

Trends in Acupuncture Therapy for Microcirculation and Hemorheology from 1998 to 2023: A Bibliometric and Visualized Study

Qi Wang^{1,2}, Quanai Zhang¹, Fengyan Lu¹, Hantong Hu¹, Muru Zhu²

¹Department of Acupuncture and Moxibustion, The Third Affiliated Hospital of Zhejiang Chinese Medical University, Hangzhou, Zhejiang, People's Republic of China; ²Third Clinical Medical College, Zhejiang Chinese Medical University, Hangzhou, Zhejiang, People's Republic of China

Correspondence: Quanai Zhang, Department of Acupuncture and Moxibustion, The Third Affiliated Hospital of Zhejiang Chinese Medical University, NO. 219 Moganshan Road, Hangzhou, Zhengjiang, 310005, People's Republic of China, Tel +86 0571 88075439, Email 20071029@zcmu.edu.cn

Background: The aim of this study is to explore and illustrate the focal points concerning acupuncture's impact on microcirculation and hemorheology over the past 26 years, and to identify future directions in this field.

Methods: Data in this area were gathered from the Web of Science Core Collection database. Employing CiteSpace, VOSviewer, Scimago Graphica, and Microsoft Excel software, we analyzed authors, institutions, and countries to evaluate scientific collaboration. Moreover, we carried out an analysis of keyword clustering, references, and burst detection to examine the prominent research areas and emerging trends in this domain.

Results: The study analyzed 706 documents, 471 institutions, 632 journals, 40 countries, 581 keywords, and 3289 authors related to acupuncture for microcirculation and hemorheology. Data revealed a consistent increase in research output over 26 years. China, with the most publications and citations, significantly contributed to the field, often collaborating with the United States. Elisabet Stener-Victorin and the China Academy of Chinese Medical Sciences were the most productive author and institution, respectively. The journal Evidence-based Complementary and Alternative Medicine held the most influence. Common keywords included "vasoactive substances", "neurotransmitters", "signaling pathways", and "oxidative stress", among others. Research topics focused on female infertility, ischemic stroke, and pain syndromes, with treatment approaches such as electroacupuncture, manual acupuncture, auricular acupuncture, and cupping therapy.

Conclusion: Women's infertility, ischemic stroke, and pain syndromes have emerged as hotspots in research. Future directions may include comparative studies of traditional and modern acupuncture techniques to evaluate their respective therapeutic effects. There is potential for in-depth research in these areas and the discovery of new intervention strategies as well as mechanisms.

Keywords: acupuncture, microcirculation, hemorheology, bibliometric analysis, visual analysis, pain

Introduction

Hemorheology involves examining blood flow and the deformation characteristics of blood and its constituent elements. This is mainly attributed to the aggregation (rouleaux) that occurs among red blood cells that create temporary networks under low shear rates, leading to significantly complex rheological behavior. Blood rheological features are closely related to circulation, tissue perfusion, and vascular endothelial function. In hemorheology, blood viscosity plays a significant role in influencing blood flow and perfusion. Key elements influencing blood viscosity encompass plasma viscosity, hematocrit levels, the deformability of red blood cells, and their aggregation.¹

Microcirculation involves blood flow between the tiniest arteries and veins, known as micro arteries and micro veins, which represent the smallest blood vessels within the body, with an internal diameter of less than 100–150 microns and upper estimates of 300 microns.^{2,3} Microcirculation has direct contact with all organs and plays a crucial role in maintaining human homeostasis, which includes clotting, delivering nutrients, eliminating waste, regulating permeability, and facilitating immune communication.

Investigating microcirculation and hemorheology is crucial for comprehensively understanding the circulatory system at the micro-level, deepening our knowledge of organ function and pathology, analyzing disease progression, predicting prognosis, and enhancing clinical efficacy.⁴ Hemorheological disturbances can lead to microcirculatory disorders, which in turn can cause various diseases, such as ischemic stroke,⁵ female infertility,⁶ pain syndrome,⁷ and so on. Microcirculatory dysfunctions play a substantial role in the prevalence, fatality rates, and health care expenses. Consequently, the investigation of microcirculation and hemorheology has emerged as a central topic in fundamental and clinical research.

Acupuncture, a key component of traditional Chinese medicine, has been practiced for thousands of years. Its origins can be traced back to ancient China, where it was developed as a method of balancing the body's life force, known as Qi, believed to flow through pathways in the body. Acupuncture has been used successfully to treat various microcirculation-related diseases such as ischemic stroke,⁵ female infertility,⁶ pain syndrome,⁷ primary open-angle glaucoma,⁸ and so on. Mechanism studies continue to improve. For instance, immediate electroacupuncture application can decrease high-shear whole blood viscosity, low-shear whole blood viscosity, platelet aggregation percentage, and fibrinogen indices, consequently enhancing neurological performance in individuals with cerebral infarction.⁹ Compared to low-pressure, short-duration cupping, 10-minute cupping therapy at -300mmHg can produce higher levels of oxyhemoglobin and deoxyhemoglobin.¹⁰ Acupuncture and massage therapy have also been proven to promote local blood circulation when treating tendons.¹¹ In rats with permanent middle cerebral artery blockage, swinging needle acupuncture at the Yanglingquan point (GB34) can boost cerebral blood circulation, improve spastic paralysis effects, and swinging needle technique is superior to conventional vertical needle insertion.¹² Auricular acupuncture therapy can significantly increase the hemoglobin content and movement-evoked potential peak values in the M1 area of the brain in stroke patients with hemiplegia, significantly activate the M1 area, and improve upper limb functional impairment.¹³

By evaluating the authors, institutions, keywords, and references in the literature of a specific field, bibliometric methods can reveal the development, emerging trends, and research hotspots of that area. As the breadth and depth of research on the effects of acupuncture therapy on microcirculation and hemorheology increase, we identify a present scarcity of comprehensive evaluations and hotspot investigations in this domain. In this paper, we employ bibliometric approaches to clarify the prevailing condition, study focal points, and growth patterns in this area, offering insights for upcoming research.

Materials and Methods

Retrieval Strategies and Data Extraction

Web of Science (WoS), a popular database employed for bibliometric assessments, delivers exhaustive and trustworthy information from nearly 20,000 academic journals.¹⁴ This study analyzed acupuncture, microcirculation, and hemorheology research using bibliometric data. The author searched synonyms for these terms in PubMed's MeSH database to avoid omissions. Data from the Science Citation Index-Expanded (SCI-E) on WoS was collected, covering inception to April 27th, 2023. No language restrictions were applied, and only "articles" or "reviews" were included. QW and MR Z independently extracted, selected, and analyzed data for reliability. Discrepancies were resolved through discussion and consensus, with unresolved issues consulted with a third party (QA Z). Table 1 displays the search strategy and results. After deduplication with CiteSpace 6.2 R2 software, 706 articles were included.

Data Visualization and Analysis

We utilized CiteSpace [6.1.R6] and VOSviewer [1.6.19] to create the knowledge network map, Scimago Graphica and Microsoft Excel were used for statistical analysis.

CiteSpace

CiteSpace (version 6.1.R6), a Java-based visualization software, was used for its high impact. The study employed co-occurrence network analysis, cluster analysis, and burst analysis to identify trends in research domains. Parameters included time slices from 1998–2023, top N selection at 50, and Pathfinder and Pruning sliced Networks pruning technique. Nodes represent entities, with size indicating frequency. The inner circle color and thickness show occurrence

Table I Search Strategy and Results. Abbreviations: Wos, Web of Science

Set	Result	Search Query
#1	24,199	[TS=(acupuncture OR Pharmacopuncture OR "Acupuncture Therapy" OR "Acupuncture Treatment*" OR "Pharmacopuncture Treatment" OR "Pharmacopuncture Therapy" OR Acupotom* OR "Acupotomy therapy" OR "Moxibustion" OR "Moxabustion" OR "medicinal moxibustion" OR "heat-sensitive moxibustion" OR Electroacupuncture OR "electro-acupuncture" OR "electric* acupuncture" OR "Ear Acupuncture*" OR "Auricular Acupuncture*" OR "auricular point plaster therapy" OR "auricular plaster" OR "scalp acupuncture" OR "abdom* acupuncture" OR "acupoint catgut embedding" OR "acupoint thread embedding" OR "warm* Acupuncture" OR "Warming needle moxibustion" OR "warm moxibustion needle" OR "warm needl*" OR "hot needling plus fire moxibustion" OR "warm needle acupuncture" OR "silver-needle warm acupuncture" OR "moxibustion with warming needle" OR "needle Warming Therapy" OR "needle warming moxibustion" OR "Wen Zhen" OR "fire needl*" OR "fire acupuncture" OR "Skin Acupuncture" OR "body acupuncture" OR "Manual Acupuncture" OR "Needle knife" OR "acupoint injection" OR "point application therap*" OR "cupping therap*" OR "Cupping" OR "fire cupping" OR "Umbilical acupuncture" OR "navel acupuncture" OR "navel acupuncture therapy" OR "navel needling therapy" OR "plum blossom needle" OR "elongated needle" OR "Acupoint herbal plaster" OR "acupoint application" OR "Wrist and ankle acupuncture" OR "Eye acupuncture" OR "small needle-knife acupuncture" OR "superficial acupuncture bleeding")]
#2	189,884	[TS=("Microcirculation" OR "Microvascular Blood Flow*" OR "Microvascular Circulation*" OR "Blood Circulation" OR "Blood Flow*" OR "Hemorheology" OR "Hemorrheology")]
#3	740	Indexes= Wos Core Collection
		Editions=SCI EXPANDED-1998-present
		Timespan= database inception-April 27th, 2023
		#1 AND #2
	706	Type of literature=Review AND articles

frequency, while a purple outer circle indicates high betweenness centrality. Nodes with centrality scores >0.1 are pivotal points. Thicker node links signify stronger relationships. The study used Q values with a modular structure >0.3 and Silhouette measure for network homogeneity, considering values >0.7 as reliable clustering outcomes.¹⁵

VOSviewer

VOSviewer (version 1.6.19) is a bibliometric network construction and visualization tool developed by Ike and Waltman from Leiden University. Node size indicates indicator strength, such as publication count or keyword frequency. Total link strength shows node relationships, with shorter distances and colors representing stronger connections and closer clusters. The overlay visualization map displays research field changes using a color spectrum from purple (earlier) to green and yellow (recent). VOSviewer was used for co-authorship analysis of countries and authors, including co-occurrence and cluster analyses.¹⁶

Statistical Analysis

Scimago Graphica (<https://graphica.app/>) and Microsoft Excel (version 16.72) were used for statistical analysis and scientific map generation. National Geographic distribution was analyzed using VOSviewer and SCImago Graphica, while annual publication analysis was visualized with CiteSpace and Microsoft Excel.

Results

Publication Output and Temporal Trend

Assessing scientific research progress is crucial. The number of publications per year and cumulative publications are important indicators reflecting knowledge growth to some extent. We input annual publication numbers into Microsoft Excel, generating a cumulative publication trend line using the chart tool. Figure 1 illustrates yearly and cumulative publications from 1998 to 2023. The literature on acupuncture therapy's effects on microcirculation and hemorrheology

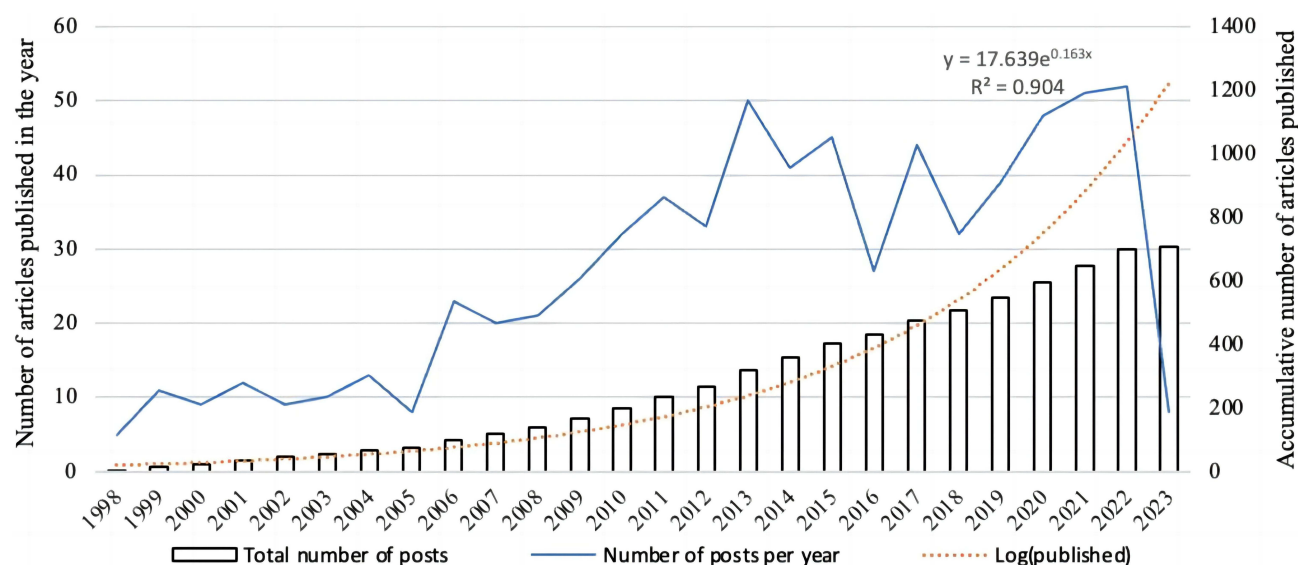


Figure 1 The number of articles published each year and the accumulative number of articles from 1998 to 2023. Analysis was performed using Microsoft Excel (version 16.72) with the following parameters: Log(published) format in Index.

demonstrates a fluctuating growth trend over time. A total of 706 publications were released - 596 articles and 110 reviews, with an average of 27 per year. The year 2022 saw the most publications (52 research articles). The production of literature adheres to the exponential curve equation ($y = 17.639e^{0.163x}$), consistent with Price's law. The annual cumulative literature growth trend fits the simulation curve well, supported by a strong coefficient of determination ($R^2=0.904$). This curve predicts a steady increase in annual articles, indicating growing research interest in acupuncture therapy's effects on microcirculation and hemorheology.

National Analysis

National analysis suggests that between 1998 and 2023, 40 countries have studied the impact of acupuncture therapy on microcirculation and hemorheology. VOSviewer was used for visualization analysis, and the generated map was imported into Scimago Graphica to create Figure 2. Figure 2a shows a network of nations with circle sizes proportional to their contributions. Distinct colors highlight collaboration clusters, divided into four groups. China significantly contributed to this research area. Figure 2b displays partnerships between countries, emphasizing China's cooperation with other nations, especially the US. Figure 2c reveals collaboration clusters in Asia and Europe, with major contributors being China, Japan, South Korea, Sweden, the UK, and Germany. Table 2 ranks the top 5 most productive countries, led by China in publications and citations, followed by the US, Japan, South Korea, and Sweden. Despite having the highest overall citations, China had a lower average citation per paper than the other top 5 countries. Sweden had the highest average citation per article, suggesting that its research quality is relatively high and has considerable reference value.

Institutional Analysis

By analyzing 706 publications, a total of 471 nodes and 547 links were identified (Figure 3). The highest number of articles were published by the China Academy of Chinese Medical Sciences, with China Medical University and Beijing University of Chinese Medicine trailing closely behind (Table 3). The articles published by these institutions have revealed that acupuncture therapy can modulate microcirculation and hemorheology through various mechanisms, such as regulating chemical components like plasma endothelin and angiotensin II, inhibiting sympathetic nerve activity, and altering hemorheological parameters such as the red blood cell aggregation index, erythrocyte sedimentation rate, and erythrocyte rigidity index.¹⁷ Centrality analysis revealed that the China Academy of Chinese Medical Sciences took the top spot with a score of 0.17, followed by Harvard University at 0.1 and the Medical University of Graz at 0.09,

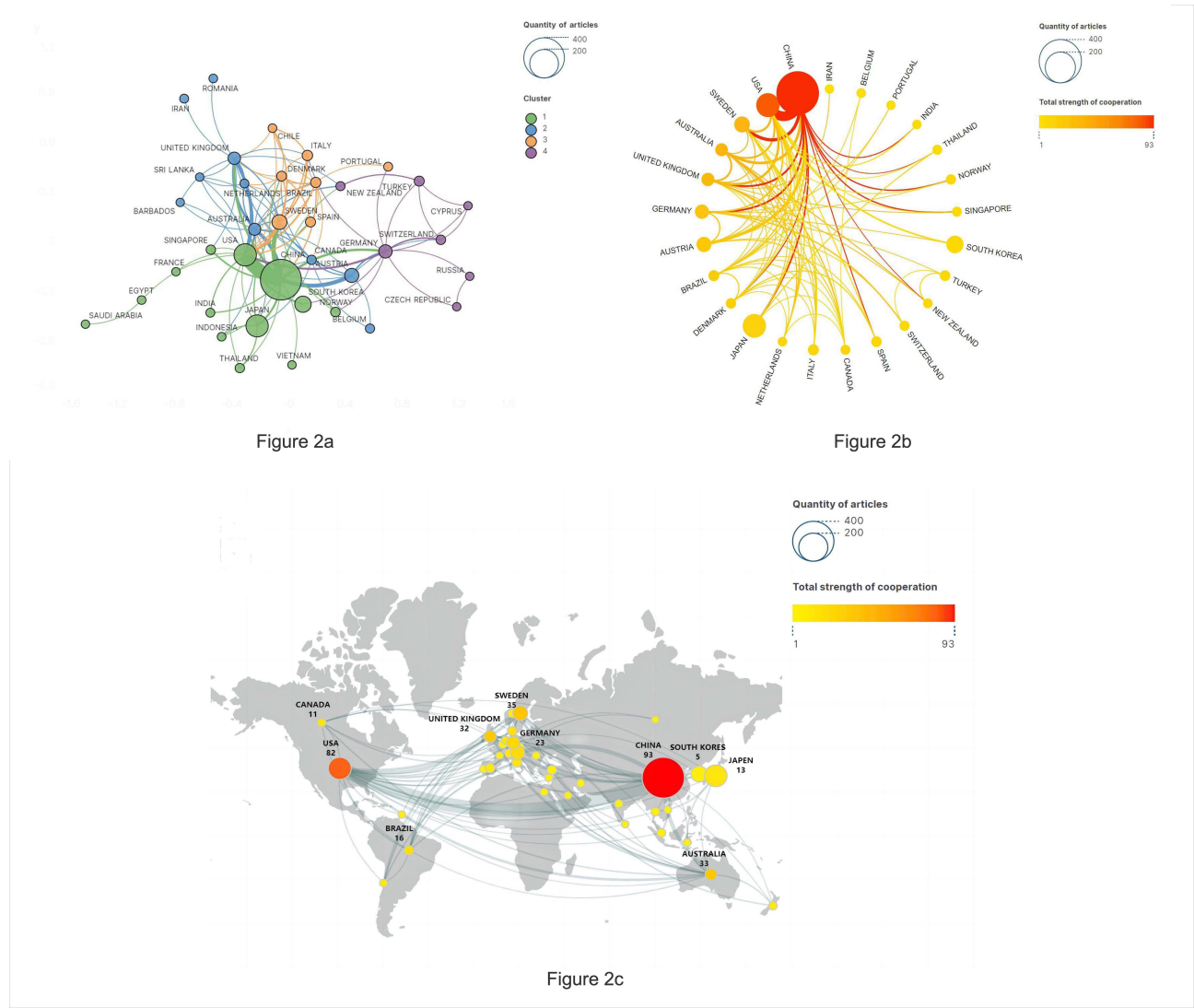


Figure 2 (a) Distribution and international cooperation of countries. The thickness of the line reflects the frequency of the cooperation. The thicker the line, the stronger the cooperation. Analysis was performed using Scimago Graphica and VOSviewer (version 1.6.19), with the following parameters: VOSviewer specific parameters included Minimum number of countries per document (1) and Minimum number of citations of a country (6). **(b)** Country collaboration map. The size of each circle represents the number of articles published by a country, while the thickness of the connecting lines indicates the level of collaboration between these two countries. Analysis was performed using Scimago Graphica. **(c)** Distribution of countries/regions. The circle's size signifies the quantity of articles published by countries, while the connecting lines indicate collaboration between nations or regions. Analysis was performed using Scimago Graphica.

signifying the leading role of the China Academy of Chinese Medical Sciences in this domain. The universities with the greatest citation frequency included the University of Gothenburg (1053), Harvard University (907), and the Karolinska Institute (683; Table 3), suggesting their high research quality. Additionally, burst analysis revealed that Guangzhou

Table 2 Top 5 Countries Related to Acupuncture Therapy on Microcirculation and Hemorheology

Rank	Countries	Article Count	Percentage (n/706)	Total Citations	Average Citation Per Article
1	China	379	53.68%	5234	13.81
2	United States	103	14.59%	3614	35.09
3	Japan	101	14.31%	1890	18.71
4	South Korea	48	6.80%	771	16.06
5	Sweden	37	5.24%	2123	57.38

CiteSpace, v. 6.1.R6 (64-bit) Advanced
 April 27, 2023 at 9:38:20 PM CST
 WoS: C:\Users\...Desktop\WOS\data
 Timespan: 1998-2023 (Slice Length=1)
 Selection Criteria: g-index (k=25), LRF=3.0, L/N=10, LBY=5, e=1.0
 Network: N=471, E=547 (Density=0.0049)
 Largest CC: 197 (41%)
 Nodes Labeled: 1.0%
 Pruning: Pathfinder

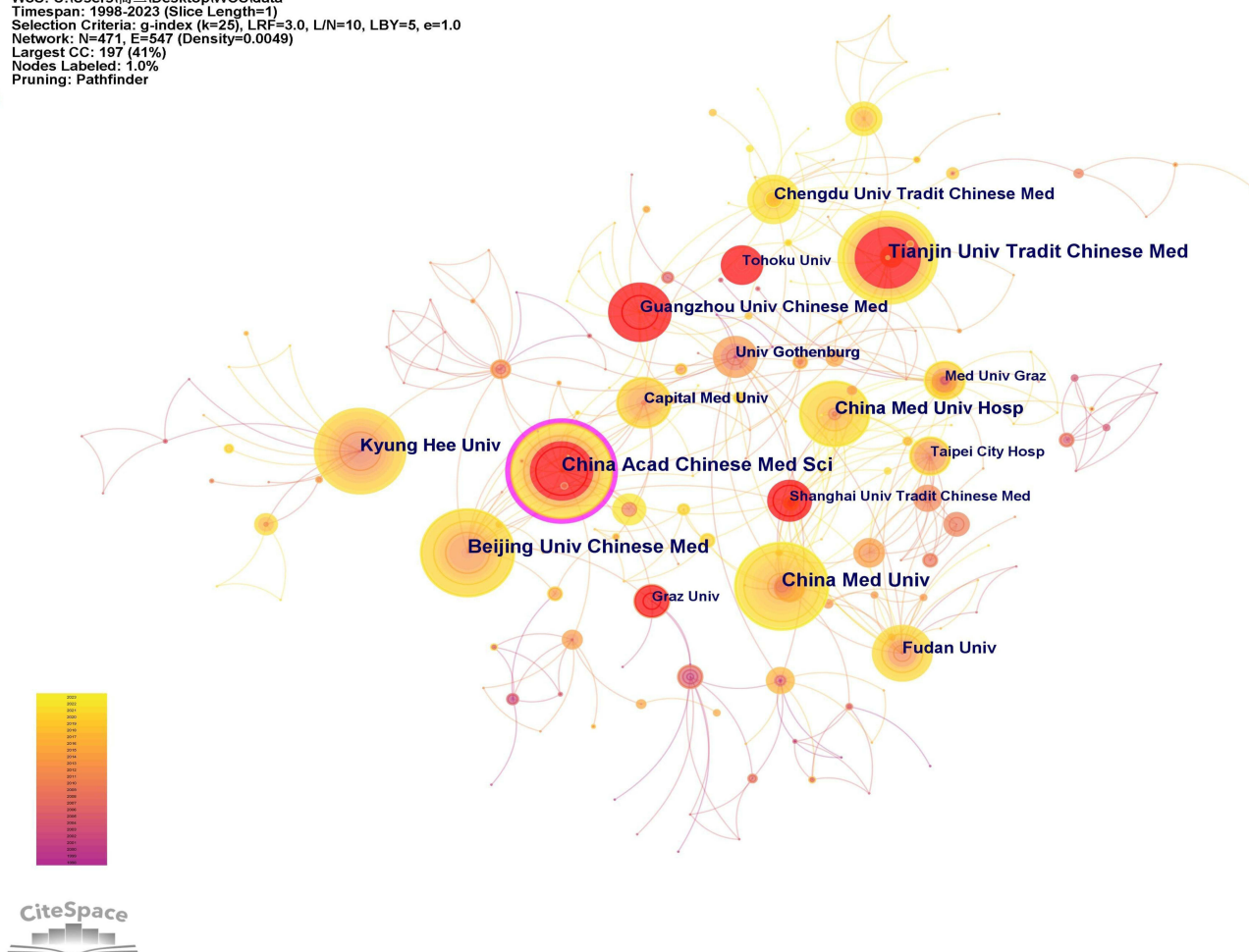


Figure 3 The collaboration map of institutions. Analysis was performed using CiteSpace (version 6.1.R6) with the following parameters: Node Types (Institution), Time Slicing (1), Pruning (Pathfinder), selection criteria (g-index with k=25), LRF (3.0), L/N (10), LBY (5), and e (1.0).

University of Chinese Medicine (2017–2023) and Shanghai University of Traditional Chinese Medicine (2019–2023) made the greatest contributions to research on acupuncture therapy and its effects on microcirculation and hemorheology in recent years.

Analysis of Authors and Cited Authors

3289 researchers have studied the effect of acupuncture on microcirculation and hemorheology. Of these, 177 have published over three articles (Figure 4a). The top 5 authors listed in Table 4 are Stener-Victorin Elisabet, Hsiu Hsin, Seki Takashi, Litscher G, and Hsu Chia-Liang, who have published many articles on acupuncture's effects on microcirculation or hemorheology. The cited authors' map consisted of 860 nodes and 3259 links (Figure 4b). The highest citation count was obtained by Sato A. (85), followed by Steiner-Victorin E. (64), Litscher G. (63), Uchida S. (60), and Sandberg M. (60) as shown in Table 5. The top 5 centralities of cited authors included Uchida S (0.16), Han JS (0.15), Berman BM (0.15), Lee MS (0.09), and Haker E (0.08), also listed in Table 5.

The analysis by the authors and cited authors emphasized that Stener-Victorin E, Litscher G, Uchida S, Sandberg M, Hsiu Hsin, and Hsu Chia-Liang have made outstanding contributions in this field. Stener-Victorin's work has significantly advanced the field, particularly through her studies on the use of electro-acupuncture therapy in treating polycystic ovary syndrome, which has illuminated the effects of acupuncture on ovarian microcirculation.¹⁸ Litscher's research, focused primarily on acupuncture's influence on cerebral microcirculation, has provided crucial insights into how

Table 3 Top 10 Institutions Related to Acupuncture Therapy on Microcirculation and Hemorheology. Abbreviations: Acad, Academy; Med, Medical; Sci, Sciences; Univ, University; Tradit, Traditional; Hosp, Hospital; Inst, Institute; Gerontol, Gerontology

Rank	Publications	Institutions	Centrality	Institutions	Citations	Institutions
1	29	China Acad Chinese Med Sci	0.17	China Acad Chinese Med Sci	1053	Univ Gothenburg
2	27	China Med Univ	0.1	Harvard Univ	907	Harvard Univ
3	26	Beijing Univ Chinese Med	0.09	Med Univ Graz	683	Karolinska Inst
4	26	Tianjin Univ Tradit Chinese Med	0.06	Fudan Univ	559	Linköping Univ
5	25	Kyung Hee Univ	0.06	Guangzhou Univ Chinese Med	477	China Med Univ
6	21	China Med Univ Hosp	0.06	Univ Gothenburg	454	Tokyo Metropolitan Inst Gerontol
7	18	Fudan Univ	0.05	Beijing Univ Chinese Med	447	Kyung Hee Univ
8	17	Guangzhou Univ Chinese Med	0.05	Kyung Hee Univ	437	China Med Univ Hosp
9	16	Chengdu Univ Tradit Chinese Med	0.05	Capital Med Univ	429	Fudan Univ
10	15	Capital Med Univ	0.04	Chengdu Univ Tradit Chinese Med	407	Beijing Univ Chinese Med

acupuncture can modulate local blood flow.¹⁹ Uchida S discovered that needling can modulate the blood flow of anesthetized animal organs, primarily through stimulation transmitted via different segments of the spinal nerve and then conveyed to the cholinergic system for vascular regulation.²⁰ Sandberg M's research concludes that the depth and intensity of acupuncture can impact microcirculation in the skin and muscles of healthy individuals.²¹ Additionally, the collaboration between Hsiu Hsin and Hsu Chia-Liang has yielded valuable findings. Their research suggests that acupuncture may modulate local sympathetic nerve activity, leading to changes in microcirculatory effects, especially in stroke patients. These insights have been instrumental in understanding the potential therapeutic applications of acupuncture in conditions related to impaired microcirculation.²²

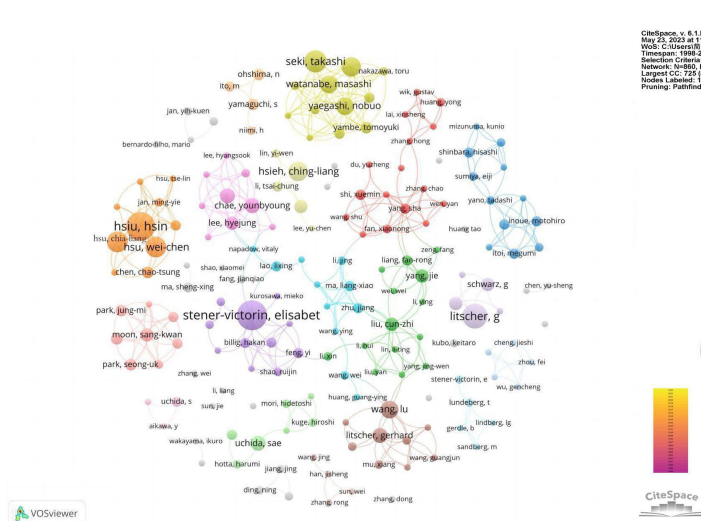


Figure 4a

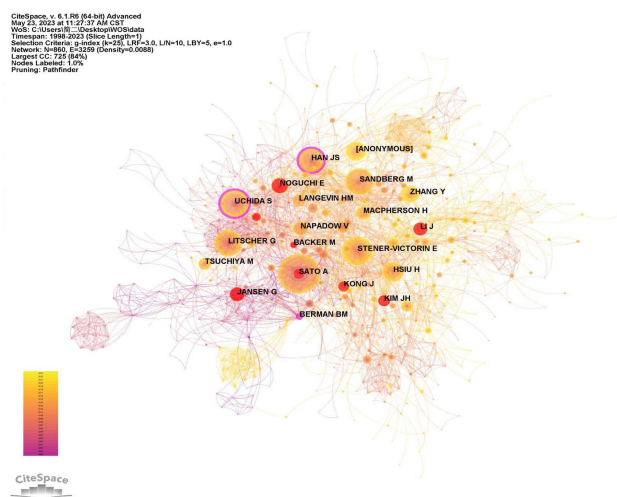


Figure 4b

Figure 4 (a) The network of co-authors. Analysis was performed using VOSviewer (version 1.6.19) with the following parameters: Minimum number of documents of an author in 3]. (b) The network of cited authors. Analysis was performed using CiteSpace (version 6.1.R6) with the following parameters: Node Types (Cited Author), Time Slicing (1), Pruning (Pathfinder), selection criteria (g-index with k=25), LRF (3.0), L/N (10), LBY (5), and e (1.0).

Table 4 Top 5 Authors in the Field of Acupuncture Therapy for Microcirculation and Hemorheology Studies

Rank	Authors	Article Count	Percentage (n/706)	Total Citations	Average Citation Per Article
1	Stener-victorin Elisabet	19	2.69%	1126	59.26
2	Hsiu hsin	18	2.55%	285	15.83
3	Litscher g	15	2.12%	436	29.07
4	Seki Takashi	13	1.84%	116	8.92
5	Hsu chia-liang	12	1.70%	188	15.67

Table 5 Top 5 Cited Authors in the Field of Acupuncture Therapy for Microcirculation and Hemorheology Studies

Rank	Publications	Cited Author	Centrality	Cited Author
1	85	SATO A	0.16	UCHIDA S
2	64	STENER-VICTORIN E	0.15	HAN JS
3	63	LITSCHER G	0.15	BERMAN BM
4	60	UCHIDA S	0.09	LEE MS
5	60	SANDBERG M	0.08	HAKE E

Analysis of Co-Cited Journals

The cited journal map (Figure 5) consisted of 632 nodes and 3436 links. The top five journals by frequency and centrality scores are listed below (Table 6). With 280 citations and a 2.65 impact factor, Evidence-based Complementary and Alternative Medicine takes the lead. The Journal of Alternative and Complementary Medicine trails closely, having 252 citations and a 2.381 impact factor, and Neuroscience Letters (241 citations, IF of 3.197). The top five journals receiving the most citations were mainly complementary medicine journals with an average IF of 3.242, indicating that research quality on acupuncture for microcirculation and hemorheology requires improvement. Regarding centrality, the top three journals include Proceedings of the National Academy of Sciences of The United States of America, Annals of Internal Medicine, and Acupuncture & Electro-therapeutics Research. These journals serve as critical hubs in the network of connections between publications, providing significant reference value. The top three journals by publication count were Evidence-Based Complementary and Alternative Medicine, Acupuncture in Medicine, and Journal of Alternative and Complementary Medicine. Evidence-Based Complementary and Alternative Medicine held the highest number of both citations and published articles. This journal primarily features clinical and animal studies on acupuncture, such as research demonstrating that acupuncture can elevate nitric oxide levels, enhance blood flow in ocular vessels and tissues of mice, and ameliorate microcirculation in patients suffering from cervical vertigo.^{23,24}

Keywords Analysis

Co-Occurring Keywords and Cluster Analysis

Commonly, cutting-edge topics or emerging trends are evaluated by the frequency of keywords in citations over time. We constructed a co-occurrence map of keywords with 581 nodes and 2089 links to identify popular research topics (see Figure 6a). Table 7 lists the top 10 keywords ranked by frequency and centrality. Main acupuncture-related keywords include acupuncture, electroacupuncture, and stimulation. Keywords related to microcirculation and hemorheology include blood flow and cerebral blood flow. Mechanism-related keywords include mechanism and nitric oxide. Pain, brain, and rat are theme-related keywords, and blood flow, acupuncture, and cerebral blood flow have higher centrality. Clustering analysis of co-occurring keywords revealed major research themes based on cluster labels. Nine clusters were obtained with silhouette values above 0.6, indicating reliability and significance. Cluster label keywords were categorized as follows: #0 blood flow, #1 laser Doppler, #2 manual acupuncture, #3 neuroprotection cell, #4 endometrial receptivity,

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 Selection Criteria: g-index (k=25), LRF=3.0, L/N=10, LBY=5, e=1.0
 Network: N=632, E=3436 (Density=0.0172)
 Largest CC: 603 (95%)
 Nodes Labeled: 1.0%
 Pruning: Pathfinder

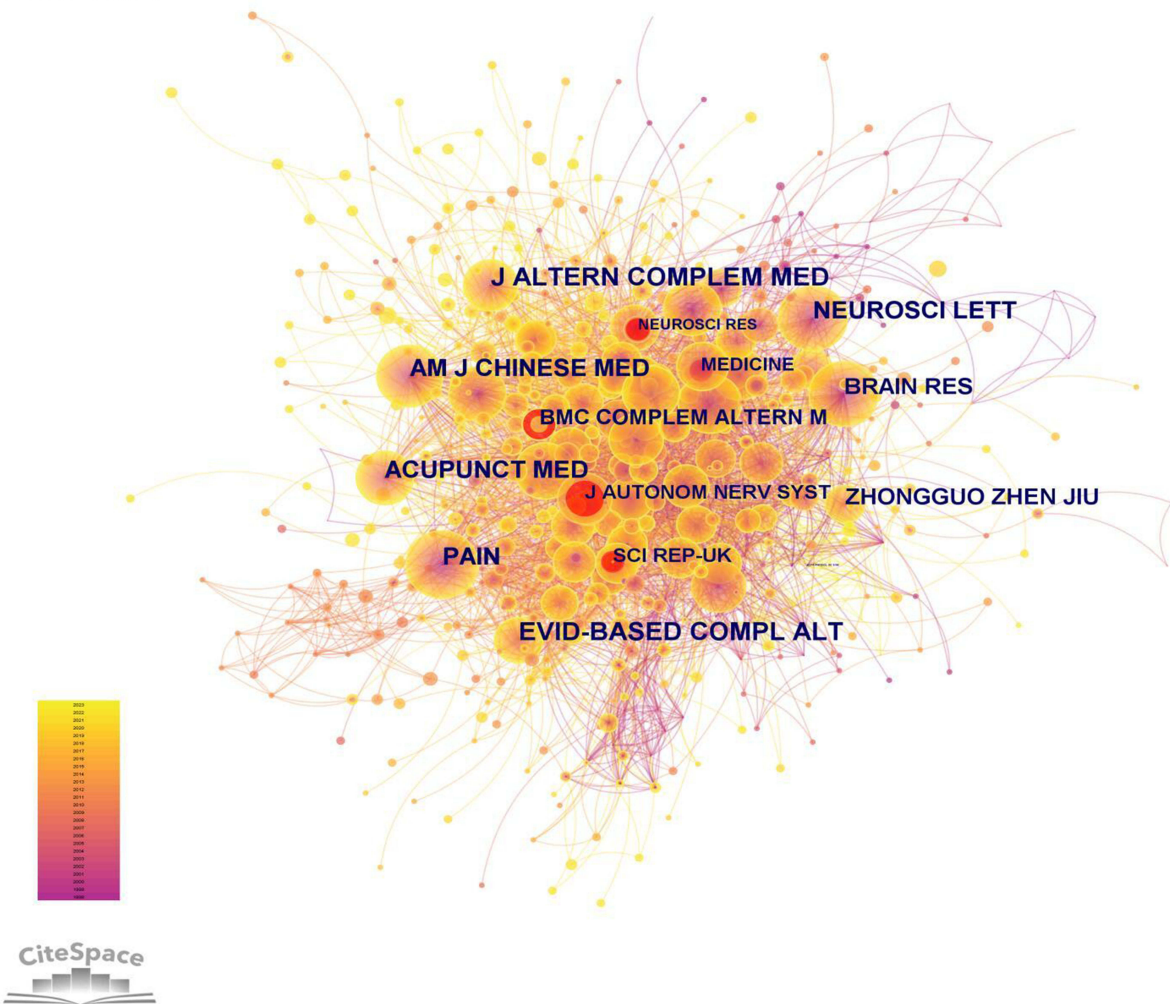


Figure 5 Co-cited map of journals. Analysis was performed using CiteSpace (version 6.1.R6) with the following parameters: Node Types (Cited Journal), Time Slicing (1), Pruning (Pathfinder), selection criteria (g-index with k=25), LRF (3.0), L/N (10), LBY (5), and e (1.0).

#5 arterial blood flow, #6 fMRI, #7 cerebral blood flow, and #8 blood flow response (as illustrated in Figure 6b and Table 8). The timeline graph of keyword clustering helps understand changes in research themes from 1998 to the present. Clusters #0, #1, #3, #4, and #7 pertain to trending and cutting-edge topics, whereas clusters #2, #5, #6, and #8 show declining research activity (Figure 6c). Blood flow velocity, cerebral blood flow, skin blood flow, perfusion, transcranial Doppler, laser Doppler, and positron emission tomography are the focus and hotspot of research. Electrical acupuncture, cupping therapy, and auricular acupuncture are the focus and hotspots of intervention. The focus and hotspot of mechanisms involve neural protective cells, injury, and pain. Potential future research directions may include endometrial receptivity, in vitro fertilization, and systematic evaluation.

Keywords with Citation Bursts

Figure 6d illustrates the top 18 keywords exhibiting the most substantial citation burst from 1998 to 2023. The blue line indicates the timeframe, whereas the red line represents the period of the keyword's burst. Initial studies concentrated on

Table 7 Top 10 Keywords in the Field of Acupuncture Therapy for Microcirculation and Hemorheology Studies

Rank	Co-occurrence	Keyword	Centrality	Keyword
1	154	Blood flow	0.32	Blood flow
2	147	Acupuncture	0.18	Acupuncture
3	109	Electroacupuncture	0.17	Cerebral blood flow
4	102	Stimulation	0.16	Stimulation
5	73	Cerebral blood flow	0.15	Electroacupuncture
6	65	Pain	0.15	Pain
7	47	Brain	0.14	Mechanism
8	40	Mechanism	0.12	Brain
9	37	Rat	0.08	Anesthetized rat
10	36	Nitric oxide	0.08	Analgesia

Table 8 Keywords Cluster Analysis

Cluster-ID	Size	Silhouette	Coverage	Label
0	76	0.89	Blood flow; stimulation; transcranial Doppler sonography (tcd); brain; blood flow velocity	Blood flow
1	64	0.795	Laser Doppler; cupping therapy; skin blood flow; electrical stimulation; perfusion	Laser Doppler
2	54	0.709	Manual acupuncture; metabolism; vasodilation; review; needle stimulation acupuncture	Manual acupuncture
3	47	0.737	Neuroprotection cell; injury; glaucoma; pain	Neuroprotection cell
4	42	0.845	Endometrial receptivity; in vitro fertilization; infertility; systematic review; embryo transfer	Endometrial receptivity
5	38	0.876	Arterial blood flow; xuanzhong gb39; sanyinjiao sp6; low back pain; primary dysmenorrhea	Arterial blood flow
6	37	0.813	fMRI; pain; neuroimaging; hypothalamus; human brain	fMRI
7	36	0.818	Cerebral blood flow; auricular acupuncture; Raynaud's phenomenon; positron emission tomography; guideline	Cerebral blood flow
8	35	0.847	Blood flow response; polycystic ovary syndrome; insulin resistance; low frequency electroacupuncture; gene expression	Blood flow response

acupuncture's role in managing polycystic ovary syndrome and in vitro fertilization, as well as exploring the mechanisms underlying oxidative stress, which has recently become a popular topic. Furthermore, systematic reviews have surged in recent years, indicating improved research quality in this field.

Reference Analysis

Co-Occurring Reference and Cluster Analysis

In our study, we created a co-occurrence map of references consisting of 953 nodes and 2573 links (Figure 7a). Table 9 and Table 10 list the top 10 articles based on frequency and centrality. The foremost recurrently co-cited source is an article in PLoS One by Kim et al. Their research revealed that EA enhanced cerebral blood flow in an acetylcholine/eNOS-dependent manner, decreased infarct size, and ameliorated neurological and vestibulo-motor functions in mice experiencing moderate ischemic damage.²⁵ The second high-frequency co-cited reference was the article published in the Journal of Applied Physiology by Stener-Victorin et al, with high citations and centrality. This article found that the reaction of ovarian blood flow to electro-acupuncture stimulation in the abdomen and hindlimbs was mediated by the ovarian sympathetic nervous system through reflexive actions, which were controlled by the ascending pathway. Additionally, the reaction of ovarian blood flow to electro-acupuncture stimulation in the abdomen was frequency-dependent and enhanced during estrus.¹⁸ The third

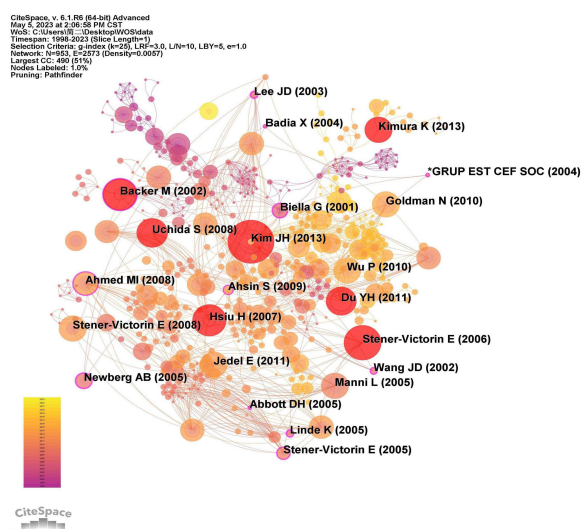


Figure 7a

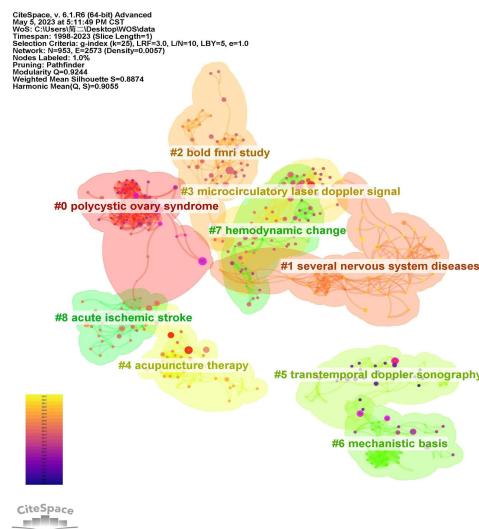


Figure 7b

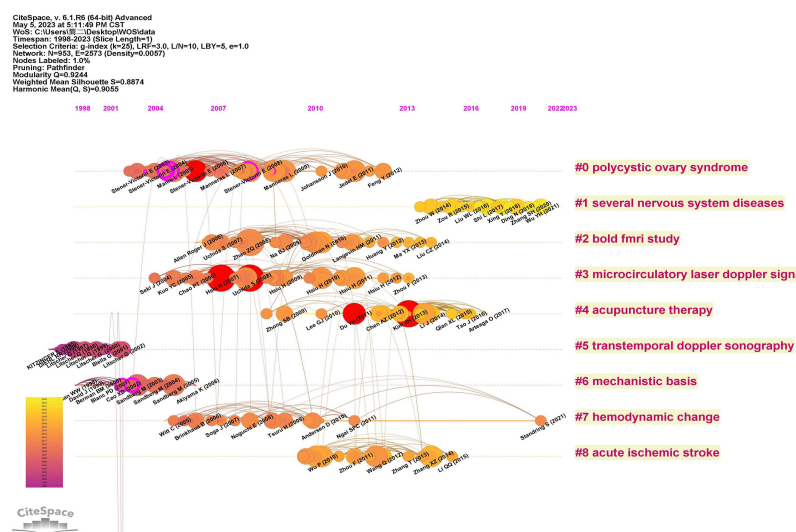


Figure 7c

Top 10 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	1998 - 2023
Litscher G, 1998, NEUROL RES, V20, P0	1998	4.91	1999	2002	
Uchida S, 2000, JPN J PHYSIOL, V50, P495, DOI 10.2170/jphysiol.50.495, DOI	2000	4.78	2002	2005	
Backer M, 2002, NEUROSCI LETT, V333, P203, DOI 10.1016/S0304-3940(02)01109-6, DOI ²⁵	2002	6.2	2003	2007	
Stener-Victorin E, 2006, J APPL PHYSIOL, V101, P84, DOI 10.1152/japplphysiol.01593.2005, DOI ²⁷	2006	5.89	2008	2011	
Manni L, 2005, REPROD BIOL ENDOCRIN, V3, P0, DOI 10.1186/1477-7827-3-21, DOI ⁸⁷	2005	4.82	2008	2010	
Hsui H, 2007, PHYSIOL MEAS, V28, PN77, DOI 10.1088/0967-3334/28/10/N01, DOI ²⁶	2007	5.89	2009	2011	
Uchida S, 2008, EVID-BASED COMPL ALT, V5, P145, DOI 10.1093/ecam/nem051, DOI ¹⁹	2008	5.86	2011	2012	
Du YH, 2011, NEUROL RES, V33, P101, DOI 10.1179/016164110X12714125204317, DOI ²⁷	2011	4.99	2013	2015	
Kim JH, 2013, PLOS ONE, V8, P0, DOI 10.1371/journal.pone.0056736, DOI ²⁴	2013	5.86	2014	2018	
Kimura K, 2013, ACUPUNCT MED, V31, P74, DOI 10.1136/acupmed-2012-010177, DOI ³⁰	2013	4.97	2015	2017	

Figure 7d

Figure 7 (a) Co-citation network map of references. Analysis was conducted using CiteSpace (version 6.1.R6) with the following parameters: Node Types—Reference, Time Slicing—I, Pruning—Pathfinder; selection criteria included g-index (k=25), LRF=3.0, L/N=10, and LBY=5, with e set to 1.0. **(b)** Cluster map of references. Analysis was conducted using CiteSpace (version 6.1.R6) with the following parameters: Node Types—Reference, Time Slicing—I, Pruning—Pathfinder; selection criteria included g-index (k=25), LRF=3.0, L/N=10, LBY=5, and e=1.0. Additionally, the Clustering Algorithm used was LLR, with the Largest K clusters set to K=9. **(c)** Co-citation cluster timeline map. Analysis was conducted using CiteSpace (version 6.1.R6) with the following parameters: Node Types—Reference, Time Slicing—I, Pruning—Pathfinder; selection criteria included g-index (k=25), LRF=3.0, L/N=10, LBY=5, and e=1.0. The Clustering Algorithm used was LLR, with the Largest K clusters set to K=9. **(d)** Top 10 references with the strongest citation bursts. Analysis was performed using CiteSpace (version 6.1.R6) with the following parameters: Node Types—Reference, Time Slicing—I, Pruning—Pathfinder; selection criteria included g-index (k=25), LRF=3.0, L/N=10, LBY=5, and e=1.0. The detection model was configured with $\gamma=1.0$ and a Minimum Duration of 2.

Table 9 Top 10 Co-Citation References with the Highest Frequency

Rank	Co-Citation Reference	Frequency	Citations
1	Kim JH, 2013, PLOS ONE, V8, P0 DOI 10.1371/journal.pone.0056736 ³⁰	15	395
2	Stener-Victorin E, 2006, J APPL PHYSIOL, V101, P84 DOI 10.1152/japplphysiol.01593.2005 ¹⁸	12	727
3	Backer M, 2002, NEUROSCI LETT, V333, P203 DOI 10.1016/S0304-3940(02)01109-6 ²⁶	11	428
4	Hsiu H, 2007, PHYSIOL MEAS, V28, PN77 DOI 10.1088/0967-3334/28/10/N01 ²⁷	11	168
5	Du YH, 2011, NEUROL RES, V33, P101 DOI 10.1179/016164110X12714125204317 ²⁸	10	292
6	Uchida S, 2008, EVID-BASED COMPL ALT, V5, P145 DOI 10.1093/ecam/nem051 ²⁰	10	310
7	Goldman N, 2010, NAT NEUROSCI, V13, P883 DOI 10.1038/nn.2562 ³¹	9	274
8	Kimura K, 2013, ACUPUNCT MED, V31, P74 DOI 10.1136/acupmed-2012-010177 ³⁰	9	81
9	Manni L, 2005, REPROD BIOL ENDOCRIN, V3, P0 DOI 10.1186/1477-7827-3-21 ³²	9	648
10	Wu P, 2010, STROKE, V41, PE171 DOI 10.1161/STROKEAHA.109.573576 ³³	9	205

Table 10 Top 10 Co-Citation References with the Highest Centrality

Rank	Co-Citation Reference	Centrality	Citations
1	Newberg AB, 2005, J NEUROIMAGING, V15, P43 DOI 10.1177/1051228404271005 ²⁹	0.23	107
2	Lee JD, 2003, NEURORADIOLOGY, V45, P780 DOI 10.1007/s00234-003-1080-3 ³⁴	0.23	44
3	Linde K, 2005, JAMA-J AM MED ASSOC, V293, P2118 DOI 10.1001/jama.293.17.2118 ³⁵	0.23	81
4	Ahmed MI, 2008, HUM REPROD, V23, P2564 DOI 10.1093/humrep/den273 ³⁶	0.18	363
5	Backer M, 2002, NEUROSCI LETT, V333, P203 DOI 10.1016/S0304-3940(02)01109-6 ²⁶	0.16	428
6	Wang JD, 2002, AUTON NEUROSCI-BASIC, V100, P90 DOI 10.1016/S1566-0702(02)00150-9 ³⁷	0.16	69
7	Abbott DH, 2005, HUM REPROD UPDATE, V11, P357 DOI 10.1093/humupd/dmi013 ³⁸	0.16	66
8	Stener-Victorin E, 2005, REPROD BIOL ENDOCRIN, V3, P0 DOI 10.1186/1477-7827-3-44 ³⁹	0.13	246
9	Ahsin S, 2009, PAIN, V147, P60 DOI 10.1016/j.pain.2009.08.004 ⁴⁰	0.11	91
10	Badia X, 2004, PHARMACOECONOMICS, V22, P591 DOI 10.2165/00019053-200422090-00004 ⁴¹	0.11	15

high-frequency co-cited reference was the article published in the Neurosci Lett by Backer et al, with high centrality. This article found that the low-frequency and high-amplitude rotation manual acupuncture mode produced a stronger initial pressor response and a more obvious long-term hypotensive response in healthy male subjects compared to the high-frequency and low-amplitude rotation mode.²⁶ Hsiu H used laser Doppler flowmetry to assess the microcirculatory conditions of acupuncture points and surrounding tissues and found that there was more blood supply in the microvascular beds of acupuncture points.²⁷

Du YH found that electro-acupuncture can increase the proliferation of endothelial cells, improve cerebral blood flow, and reduce neurological deficits.²⁸ Uchida S's investigation reveals that the rise in cerebral cortex blood flow represents a non-segmental reflex reaction, whereas the augmentation in uterine blood flow corresponds to a segmental spinal reflex response.²⁰ The literature written by Newberg et al, published in the Journal of Neuroimaging, had the highest centrality. This piece of research discovered that acupuncture has the potential to boost activity within the thalamus and prefrontal cortex, augment cerebral blood flow, and produce analgesic outcomes. These findings propose that by focusing on particular brain regions and enhancing blood circulation, acupuncture could be a hopeful therapeutic strategy for managing pain.²⁹

We performed a cluster analysis (Figure 7b) on our collected literature, using a modularity Q value of 0.9244 and a mean silhouette of 0.8874, to determine the knowledge structure of the field. Our literature was classified into nine distinct clusters through the cluster analysis process (Table 11). The most prominent cluster was "polycystic ovary syndrome", which contained 59 references. Other active clusters included "several nervous system diseases", "bold fMRI study", and "microcirculatory laser Doppler signal". From the timeline view map (Figure 7c), clusters 1 and 7 were depicted in warm colors, indicating that they represent the latest research. This implies that examining acupuncture and its influence on blood flow patterns has consistently been a prevalent subject, with the related action mechanisms gaining attention as a novel research focus in recent years. The involved mechanisms encompass neurological disorders, reperfusion damage, and signaling pathways. For example, studies investigating acupuncture and the forkhead box protein O1 (Foxo1) signaling pathway have demonstrated that electro-acupuncture may ameliorate brain ischemia/reperfusion damage by suppressing autophagy via the SIRT1-Foxo1 signaling route.⁴² Conversely, other clusters have experienced a decline in research activity in recent times.

Reference with Citation Bursts

Figure 7d shows the top 10 references with the greatest burst intensity in chronological sequence. The early research was mainly studied in humans or animals, focusing on acupuncture's effects on the brain, skin, ovarian, and other visceral blood flow. In contrast, recent research has primarily focused on mechanistic studies. For example, Kimura K found that the skin vascular dilation induced by acupuncture stimulation might be attributed to the contribution of nitric oxide to the vascular dilation response, rather than the axon reflex.³⁰

Table 11 Co-Citation References Cluster Analysis

ID	Size	Silhouette	Coverage	Label
0	59	0.991	Polycystic ovary syndrome; dihydrotestosterone-induced polycystic ovary syndrome; low-frequency electro-acupuncture; dihydrotestosterone-induced pco; sympathetic marker	Polycystic ovary syndrome
1	56	0.991	Several nervous system diseases; signaling pathway; reperfusion injury; sirt1-foxo1 signaling pathway; samp8 mouse model	Several nervous system diseases
2	55	0.93	Bold fMRI study; resting state brain activities; acupoint specificity research; status quo; Parkinson's disease	Bold fMRI study
3	48	0.944	Microcirculatory laser Doppler signal; spectral analysis; microcirculatory blood flow; arteriolar opening; complexity analysis	Microcirculatory laser Doppler signal
4	46	0.949	Acupuncture therapy; cerebral ischemia; literature review; ischemic stroke rehabilitation; basic studies	Acupuncture therapy
5	45	0.93	Transtemporal Doppler sonography; cerebral vascular effect; non-invasive laserneedle; brain function; functional transcranial Doppler sonography	Transtemporal Doppler sonography
6	41	0.981	Mechanistic basis; surface tissue; gua sha treatment; vitro fertilization; clinical efficacy	Mechanistic basis
7	38	0.983	Hemodynamic change; acupuncture research; brachial artery; single-blind randomized controlled trial; haemodynamic change	Hemodynamic change
8	35	0.943	Acute ischemic stroke; brain protection; hippocampal ca1 area; vascular dementia rat; cognitive deficit	Acute ischemic stroke

Discussion

Status Quo of Acupuncture Therapy on Microcirculation and Hemorheology

To our knowledge, this is the first bibliometric analysis of acupuncture's role in microcirculation and hemorheology. Our analysis reveals a consistent rise in yearly publication counts, showing an exponential growth trend and peaking in 2022 with 52 papers. Acupuncture has shown promise in treating various conditions, such as ischemic stroke,⁵ female infertility,⁶ pain syndrome,⁷ deep vein thrombosis,⁴³ and spastic paralysis,¹² by regulating local blood flow and hemorheology.

Our country assessment reveals China leads in article count, followed by the US and Japan. Despite China's high total citations, its low average citation per article indicates room for quality improvement.⁴⁴ Sweden, ranking fifth, has the highest average citation per article, reflecting exceptional publication quality and research potential. China shows strong international collaboration, especially with the US. Key drivers of Asian research include China, Japan, and South Korea, while Sweden, the UK, and Germany lead European research, possibly due to higher research and development expenditure.⁴⁵ Regarding the institutions at the forefront of this research field, The China Academy of Chinese Medical Sciences, Guangzhou University of Chinese Medicine, and the Shanghai University of Traditional Chinese Medicine have been central to advancing research on acupuncture's impact on microcirculation and hemorheology. Their work has significantly contributed to establishing China's dominant position in this research area. Moreover, the University of Gothenburg, Harvard University, and the Karolinska Institute have been influential through their high citation rates, indicating the impactful nature of their research. These institutions, particularly in Sweden, have been recognized for their high-quality publications and the potential for future research developments.

In addition, journals with the most publications and citations focus on complementary medicine but have low IF values, indicating a need for improved research quality in acupuncture articles related to microcirculation and hemorheology.

Last, a thorough analysis revealed that Stener-Victorin E and Litscher G were highly active in this field and had a significant impact on acupuncture therapy with microcirculation and hemorheology. Stener-Victorin E, an individual with a high number of published papers and citation frequency, has carried out multiple investigations on the use of electroacupuncture therapy in treating polycystic ovary syndrome.⁴⁶ Litscher G's research primarily focused on investigating the impact of acupuncture on microcirculation.¹⁹ In terms of cooperation, Hsiu Hsin and Hsu Chia-Liang both of whom have a high number of published papers have a collaborative relationship. Their research indicates that acupuncture may modulate local sympathetic nerve activity, leading to asymmetric microcirculatory effects in stroke patients.⁴⁷

Analysis of Hotspots and Frontiers in Acupuncture Therapy for Microcirculation and Hemorheology

A comprehensive analysis reveals popular intervention methods: electroacupuncture, auricular acupuncture, manual acupuncture, and cupping. Mechanisms of action, including vasoactive substances, neurotransmitters, signaling pathways, endothelial cells, neuroprotection, sympathetic nerves, and oxidative stress, are research hotspots. Key areas focus on female infertility, ischemic stroke, and pain syndromes. We summarize these diseases, highlighting current trends and hotspots as follows.

Female Infertility

Approximately 15% of couples globally face infertility, with female factors contributing to 20–70% of cases.⁴⁸ Acupuncture has emerged as a popular therapeutic approach for infertility, targeting issues such as in vitro fertilization and embryo transfer, polycystic ovary syndrome, and primary ovarian insufficiency, among others. Acupuncture therapy can improve ovarian and uterine microcirculation by modulating the sympathetic nervous system. Acupuncture diminishes the levels of endothelins, corticotropin-releasing factors, and nerve growth factors in the ovaries of rats affected by polycystic ovary syndrome, consequently inhibiting the excitation of ovarian sympathetic nerves.⁴⁹ Low-frequency electroacupuncture (EA) targeting abdominal and hindlimb muscles can modulate ovarian sympathetic nerves via the supraspinal pathway, enhancing ovarian blood flow (OBF). Acupuncture has the ability to stimulate sensory nerves, which consequently triggers the discharge of substance P and calcitonin gene-related peptide, thereby enhancing microcirculation.⁵⁰

Studies show electroacupuncture enhances antral follicle angiogenesis in rats with polycystic ovary syndrome, aiding follicle maturation, ovulation, and corpus luteum development.⁵¹ A study on in-vitro fertilization patients found significant reductions in the mean pulsatility index of uterine arteries after electroacupuncture.⁵² Reduced uterine artery resistance improves endometrial microcirculation, enhancing uterine receptivity and increasing pregnancy chances in infertile patients.⁵³

Ischemic Stroke

Research shows acupuncture enhances microcirculation and hemorheology after ischemic stroke, helping rescue the penumbra early on and promoting neural regeneration later. Acupuncture reduces whole blood viscosity, plasma viscosity, hematocrit, and profibrin levels in ischemic stroke patients.⁵

In addition, acupuncture therapy improves microcirculation in ischemic areas by modulating cell metabolism-related enzymes.^{54,55} Acupuncture can also modulate ischemic perfusion by targeting the endothelial nitric oxide system and the brain renin-angiotensin system.^{25,56,57}

During initial ischemic stroke phases, collateral circulation relies on expanding pre-existing vascular networks, while later stages depend on new blood vessel development. Angiogenesis involves endothelial progenitor cells (EPCs) moving from bone marrow to the brain, transforming into mature endothelial cells (ECs), which then proliferate, migrate, differentiate, and establish vascular lumens, forming new blood vessels. Studies show electroacupuncture increases EPC quantity and accelerates EC growth.⁵⁸ Moreover, acupuncture may stimulate angiogenesis via Vascular Endothelial Growth Factor (VEGF),⁵⁹ EphB4/EphrinB2,⁶⁰ SDF-1 α /CXCR4,⁵⁸ and Apelin/APJ pathways.⁶¹

Pain

Acupuncture for pain management has consistently been a focal point in academic research. Min et al investigated the repeated application of LI4 acupuncture, which enhanced local microcirculation and amplified analgesic effects.⁶² These factors were found to be interconnected, suggesting that improved microcirculation may influence acupuncture's pain-relieving properties. Acupuncture's impact on pain mechanisms is linked to microcirculation, primarily mediated by neurotransmitter regulation.

Adenosine, specifically through A1 and A2 receptors, is a potential analgesic target for inflammation and neuropathic pain. The extracellular distribution of the adenosine A1 receptor in acupoint regions regulates analgesic effects. Acupuncture can activate this receptor, raising adenosine levels and increasing the pain threshold. Acupuncture can extend the extracellular residence time of easily assimilated and degraded adenosine, prolonging analgesic outcomes.³¹ Adenosine interacts with A1 and/or A2 receptors on vascular endothelial cells, promoting NO synthesis. NO then reaches adjacent vascular smooth muscle cells, inducing relaxation and vasodilation.⁶³

Acupuncture-induced neural signaling is believed to cause alterations in blood perfusion, resulting from the local effects of vasodilatory factors such as substance P and CGRP.⁶⁴

Advantages and Disadvantages of Using Acupuncture in Microcirculation Compared with Other Therapies

Primarily, acupuncture's holistic approach can be tailored to individual patient needs, making it a versatile tool in managing various health conditions. Unlike many pharmacological treatments, acupuncture has minimal side effects, making it a preferred choice for patients who might be sensitive to certain medications or those seeking alternative treatments.

However, acupuncture's disadvantages should be noted. The effectiveness of acupuncture can vary significantly from person to person, and its subjective nature can make it difficult to quantify results in a standardized way. Some patients may not respond to acupuncture or fear to receive acupuncture. As an integrative treatment, acupuncture should be considered in conjunction with other medical practices, especially when dealing with complex or severe diseases related to microcirculation and hemorheology.

Implications for Future Research and Clinical Practice

Our bibliometric analysis reveals a rising trend in acupuncture research related to microcirculation and hemorheology, with a notable peak in 2022. This upward trajectory suggests an expanding interest and potential in this field. Countries like China, the US, and Japan are at the forefront, indicating a geographical concentration of research efforts. However, the majority of involved institutions are universities, suggesting a power disparity in this field due to uneven research investment or insufficient attention from non-university institutions. To address this, increased investment, talent attraction, and academic exchanges are recommended.

Future studies should aim to diversify the research landscape, encouraging contributions from a broader range of countries and institutions. Key areas like female infertility, ischemic stroke, and pain syndromes have emerged as research hotspots. Moving forward, it is imperative to delve deeper into these areas, exploring new intervention methods and their mechanisms. Additionally, a more nuanced understanding of how acupuncture influences local blood flow and hemorheology in these conditions is essential. For future research, there is a need to explore the molecular and cellular mechanisms underlying acupuncture's effects. Future research directions might also include comparative studies between traditional and modern acupuncture techniques and their respective efficacies.

In addition, the findings of our study have significant Implications for clinical practice. Acupuncture's role in improving microcirculation and hemorheology suggests its potential as a therapeutic tool for conditions like ischemic stroke, female infertility, and pain management. Clinicians might consider integrating acupuncture into treatment protocols, particularly for patients seeking alternative or complementary therapies. Investigating the potential of acupuncture in other medical conditions and its integration with conventional medical treatments could provide new avenues for improving patient care.

Strengths and Limitations

This is the first bibliometric analysis examining the correlation between acupuncture therapy and microcirculation as well as hemorheology in the medical literature. The investigation benefits from the implementation of bibliometric analysis to explore global research on this subject. While our study provides valuable insights, it is important to acknowledge its limitations. First, the primary source of our data, the Web of Science Core Collection, offers a reliable but limited perspective, predominantly consisting of English-language articles. This linguistic and database bias might have excluded relevant research published in other languages or databases. Future studies should consider incorporating a broader range of databases and languages to achieve a more comprehensive overview. Second, given that China is the primary country where acupuncture therapy is practiced, over half of the analyzed publications in our bibliometric analysis were authored by Chinese researchers, potentially limiting the generalizability of the study's findings to other countries.

Conclusion

This study utilized bibliometric analysis to systematically categorize and objectively assess the literature on acupuncture treatment in microcirculation and hemorheology over the past 26 years. The findings reveal that the application of acupuncture in microcirculation and hemorheology has become a research hotspot for scholars. The primary diseases investigated include female infertility, ischemic stroke, and pain syndromes, with a relatively narrow range of conditions studied. Future research could broaden the scope to encompass additional diseases. Moreover, mechanistic research highlights include vasoactive substances, neurotransmitters, signaling pathways, endothelial cells, neuroprotection, sympathetic nerves, and oxidative stress. As mechanistic studies are still in the exploratory stage, additional top-notch fundamental and clinical studies are required to confirm and develop an all-encompassing theoretical structure. Common intervention methods studied in microcirculation and hemorheology include electroacupuncture, auricular acupuncture, manual acupuncture, and cupping, with electroacupuncture showing the greatest potential. Future research directions might include comparative studies between traditional and modern acupuncture techniques and their respective efficacies.

Abbreviations

TCM, traditional Chinese medicine; MBF, microcirculatory blood flow; Foxo1, forkhead box protein O1; EA, electroacupuncture; OBF, ovarian blood flow; CYP2C11, cytochrome P450 arachidonic acid epoxygenase; ACh, acetylcholine; eNOS, endothelial nitric oxide synthase; Ang II, Angiotensin II; AT1R, Ang II type 1 receptor; DAG, Diacylglycerol; IP3, Inositol trisphosphate; EPCs, Endothelial progenitor cells; ECs, Endothelial cells; VEGF, Vascular Endothelial Growth Factor; NO, nitric oxide.

Data Sharing Statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

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Disclosure

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