. M. Dou, et al., An inspiration to the studies on mechanisms of acupuncture and moxibustion action derived from 2021 Nobel Prize in Physiology or Medicine, *Acupunct. Herb. Med*., **2** (2022), 1–8. https://doi.org/1097.9/HM0000000000000023
8. Y. Q. Zhang, L. Lu, N. Xu, X. Tang, X. Shi, A. Carrasco-Labra, et al., Increasing the usefulness of acupuncture guideline recommendations, *BMJ*, **25** (2022), e070533. https://doi.org/10.1136/bmj-2022-070533
9. C. Feng, S. Zhou, Y. Qu, A. Wang, S. Bao, Y. Li, et al., Overview of artificial intelligence applications in Chinese Medicine Therapy, *Evid. Based. Complement. Alternat. Med*., **3** (2021), 6678958. https://doi.org/10.1155/2021/6678958
10. T. M. Man, L. Wu, J. Y. Zhang, Y. T. Dong, Y. T. Sun, L. Luo, Research trends of acupuncture therapy for hypertension over the past two decades: A bibliometric analysis, *Cardiovasc. Diagn. Ther*., **13** (2023), 67–82. https://doi.org/10.21037/cdt-22-480
11. F. Danış, E. Kudu, The evolution of cardiopulmonary resuscitation: Global productivity and publication trends, *Am. J. Emerg. Med*., **54** (2022), 151–164. https://doi.org/10.1016/j.ajem.2022.01.071
12. J. Huang, M. Lu, Y. Zheng, J. Ma, X. Ma, Y. Wang, et al., Quality of evidence supporting the role of acupuncture for the treatment of Irritable Bowel Syndrome, *Pain Res. Manag*., **12** (2021), 2752246. https://doi.org/10.1155/2021/2752246
13. J. Huang, J. Liu, Z. Liu, J. Ma, J. Ma, M. Lv et al., Reliability of the evidence to guide decision-making in acupuncture for functional dyspepsia, *Front. Public Health*., **4** (2022), 842096. https://doi.org/10.3389/fpubh.2022.842096

14. J. Huang, M. Shen, X. Qin, M. Wu, S. Liang, Y. Huang, Acupuncture for the treatment of Alzheimer's Disease: An overview of systematic reviews, *Front. Aging Neurosci*., **12** (2020), 574023. https://doi.org/10.3389/fnagi.2020.574023
15. J. Huang, M. Wu, S. Liang, X. Qin, M. Shen, J. Li J, et al., A critical overview of systematic reviews and Meta-analyses on acupuncture for Poststroke Insomnia, *Evid. Based Complement. Alternat. Med*., **10** (2020), 2032575. https://doi.org/10.1155/2020/2032575
16. J. Huang, M. Shen, X. Qin, W. Guo, H. Li, Acupuncture for the treatment of tension-type headache: An overview of systematic reviews, *Evid. Based Complement. Alternat. Med*., **3** (2020), 4262910. https://doi.org/10.1155/2020/4262910
17. I. Wahyudi, C. P. Utomo, S. Djauzi, M. Fathurahman, G. R. Situmorang, A. Rodjani, et al., Digital pattern recognition for the identification of various hypospadias parameters via an artificial neural network: Protocol for the development and validation of a system and mobile App, *JMIR Res. Protoc*., **11** (2022), e42853. https://doi.org/10.2196/42853
18. J. Yu, Y. Jiang, M. Tu, B. Liao, J. Fang, Investigating prescriptions and mechanisms of acupuncture for chronic stable angina pectoris: An association rule mining and network analysis study, *Evid. Based Complement. Alternat. Med*., **10** (2020), 1931839. https://doi.org/10.1155/2020/1931839
19. S. Yu, J. Yang, M. Yang, Y. Gao, J. Chen, Y. Ren et al., Application of acupoints and meridians for the treatment of primary dysmenorrhea: A data mining-based literature study, *Evid. Based Complement. Alternat. Med*., **2** (2015), 752194. https://doi.org/10.1155/2015/752194
20. W. Tang, H. Yang, T. Liu, M. Gao, X. Gang, Study on quantification and classification of acupuncture lifting-thrusting manipulations on the basis of motion video and self-organizing feature map neural network, *Shanghai J. Acupunct. Moxib*., **35** (2017), 1012–1020. https://doi.org/10.13460/j.issn.1005-0957.2017.08.1012
21. J. Zhang, Z. Li, Z. Li, J. Li, Q. Hu, J. Xu, et al., Progress of acupuncture therapy in diseases based on magnetic resonance image studies: A literature review, *Front. Hum. Neurosci*., **15** (2021), 694919. https://doi.org/10.3389/fnhum.2021.694919
22. T. Yin, P. Ma, Z. Tian, K. Xie, Z. He, R. Sun, et al., Machine learning in neuroimaging: A new approach to understand acupuncture for neuroplasticity, *Neural. Plast*., **8** (2020), 8871712. https://doi.org/10.1155/2020/8871712
23. J. Xu, H. Xie, L. Liu, Z. Shen, L. Yang, W. Wei, et al., Brain mechanism of acupuncture treatment of chronic pain: An individual-level positron emission tomography study, *Front. Neurol*., **13** (2022), 884770. https://doi.org/10.3389/fneur.2022.884770