



Research article

Acupuncture for stroke: A bibliometric analysis of global research from 2000 to 2022

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ABSTRACT

Objective: This study aimed to explore the global and future research trends in acupuncture interventions for stroke between 2000 and 2022 using bibliometric analysis.

Method: A bibliometric analysis of literature from 2000 to 2022 in the Web of Science Core Collection was conducted in this study. The analysis utilized CiteSpace, VOSviewer, and Scimago Graphica software to identify the major contributors to publications, including authors, countries, institutions, journals, references, and keywords.

Results: The bibliometric analysis yielded a total of 860 publications. There was a gradual increase in the number of publications over the study period. China published the most articles. *Evidence-Based Complementary and Alternative Medicine* was the journal with the greatest number of publications. The most frequently used keywords were “acupuncture,” “stroke,” and “electroacupuncture.”

Conclusion: These analysis uncovers the research trends in acupuncture for stroke spanning 2000 to 2022 and points to prospective research frontiers. This study provides a deeper and more thorough understanding of the connotations of acupuncture for stroke and guidance and support for future research in this field.

1. Introduction

Among all neurological diseases, stroke contributes the most to death and disability-adjusted life years (DALYs) [1]. Nearly 60 percent of strokes occur in people under the age of 70, and stroke rates are steadily rising among young people aged 15–49, causing financial hardship for families of stroke patients [2]. Stroke burdens patients and societies, especially in low- and middle-income countries [3]. Ischemic and hemorrhagic strokes are prevalent forms of stroke. Ischemic stroke, representing the majority of cases, occurs due to the embolization of cerebral arteries. Insufficient blood supply leads to the loss of essential glucose and oxygen in brain

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cells, disrupts the balance of the intracellular environment, and causes excitotoxicity, oxidative stress, apoptosis, inflammation, and other pathophysiological processes, eventually causing neuronal death and neurologic deficits [4]. Stroke results in functional impairments that affect daily activities, including eating, bathing, dressing, and walking [5]. Tissue-type plasminogen activator (tPA) therapy is an effective stroke treatment. However, owing to the narrow window of tPA treatment, only a small number of patients with stroke benefit from this therapy [6]. Thus, it is crucial to investigate alternative therapies to improve the living conditions of stroke patients.

Acupuncture refers to the insertion of metal needles to stimulate acupoints located in specific body parts using electrical, manual, or other types of stimulation [7]. This is an ancient method used to treat various conditions, including stroke and other neurological disorders [8]. Acupuncture can improve a variety of post-stroke dysfunctions, such as motor dysfunction, cognitive impairment, shoulder pain, walking and balance problems, dysphagia, spasticity, post-stroke pain, depression, and sleep problems [9]. Studies have shown that acupuncture can attenuate ischemic brain injury by modulating inflammation, apoptosis, autophagy, glutamate and its receptors, microRNAs (miRNAs), and other molecules involved in various signaling pathways [10,11]. Therefore, exploring the research status and developmental trends of using acupuncture to treat stroke is of great clinical significance.

Bibliometrics is an interdisciplinary science of mathematics and statistics that describes and analyzes the dynamics and progress of a particular discipline or research field. Bibliometrics is extensively employed to identify research hotspots and trends and help us understand the knowledge base of a specific field and the progress of research frontiers. Bibliometric analysis has been increasingly applied to acupuncture research, including studies on acupuncture treatments for pain, insomnia, and depression [12–14]. With the further strengthening of international exchange and cooperation, researchers worldwide are paying increasing attention to acupuncture for stroke treatment. This study involved an exhaustive and systematic analysis of the research status and developmental trends of acupuncture for stroke using bibliometrics. The classification, prospects, popular research fields, and developmental trends of acupuncture for stroke were summarized.

2. Methods

2.1. Data sources and search strategy

We selected the Web of Science Core Collection (WoSCC) as the data source for identifying and extracting relevant publications. To cover as many target documents as possible, we built our search strategy by choosing terms that most scientific publications may use. To prevent issues such as duplication, missing data, or thematic inconsistencies, data screening and standardization before the analysis was necessary to ensure that the data quality was not affected by the results. The retrieval strategy was (TS=(“electroacupuncture”) OR TS=(“acupuncture”)) AND (TS=(“stroke”) OR TS=(“apoplexy”) OR TS=(“cerebrovascular accident”) OR TS=(“cerebral hemorrhage”) OR TS=(“hematencephalon”) OR TS=(“encephalorrhagia”) OR TS=(“cerebral ischemia”)) AND DOP=(2000-01-01/2022-12-31) AND LA=(English) AND DT=(article OR review).

The search strategy was applied on March 18, 2023, and yielded 1404 results. After screening, 382 articles that were inconsistent

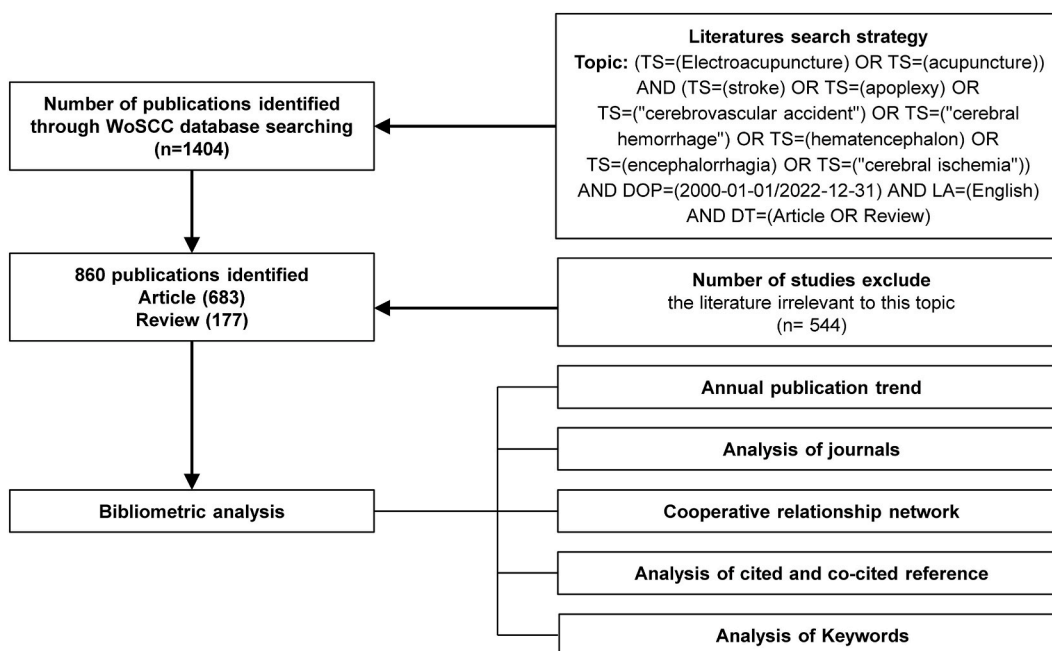


Fig. 1. Experiment flowchart.

with the theme were eliminated, and 860 articles were finally included.

2.2. Statistical analysis

The data review and screening process involved the following steps: (1) Two members of the team independently evaluated the papers, excluding those not aligned with the topic. (2) The selected documents, institutions, and countries were standardized to prevent variations in institution, or country names from affecting the results. (3) Inconsistent formations and variations between singular and plural terms may lead to redundant repetitions. Therefore, keywords were standardized. For instance, the keywords “metaanalysis,” “meta-analysis,” and “Meta-analysis” were all standardized to “meta-analysis” in this study.

We utilized CiteSpace (version 6.1 R1), VOSviewer (version 1.6.18), and Scimago Graphica (version 1.0.34) for bibliometric analysis of key literature characteristics, such as publication count, countries/regions, institutions, authors, journals, documents, and keywords. VOSviewer and CiteSpace are extensively used bibliometric tools [15]. VOSviewer is a free program that excels in graphically representing large, easily interpretable bibliometric maps [16]. CiteSpace is also a free program, notable for its ability to intuitively present research hotspots, evolutionary processes, and predict trends across multiple fields [17]. The parameters for CiteSpace were set as follows: method (LLR), Time Slicing (2000–2022), Year per slice (1), Term source (all selected), Selection Criteria (g-index: $k = 25$) and pruning(pathfinder, pruning sliced networks). Additionally, Scimago Graphica was employed to create networks illustrating collaborations among countries. Fig. 1 displays the flowchart of the experiment.

3. Results

3.1. General analysis

Between 2000 and 2022, 860 publications, including articles and reviews, were related to research on acupuncture for stroke. Fig. 2 shows the quantity of publications and overall number of citations on acupuncture for stroke. From 2000 to 2022, both the annual number of publications and total citations experienced an increase, indicating a rising trend in yearly output.

3.2. Country and institutional analyses

According to the authors’ addresses, the publications originated from 34 countries or regions. Table 1 displays the top ten countries and institutions. The countries with the highest number of publications were China, the United States, South Korea, the United Kingdom, and Australia. China, which had the most published articles, is the birthplace of acupuncture and the country where acupuncture is most commonly used to treat diseases.

Fig. 3 shows the co-occurrence knowledge map drawn by VOSviewer for the 27 institutions that published at least five articles on acupuncture for stroke. As shown in Fig. 3A, China has established collaborations with many countries, indicating that China plays a leading role in international research on acupuncture treatment of stroke. As shown in Fig. 3B, China and the United States had the closest collaborations, suggesting close cooperative relationships between them in acupuncture for stroke.

For acupuncture for stroke, the top three research institutions with multiple publications were Guangzhou University of Chinese Medicine, Fujian University of Traditional Chinese Medicine, and Beijing University of Chinese Medicine. Table 1 displays the leading ten institutions. Nine of the top ten institutions were from China, following the same trend as the national distribution. Following selection based on visualization criteria, 70 institutions each with at least five publications were chosen. We then constructed a collaborative network using the publication counts and inter-institutional relationships. As shown in Fig. 4, Guangzhou Provincial Hospital of Traditional Chinese Medicine and Guangzhou University of Chinese Medicine are close to each other, reflecting the collaboration between the college and hospital.

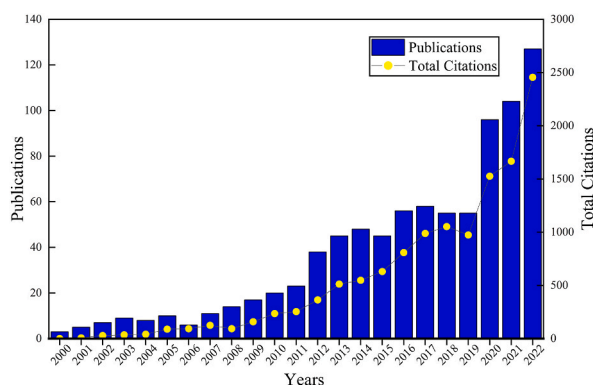


Fig. 2. Annual number of publications on acupuncture for stroke (2000–2022).

Table 1
Top ten productive countries and institutions.

Ranking	Country	Frequency (articles)	Citations	Ranking	Institution	Frequency (articles)	Citations
1	Peoples R China	745	9858	1	Guangzhou University of Chinese Medicine	68	477
2	South Korea	66	1380	2	Fujian University of Traditional Chinese Medicine	58	1239
2	USA	66	1591	3	Beijing University of Chinese Medicine	52	517
4	England	20	877	4	Tianjin University of Traditional Chinese Medicine	49	520
5	Australia	11	125	5	China Medical University	37	835
6	Canada	10	399	6	Shanghai University of Traditional Chinese Medicine	35	207
7	Japan	8	120	7	Fudan University	32	403
8	Austria	7	151	8	China Medical University Hospital	30	705
8	Germany	7	108	9	Kyung Hee University	29	495
10	Spain	5	153	10	Capital Medical University	28	378

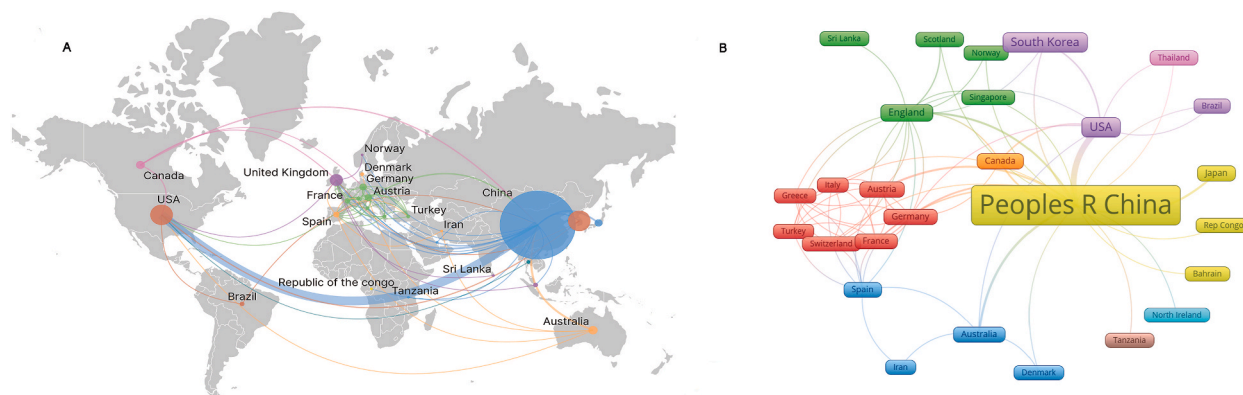


Fig. 3. Map of countries with acupuncture in stroke research publications from 2000 to 2022.

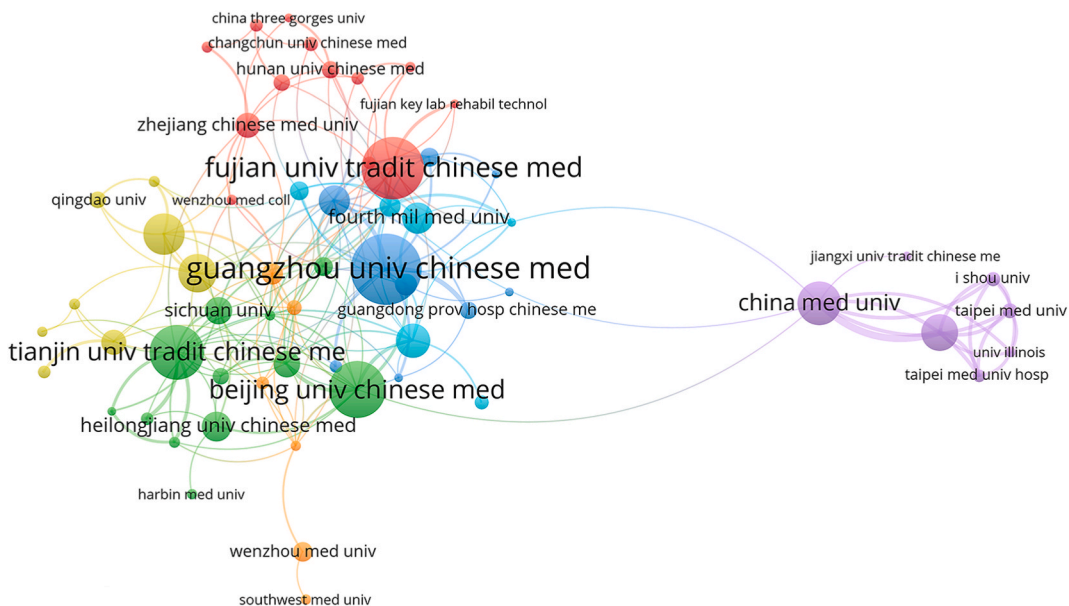


Fig. 4. Network map of co-authorship between institutions of acupuncture in stroke research from 2000 to 2022.

3.3. Journal analysis

A compilation of 860 articles related to acupuncture for stroke were published in 178 journals. The ten journals with the highest frequency of publications are listed in Table 2. *Evidence-Based Complementary and Alternative Medicine* had the most publications, with 79 articles. *Neural Regeneration Research* was the next highest, with 71 articles. According to the 2021 impact factor (IF) ranking, *Neural Regeneration Research* had the highest IF of 6.058. According to the Journal Citation Reports (JCR) 2021 criteria, of the top ten journals, two were classified in the first quartile (Q1), two in the second quartile (Q2), and five in the third quartile (Q3). The top ten academic journals published 372 articles, representing 43.26 % of the total articles. This indicates that the top ten academic journals played a pivotal role in disseminating research on acupuncture for stroke. Notably, six of these journals are open-access (OA), underscoring the significant contribution of the recent expansion of OA journals to advancements in this research area. The published journals mainly focus on "integrative and complementary medicine," and increasing research is communicated through the leading journals in this field. Therefore, greater international acceptance of acupuncture for stroke is required, while publishing relevant papers in high-IF journals has significant challenges. The journal with the most single citations was *BMC Complementary and Alternative Medicine*, the Q1 journal in "INTEGRATIVE & COMPLEMENTARY MEDICINE," with an average of 23.50 citations per article. This result suggests that high-quality journals receive greater attention from other researchers.

A total of 860 articles from 5340 journals were cited. Table 2 enumerates the ten journals that received the most citations. The top three most-cited journals were *Stroke*, *Zhongguo Zhenjiu*, and *Evidence-Based Complementary and Alternative Medicine*. According to the JCR 2021 criteria, of the top ten co-cited journals, three were classified into Q1, three into Q2, and three into Q3. *Stroke*, a regional journal of peripheral vascular disease and clinical neurology, is a leading journal in stroke research. Researchers in this field cited literature in *Stroke* 2075 times, laying a solid foundation for research in this field. *Zhongguo Zhenjiu*, which is not included in the Science Citation Index (SCI), is an authoritative journal of Chinese acupuncture research. This has an important influence on acupuncture and represents the frontier of acupuncture research. The diagram illustrates citation dynamics: the left side lists the citing journals, while the right side displays the cited journals, with citation links shown as colored lines extending from left to right. These colored trajectories represent citation pathways, notably including one orange and one pink path. Typically, studies in the fields of molecular biology, genetics, neurology, sports, and ophthalmology cite works published in journals focused on molecular biology and genetics (Fig. 5).

3.4. Author analysis

Through the analysis of the publication volume per author, we pinpointed the key scholars and central research groups in acupuncture for stroke. Table 3 lists the major contributors to studies related to acupuncture for stroke. Tao Jing emerged as the most prolific author, contributing to 43 publications, with Chen Lidian closely following with 40 publications. The top nodes are closely related, with four of the top five authors working at Fujian University of Traditional Chinese Medicine. The top two authors, Jing Tao and Lidian Chen, were close collaborators who have published 31 articles. The most frequently cited article by Jing Tao and Lidian Chen was "Electroacupuncture exerts anti-inflammatory effects in cerebral ischemia-reperfusion injured rats via suppression of the TLR4/NF-kappa B pathway" [18]. The investigation revealed that acupuncture modulates key signaling molecules within the TLR4/NF-kappa B pathway, correlating with the suppression of inflammatory cytokine secretion, including TNF- α , IL-1 β , and IL-6. Furthermore, electroacupuncture (EA) is posited to exert a neuroprotective effect in ischemic stroke by inhibiting TLR4/NF-kappa B-mediated inflammation. Tao and Chen's research team has a wide range of research interests, including inflammation [19], apoptosis [20], nerve cell proliferation [21], synaptic plasticity [22], neuroimaging [23], and the clinical efficacy [24] of acupuncture

Table 2
Top ten most productive and co-cited journals.

Ranking	Journal	Frequency	IF (2021)	Q (2021)	Ranking	Co-cited journal	Frequency	IF (2021)	Q (2021)
1	<i>Evidence-Based Complementary and Alternative Medicine</i>	79	–	–	1	<i>Stroke</i>	2075	10.17	Q1
2	<i>Neural Regeneration Research</i>	71	6.058	Q1	2	<i>Zhongguo Zhen jiu</i>	708	–	–
3	<i>Medicine</i>	60	1.817	Q3	3	<i>Evidence-based Complementary and Alternative Medicine</i>	591	–	–
4	<i>Acupuncture in Medicine</i>	33	1.984	Q3	4	<i>Neuroscience Letters</i>	431	3.197	Q3
5	<i>Trials</i>	26	2.728	Q4	5	<i>Brain Research</i>	370	3.61	Q3
6	<i>Frontiers in Neurology</i>	24	4.086	Q2	6	<i>PLoS One</i>	455	3.752	Q2
7	<i>Journal of Traditional Chinese Medicine</i>	21	2.547	Q3	7	<i>Cochrane Database of Systematic Reviews</i>	482	2.381	Q1
8	<i>BMC Complementary and Alternative Medicine</i>	20	4.782	Q1	8	<i>Archives of Physical Medicine and Rehabilitation</i>	449	7.538	Q1
9	<i>Journal of Alternative and Complementary Medicine</i>	19	2.381	Q3	9	<i>Journal of Alternative and Complementary Medicine</i>	417	2.381	Q2
10	<i>Acupuncture & Electro-therapeutics Research</i>	19	0.684	Q4	10	<i>Journal of Cerebral Blood Flow and Metabolism</i>	355	6.597	Q1

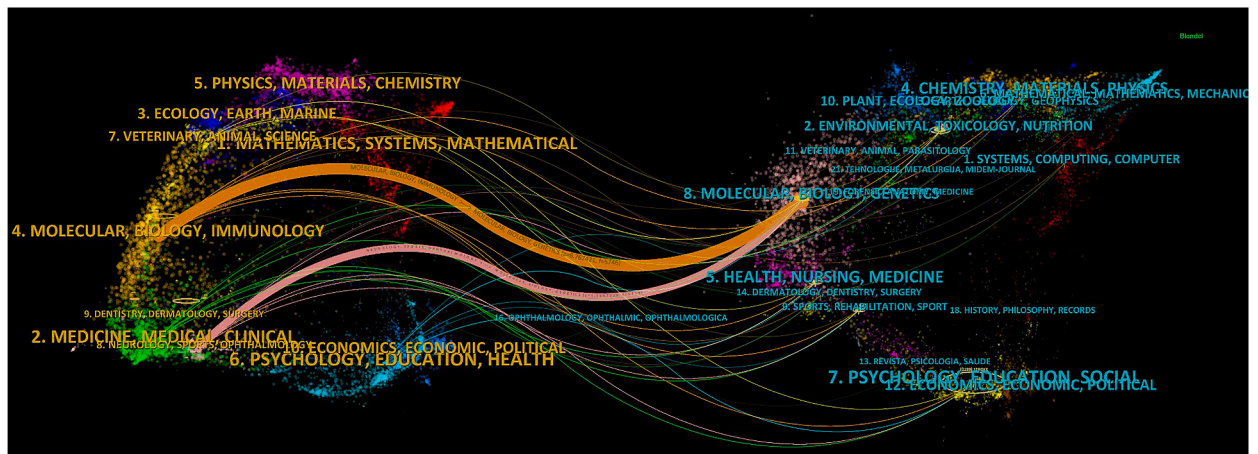


Fig. 5. The dual-map overlay of journals associated with acupuncture for stroke research from 2000 to 2022.

Table 3
Top ten authors of publications on acupuncture for stroke.

Ranking	Author	Publications	Citations	Average Citations/Publication
1	Tao, Jing	43	1129	26.26
2	Chen, Lidian	40	982	24.55
3	Wang, Qiang	26	861	33.12
4	Huang, Jia	25	782	31.28
5	Liu, Weilin	22	468	21.27
6	Yang, Shanli	19	510	26.84
7	Xiong, Lize	17	675	39.71
8	Lin, Jaung-Geng	14	443	31.64
9	Zou, Yihuai	13	150	11.54
10	Huang, Yong	12	142	11.83
10	Lin, Ruhui	12	299	24.92
10	Xu, Nenggui	12	70	5.83
10	Zheng, Guo-Qing	12	330	27.50

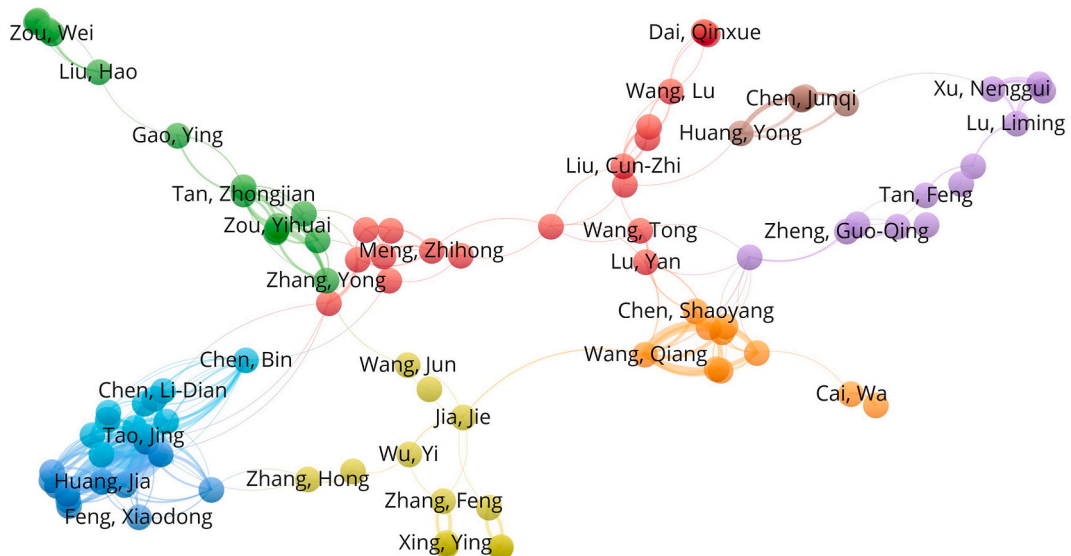


Fig. 6. The network map of co-authorship of acupuncture in stroke research from 2000 to 2022.

for stroke.

We identified 95 authors who had each published at least five articles and then developed a collaborative network that mapped the publication outputs and relationships among these authors. Fig. 6 shows a relatively mature research group that formed on acupuncture for stroke. However, most authors collaborated with members of the same institution, and more collaboration among authors across institutions and countries is needed.

3.5. Reference and co-citation analysis

Table 4 enumerates the articles on acupuncture for stroke that have received the most citations. Among the top ten most-cited publications concerning acupuncture treatment for stroke are three articles and seven reviews. Table 5 displays the articles most frequently co-cited in the domain of acupuncture for stroke, with the leading ten entries comprising six articles and four reviews. Fig. 7A presents the co-cited references. An analysis of citation references concerning acupuncture for stroke from 2000 to 2022 was conducted. All these references were organized into 20 distinct clusters, each labeled accordingly, as illustrated in Fig. 7B. The clusters with the highest burst strengths were cerebral ischemia, post-stroke depression, and cerebral infarction.

The article receiving the most citation, which was written by Chamila Geeganage and published in *Cochrane Database of System Review* in 2012, showed that acupuncture reduced dysphagia [25]. This article was one of the most frequently cited review articles in the field.

The most frequently co-cited article was written by E Z Longa in 1989 and introduced the most commonly used Middle cerebral artery occlusion(MCAO) model modeling method in basic acupuncture for stroke research, laying the foundation for acupuncture for stroke research [26].

Wang Qiang wrote the second most-cited and sixth most-co-cited article in 2009 and showed that pre-treatment with EA enhanced the synthesis of the endocannabinoids 2-arachidonyl glycerol and n-arachidonyl ethanolamine-anandamide, thereby activating CB1 receptor-mediated protection against transient cerebral ischemia [27].

The third most-cited and second most co-cited article was written by Wu Ping and published in *Stroke* in 2010; the meta-analysis encompassing 56 randomized controlled trials concluded that acupuncture might be beneficial for post-stroke rehabilitation. Additionally, this particular reference exhibited the most intense citation burst, underscoring its prominent impact within the field [28].

The fourth most co-cited article was also the seventh most-cited. In 2002, Frank Kai-hoi Sze published an article in *Stroke* that analyzed 14 randomized controlled trials and determined that acupuncture positively affected disability; however, the poor-quality literature remained [29].

The fourth most-cited document was the third most-co-cited. In 2017, Lina M. Chavez, reviewed the basic research concerning acupuncture for stroke in the *International Journal of Molecular Science*. The authors suggested that acupuncture benefits ischemic stroke by regulating different mechanisms originating from the central nervous system [30].

3.6. Keyword analysis

Frequently utilized keywords can illuminate the main areas of focus in past research, while keywords exhibiting strong burst

Table 4
The top ten references based on the number of citations.

Rank	Citations	Title	First Author	Year	Journal	Document type
1	171	Interventions for dysphagia and nutritional support in acute and subacute stroke	Geeganage, Chamila	2012	<i>Cochrane Database of System Review</i>	Review
2	152	Pretreatment With Electroacupuncture Induces Rapid Tolerance to Focal Cerebral Ischemia Through Regulation of Endocannabinoid System	Wang, Qiang	2009	<i>Stroke</i>	Article
3	143	Acupuncture in Poststroke Rehabilitation A Systematic Review and Meta-Analysis of Randomized Trials	Wu, Ping	2010	<i>Stroke</i>	Review
4	121	Mechanisms of Acupuncture Therapy in Ischemic Stroke Rehabilitation: A Literature Review of Basic Studies	Chavez, Lina M.	2017	<i>International Journal of Molecular Sciences</i>	Review
5	118	Acupuncture and transcutaneous nerve stimulation in stroke rehabilitation - A randomized, controlled trial	Johansson, B. B.	2001	<i>Stroke</i>	Article
6	111	Acupuncture: An evidence-based review of the clinical literature	Mayer, D. J.	2000	<i>Annual Review of Medicine</i>	Review
7	102	Does acupuncture improve motor recovery after stroke? A meta-analysis of randomized controlled trials	Sze, F. K. H.	2002	<i>Stroke</i>	Review
8	92	Electroacupuncture exerts anti-inflammatory effects in cerebral ischemia-reperfusion injured rats via suppression of the TLR4/NF-kappa B pathway	Lan, Lan	2013	<i>International Journal of Molecular Medicine</i>	Article
9	91	Treatment of urinary incontinence after stroke in adults	Thomas, L. H.	2008	<i>Cochrane Database of System Review</i>	Review
9	91	Prevention and treatment of urinary incontinence after stroke in adults	Thomas, L. H.	2005	<i>Cochrane Database of System Review</i>	Review

Table 5
The top ten co-cited references based on the number of citations.

Rank	Citations	Title	First Author	Year	Journal	Document type
1	161	Reversible middle cerebral artery occlusion without craniectomy in rats	E. Z. Longa	1989	<i>Stroke</i>	Article
2	93	Acupuncture in Poststroke Rehabilitation A Systematic Review and Meta-Analysis of Randomized Trials	Wu, Ping	2010	<i>Stroke</i>	Review
3	65	Mechanisms of acupuncture therapy in ischemic stroke rehabilitation: A literature review of basic studies	Chavez, Lina M.	2017	<i>International Journal of Molecular Sciences</i>	Review
4	65	Does acupuncture improve motor recovery after stroke? A meta-analysis of randomized controlled trials	Sze, F. K. H.	2002	<i>Stroke</i>	Article
5	51	Effects of acupuncture treatment on daily life activities and quality of life - A controlled, prospective, and randomized study of acute stroke patients	Gosman-Hedstrom, G.	1998	<i>Stroke</i>	Article
6	51	Pretreatment With Electroacupuncture Induces Rapid Tolerance to Focal Cerebral Ischemia Through Regulation of Endocannabinoid System	Wang, Qiang	2009	<i>Stroke</i>	Article
7	48	Acupuncture for functional recovery after stroke: a systematic review of sham-controlled randomized clinical trials	Kong, Jae Cheol	2010	<i>Canadian Medical Association Journal</i>	Review
8	48	Effectiveness of acupuncture for stroke: A systematic review	Park, J.	2001	<i>Journal of Neurology</i>	Review
9	47	Acupuncture	Ramsay, D. J.	1998	<i>JAMA</i>	Article
10	46	A randomized controlled trial on the treatment for acute partial ischemic stroke with acupuncture	Hu, H. H.	1993	<i>Neuroepidemiology</i>	Article



Fig. 7. The network map of co-cited references in acupuncture in stroke from 2000 to 2022. (A) Co-occurrence visualization of co-cited references. (B) Clusters of co-cited references of acupuncture in stroke.

strengths may indicate emerging frontiers for future investigations. The 20 most frequently used keywords are listed in Table 6. The most frequently used keywords were "acupuncture," "stroke," "electroacupuncture," "cerebral ischemia," and "ischemic stroke."

The keywords used are shown in Fig. 8A. All cited references were classified into 12 different clusters (Fig. 8B). The clusters with the highest burst strengths were "cerebral ischemia reperfusion," "cerebral ischemia," and "systematic review."

"Bursts" occurred in the keywords network. The top 21 keywords with the strongest citation bursts are shown in Fig. 8C. Keywords

Table 6
Top 20 keywords used in the treatment of acupuncture for stroke.

Rank	Keyword	Frequency	Rank	Keyword	Frequency
1	"acupuncture"	419	11	"stimulation"	96
2	"stroke"	380	12	"activation"	92
3	"electroacupuncture"	335	13	"artery occlusion"	90
4	"cerebral ischemia"	168	14	"meta analysis"	87
5	"ischemic stroke"	133	15	"apoptosis"	72
6	"rehabilitation"	121	16	"randomized controlled trial"	69
7	"recovery"	119	17	"cerebral ischemia reperfusion"	68
8	"rat"	103	18	"mechanism"	63
9	"expression"	98	19	"systematic review"	63
10	"brain"	96	20	"injury"	59

4.2.1. Clinical efficacy and safety of acupuncture for stroke

The red keyword cluster (cluster 1) was focused on evaluating the clinical effectiveness and safety of acupuncture for stroke. Acupuncture belongs to the traditional Chinese medicine category. For the rehabilitation and supportive nursing of stroke patients, techniques like acupuncture, EA, and scalp acupuncture (SA) are regularly applied. EA is a modern technique that combines traditional manual acupuncture and electrotherapy. Compared to manual acupuncture, EA has the advantage of controllable stimulation and is widely used in clinical treatment and basic research. Thus, EA is the most widely used acupuncture method for stroke treatment. SA is a traditional treatment widely used in clinical practice. The 2018 meta-analysis indicated that combining traditional manual acupuncture with rehabilitation therapy was superior in alleviating pain and improving both limb movement and activities of daily living [31]. In stroke treatment, SA is believed to improve blood circulation in the brain, reduce inflammation, and promote neuroplasticity, i.e., the ability of the brain to self-adapt and reorganize after an injury.

Randomized controlled trials, meta-analyses, and systematic reviews have been conducted to study the clinical efficacy and safety in treating stroke using acupuncture [32]. Clinical studies have mainly focused on improving the quality of life, dysphagia after stroke, depression after stroke, motor function, and spasmodic state in stroke patients treated with acupuncture [33–36]. The Fugl-Meyer Assessment and Barthel Index are commonly used tools in this field that evaluate symptoms [32,37].

4.2.2. Basic research of acupuncture for stroke

The green keyword cluster (cluster 2) was centered on basic research on acupuncture treatment for stroke. MCAO model rats have been used as experimental materials in basic research [38]. EA pretreatment before modeling and EA stimulation after modeling are standard intervention methods [39,40]. The research fields on acupuncture treatment for stroke mainly include apoptosis, nerve regeneration, oxidative stress, neuroprotection, and neuroinflammation [41–44]. Studies have demonstrated that acupuncture can increase the generation of neurotrophic factors in the brains of stroke patients, promote the repair of synaptic ultrastructures, promote nerve cell regeneration or synaptic remodeling, inhibit neuroinflammation, improve the microenvironment around the infarction, and reduce nerve cell death [45,46].

4.2.3. Brain mechanism of acupuncture for stroke

The blue keyword cluster (cluster 3) was centered on studying the brain mechanisms of acupuncture treatment for stroke. Post-stroke cognitive impairment (PSCI) can seriously affect the rehabilitation process and quality of life of patients. A 2022 study using Bayesian analysis of 55 randomized controlled trials found that acupuncture was the optimal treatment for post-stroke cognitive impairment [47]. Evidence from studies suggests that the potential improvement in cognitive functions following stroke through acupuncture is mediated by mechanisms such as the inhibition of inflammatory responses, enhancement of synaptic plasticity, regulation of the central cholinergic system, modulation of apoptosis and autophagy, and alteration of brain-derived neurotrophic factor and nerve growth inhibitory factor expression.

4.3. Research hotspots of acupuncture for stroke

Utilizing reference and keyword clustering methods, research hotspots of acupuncture for stroke focused on three fields: acupuncture for cerebral ischemia, acupuncture for cerebral ischemia-reperfusion, and acupuncture for stroke during nerve regeneration.

4.3.1. Ischemic stroke

Worldwide, ischemic stroke is the predominant cause of death and disability. A 2015 meta-analysis demonstrated that EA significantly enhanced the outcomes on Barthel Index, Fugl-Meyer motor function assessment, National Institutes of Health Stroke Scale, and revised Scandinavian Stroke Scale in ischemic stroke patients [48].

Basic research has found that, when treating cerebral ischemia, acupuncture can improve cerebral blood flow [49], regulate glucose metabolism [50], reduce excitotoxicity, inhibit oxidative stress [51], inhibit neuroinflammation [52], inhibit apoptosis [53], and promote angiogenesis [54].

Xiong et al. first proposed the concept of EA preconditioning in 2003 and confirmed that applying repeated EA at the Baihui (DU19) acupoint prior to cerebral ischemia could alleviate the degree of nerve defects after cerebral ischemia and serve a neuroprotective function during animal experiments [55]. Over the subsequent ten years, how EA preconditioning affects ischemic stroke treatment was extensively studied. EA preconditioning acts on neurons, astrocytes, microglia, and other targets; regulates the endocannabinoid system [27]; inhibits excitotoxicity, oxidative stress, and inflammatory responses; protects the blood-brain barrier [56]; inhibits neural apoptosis; and promotes the development of ischemic stroke. Autophagy regulation plays a protective role in the brain.

4.3.2. Cerebral ischemia-reperfusion

Ischemic stroke is primarily treated using a recanalization strategy. However, revascularization promotes oxidative stress in ischemic tissues and leads to an increased release of proinflammatory cytokines, which directly or indirectly leads to apoptosis, blood-brain barrier destruction, brain edema, and hemorrhagic transformation [57]. Thus, EA can improve cerebral ischemia-reperfusion injury [18]. Studies have shown that acupuncture may alleviate cerebral ischemia-reperfusion injury by improving blood-brain barrier damage [58], inhibiting apoptosis [59], regulating mitophagy [45], inhibiting cellular inflammation and oxidative stress, and promoting neuroplasticity. However, acupuncture preconditioning can induce cerebral protection against cerebral ischemia-reperfusion. EA inhibits excitotoxicity induced by cerebral ischemia-reperfusion, oxidative stress [53], endoplasmic

reticulum stress [53], inflammatory responses, and apoptosis and regulates autophagy.

4.3.3. Nerve regeneration

Acupuncture regulates neuroplasticity in glial cells [60]. The regulation of acupuncture-induced neuroplasticity involves significant contributions from glial cells such as astrocytes, oligodendrocytes, and microglia [61]. Their engagement with neurons aids in the formation and remodeling of synapses and neural circuits, ultimately supporting the functional reconstruction of the brain [61]. A large body of evidence has shown that acupuncture improves neurological recovery after stroke. Acupuncture can inhibit excessive apoptosis of neurons to maintain the number of cells, generate new neurons to replace apoptotic neurons, and accelerate the process of neurogenesis [62]. Acupuncture promotes the expression of many growth factors, such as glial cell line-derived neurotrophic factor (GDNF), stromal cell-derived factor-1 α (SDF-1 α) [63], brain-derived neurotrophic factor (BDNF), and basic fibroblast growth factor (bFGF) [64], enabling neuronal survival and angiogenesis after stroke [65]. It also promotes neurogenesis and inhibits apoptosis. Acupuncture regulates neuroplasticity via glial cell [66]. Glial cells facilitate synapse formation and neural circuit remodeling by interacting with neurons, thereby contributing to functional brain reconstruction. In recent years, studies have examined the combination of stem cell therapy and acupuncture for stroke treatment. Combination therapy is more advantageous than cell transplantation alone due to its synergistic effects in co-regulating brain neurotrophic factors, promoting angiogenesis, inhibiting apoptosis, and promoting neurological functional recovery in rats with cerebral ischemia [67].

4.4. Research trends of acupuncture for stroke

Based on keyword burst analysis, in recent years, the research hotspots of acupuncture for stroke mainly focused on acupuncture for intracerebral hemorrhage, systematic reviews and network meta-analysis, acupuncture for post-stroke depression, and the combined application of acupuncture and transcranial magnetic stimulation. We believe that these will be a popular research topics in the future.

4.4.1. Acupuncture for intracerebral hemorrhage

Hemorrhagic stroke represents roughly 15 % of all stroke incidents and is linked to high rates of morbidity and mortality. Findings from a meta-analysis of seven independent trials, encompassing 230 patients, revealed that EA enhanced neurological deficit scores in those suffering from acute hypertensive intracerebral hemorrhage [68]. The 2022 clinical trial, which assessed 100 patients with hypertensive basal ganglia hemorrhage, found that the combination of rehabilitation training and acupuncture provided significantly greater benefits than rehabilitation training alone in addressing limb dysfunction, daily life activities, and quality of life in hypertensive patients following surgery. Some studies have shown that EA of cerebral hemorrhage may promote brain iron metabolism [69], enhance mitophagy, reduce apoptosis [70], increase microglia polarization [71], upregulate the expression of neurotrophic factors [72], upregulate the expression of hypoxia-inducible factor-1 α (HIF-1 α), and promote angiogenesis [73]. Additionally, studies have shown that EA can promote the therapeutic effect of mesenchymal stem cells on intracerebral hemorrhage. Moreover, a 2019 study showed that early acupuncture intervention after ICH (3 or 9 h) was associated with better treatment outcomes [74]. Consequently, it is imperative to conduct high-quality clinical trials on early EA interventions following cerebral hemorrhage to establish the safety and clinical efficacy of acupuncture in treating this condition and to provide more robust evidence for its application.

4.4.2. Systematic reviews and meta-analyses

Evidence-based medicine (EBM) refers to the process of applying the best research evidence to clinical practice. As the core EBM research method, meta-analyses collect multiple current research results, conduct comprehensive and systematic quality assessments, and draw reliable conclusions [75]. Meta-analyses are at the top of the evidence pyramid and exhibit high repeatability and reliability. Meta-analyses can synthesize published research results and provide further analysis of higher-quality evidence. Acupuncture is an alternative, complementary therapy. Because double-blind acupuncture procedures are challenging to execute, single-blind randomized controlled trials are often utilized to verify acupuncture's efficacy in treating stroke. Therefore, more rigorously designed clinical controlled trials are needed in future studies to obtain evidence with sufficient statistical power to promote acupuncture for stroke. Network meta-analysis has become a research hotspot in recent years because it can evaluate the advantages of two treatment regimens without direct clinical trial comparisons.

4.4.3. Acupuncture for post-stroke depression

Post-stroke depression (PSD) is a critical factor that affects recovery and quality of life in stroke patients, with approximately one-third of individuals experiencing PSD following a stroke. A network meta-analysis showed that acupuncture may effectively and safely improve the condition of patients with PSD [76]. Animal studies showed that EA could reduce the degree of hippocampal and frontal edema, restore the morphology of nerve cells, decrease the expressions of nuclear transcription factor κ B (NF- κ B), tumor necrosis factor- α (TNF- α), and interlenkin -1 β (IL-1 β), upregulate 5-HT and NE levels, and downregulate Ach, γ -GABA, and Glu levels in a rat PSD model [77]. Some researchers believe that EA can increase the expression of BDNF and tyrosine receptor kinase B (TrkB) in the treatment of PSD via tPA/BDNF/TrkB signaling. This pathway participates in symptom improvement in patients with PSD [35,78–80]. Therefore, future studies should focus on acupuncture rehabilitation in stroke patients with PSD.

4.4.4. Combination acupuncture and transcranial magnetic stimulation

Transcranial magnetic stimulation (TMS) is frequently utilized as a non-pharmacological treatment in post-stroke rehabilitation. Current studies have demonstrated that both acupuncture and TMS are effective interventions for addressing dysphagia, cognitive

impairment, pain, and dyslexia after stroke [81–84]. The combined use of acupuncture and TMS has significant benefits for insomnia and hand motor dysfunction in patients after stroke [85,86]. Studies have found that SA combined with low-frequency repetitive transcranial magnetic stimulation (rTMS) can promote white matter tract repair more effectively than SA alone. Acupuncture combined with TMS is the best choice for improving the Barthel Index score for cognitive impairment after stroke [87]. Researchers have used TMS as an indicator of the efficacy of acupuncture. Research findings indicate that transcranial magnetic stimulation (TMS) was utilized to activate the left and right primary motor cortex (M1) in healthy participants both before and after administering electroacupuncture (EA) at various frequencies. The resting motor thresholds (RMTs) of the bilateral thenar muscles were measured, and motor-evoked potentials (MEPs) were recorded to determine the optimal frequency for EA. Subsequently, cortical stimulation was directed at the left and right M1 regions in hemiplegic stroke patients prior to the application of EA at this optimal frequency. RMTs and MEPs of the bilateral thenar muscles were further evaluated in these patients to investigate the therapeutic effects of acupuncture on motor cortex recovery [88]. Therefore, future studies should focus on combining acupuncture with other nonpharmaceutical therapies to provide better treatment effects for patients with stroke.

5. Research limitations

The limitations of acupuncture in stroke should be considered in future studies. First, our search was confined to the Web of Science, excluding other academic databases, which might have caused us to miss some influential articles. Second, although we aimed to analyze global trends in acupuncture for stroke, the language scope of our study was limited. This restriction might have introduced selection bias. Third, our analysis included both articles and reviews, which could result in bias when evaluating the academic impact of reports based on citation counts.

6. Conclusion

Our study has important research value and broad applications for determining the clinical efficacy of acupuncture for stroke, understanding the mechanism of acupuncture for stroke motor dysfunction, improving PSD, and combining different non-pharmaceutical therapies and acupuncture to treat stroke. Using CiteSpace, Scimago Graphica, and VOSviewer software for visual analysis, we demonstrated that research on acupuncture treatment of stroke has generally increased yearly. China is the leading country in this research field. Among the research institutions, Guangzhou University of Traditional Chinese Medicine was the most influential. Different countries and institutions must strengthen their collaboration and exchange. Tao Jing is a notable contributor to the field of acupuncture treatment of stroke. Most articles on acupuncture treatment of stroke have been published by journals in this field, indicating that acupuncture treatment for stroke has received attention but still needs further promotion. In the research fields of acupuncture for stroke, research includes the examination of clinical efficacy and safety, exploration of fundamental research aspects, and investigation into underlying brain mechanisms. The research hotspots of acupuncture for stroke include ischemic stroke, cerebral ischemia/reperfusion, and nerve regeneration. Future research on acupuncture treatment for cerebral ischemia may focus on acupuncture for intracerebral hemorrhage, systematic reviews and meta-analyses, acupuncture for post-stroke depression, and the combined application of acupuncture and TMS.

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Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Chong Guan: Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization. **Yashuo Feng:** Writing – review & editing, Writing – original draft, Validation, Conceptualization. **Lu Cao:** Writing – original draft. **Yiyuan Wang:** Writing – original draft. **Qun Zhang:** Writing – review & editing. **Li Liu:** Writing – review & editing. **Hongyu Xie:** Writing – review & editing. **Kewei Yu:** Writing – review & editing, Writing – original draft. **Xueyan Shen:** Writing – review & editing, Writing – original draft. **Yi Wu:** Writing – review & editing, Conceptualization. **Nianhong Wang:** Writing – review & editing, Conceptualization.

Declaration of competing interest

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