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ACUPUNCTURE TREATMENT FOR SPINAL CORD INJURY: A RESEARCH BASED ON BIBLIOMETRICS AND DATA MINING

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Abstract: Introduction: Acupuncture, as one of the alternative medical therapies for Spinal Cord Injury (SCI), offers various advantages. However, there is a significant diversity in research directions and acupoint selection for acupuncture treatment of SCI. This study aims to analyze the research directions and acupoint selection in acupuncture treatment for SCI through bibliometric methods and data mining techniques, exploring their characteristics and principles. Methods: This research commenced with a retrieval of literature on acupuncture treatment for SCI from the WOS database. Analysis was conducted using Citespace on authors, institutions, keywords, clustering, and timeline visuals. Moreover, association rule analysis, network analysis, and hierarchical cluster analysis were utilized to determine the correlations between different acupoints. Results: The results reveal a year-on-year increase in publications on acupuncture treatment for SCI, with research teams centered around Ding Ying and Guo Yi; leading research institutions include Kyung Hee University and Beijing University of Chinese Medicine. High-frequency keywords include "spinal cord injury" and "neuropathic pain," with a trend toward basic research. The most frequently used acupoints are ST36, EX-B2, SP6, GV14, and GV4; GV, ST, BL, GB are the four meridians with the most treatments; specific acupoints account for 51.72% of the total number of acupoints used, with the Five Shu Points being the most common; the back and lumbar regions are the most frequent acupoint areas used, followed by the upper limbs; ST36 and SP6, GV4 and GV14 are the most commonly used acupoint combinations, forming four clusters. Conclusion: This study analyzes and visualizes the current state and trends in acupuncture treatment for SCI, including the frequency of acupoint use, characteristics of acupoints, and combinations thereof. However, further expansion of data volume and clinical research is needed to validate the reliability and importance of these conclusions.
Keywords: Acupuncture treatment; Spinal cord injury; Data mining; Citespace

1 INTRODUCTION

Spinal Cord Injury (SCI) is a leading cause of death and disability globally, associated with severe neurological dysfunction and complications, including neuropathic pain, pressure ulcers, and urinary tract infections, affecting 930,000 patients worldwide each year, leading to irreversible sequelae and even permanent disability [1-4]. Over the past 30 years, the incidence of SCI has increased, with higher rates in men than in women, and in the elderly than in the young [5]. Current main clinical treatment strategies for SCI include surgery, pharmacotherapy, as well as behavioral, physical, and supportive therapies [6]. However, there are issues such as postoperative complications, drug side effects, and rehabilitation obstacles [7-9]. Due to potential complications [10], an increasing number of patients are choosing alternative medical therapies, such as acupuncture [11]. Evidence shows that acupuncture therapy offers advantages of being non-toxic, easy to operate, and low-cost, and is widely applied in clinical treatment of SCI [2, 12-14].

Citespace is a Java-based application that analyzes hotspots and research frontiers in a given knowledge domain over a certain period [15]. In this study, we aim to analyze the hotspots and research frontiers in acupuncture treatment for SCI using Citespace, which can aid our understanding of acupuncture's therapeutic effect on SCI.

The selection and combination of acupoints in acupuncture therapy play a crucial role in developing standardized clinical diagnosis and treatment plans. While many studies have evaluated the efficacy of acupuncture in treating SCI, it is challenging to ascertain the optimal selection and combination of acupoints due to the significant variation in prescriptions among these studies [12, 16]. The emergence of data mining technology offers a new effective method for analyzing acupuncture information. Data mining is the process of extracting potentially useful information and knowledge from large volumes of messy, imprecise random data in real applications [17]. Thus, this study aims to mine acupuncture prescriptions for treating SCI using data analysis and visualization software, to identify the characteristics and patterns of acupuncture treatment for SCI, which is important for future research and clinical practice.

2 METHODS

2.1 Search Strategy

From October 1983 to October 2023, four members searched the following five electronic databases: PubMed, Excerpta Medica Database (Embase), Web of Science Core Collection (WOS), Cochrane Library, Springer. The search strategy

combined keywords (a) “acupuncture” or “acupuncture therapy” and (b) “SCI” or “spinal cord injury”.

2.2 Study Selection Criteria

The inclusion criteria were as follows: (1) Types of literature included Randomized Controlled Trials (RCTs), Clinical Controlled Trials (CCTs), and animal studies; (2) Subjects of the literature were patients or animals diagnosed with Spinal Cord Injury (SCI); (3) Studies that used acupuncture therapy as the primary intervention, with complete prescriptions and detailed acupoint selections; (4) Acupuncture treatment addressing a series of complications arising from SCI.
Exclusion criteria included: (1) Reviews, systematic reviews, meta-analyses, commentaries, clinical guidelines; (2) Post-operative rehabilitation of SCI with acupuncture; (3) Treatments involving acupoints other than acupuncture; (4) Studies with incomplete or unspecified acupoint prescriptions; (5) Trials involving microsystem acupuncture, ear acupuncture, head acupuncture, wrist and ankle acupuncture, and other non-traditional body acupuncture practices, as they do not apply to conventional acupuncture theory; (6) SCI caused by acupuncture treatment.
Data collected were entered into Note Express 3.7, with titles, abstracts, and full texts of retrieved papers screened according to the inclusion and exclusion criteria to determine the suitable data. A predefined data extraction form was used to collate comprehensive data. Characteristics of the included studies covered acupoints, meridians, acupuncture methods, and acupoint combinations.

2.3 Data Processing

Initially, data retrieved from the Web of Science were filtered, standardized, and imported into Note Express 3.7 in "plain text" format for statistical analysis and elimination of duplicate documents. The standardized literature results were then exported in "Refworks-Citespace" format, named "download_WOS.txt," for subsequent analysis in CiteSpace6.1.R6. Furthermore, using pivot tables in Excel, the frequency of acupoints and meridians in SCI acupuncture prescriptions was summarized, and further analysis was conducted on the distribution of these acupoints across different body parts and the details of specific acupoints. To identify the most commonly used acupoint combinations, IBM SPSS Modeler 18.0 was utilized to discern correlations between different acupoints. Finally, as much data as possible was extracted from the qualifying studies, including results and acupuncture methods, and reanalyzed to obtain more information about acupuncture for SCI.

2.4 Data Analysis

The processed "download_WOS.txt" file was imported into Citespace, with settings adjusted for analysis: the time span was set from January 1995 to October 2023, with Time Slicing set to 1 year, the g-index option set to a k value of 25, Top N option set to 50, Pruning options set to Pathfinder and Pruning sliced networks, and Node Types set to Keyword, with all other settings default. This setup facilitated the creation of a keyword co-occurrence visualization, with node types set for authors and institutions, followed by K-means clustering analysis to generate keyword clusters and a timeline visual.
Data was then analyzed and visualized using IBM SPSS Modeler18.0, assessing each acupoint's association strength, confidence, and lift. Support and confidence measures were used to gauge the strength of the acupoint association rules. Support is a metric indicating the probability of events A and B occurring together under certain conditions, reflecting the statistical significance of association rules within the entire dataset. Confidence signifies the likelihood of a subsequent event occurring given a premise, indicating the credibility of the association rule. In essence, support (A→B) represents the percentage of prescriptions containing both acupoints A and B out of the total number of prescriptions; confidence (A→B) shows the percentage of prescriptions containing both acupoints A and B out of the prescriptions that contain acupoint A. Lift indicates the relationship between the rule's confidence and the prior probability of the outcome occurring. Rules with a lift different from 1 are usually more interesting than those with a lift close to 1 [18]. Additionally, IBM SPSS Modeler was used to create a complex network display of the acupoint association rule matrix and the frequency of acupoint combinations in prescriptions.
Data processing and analysis, including visualization, were performed using RStudio. Data reading utilized the "read.transactions" function, with the "apriori" function for association rule analysis, "arules" for analyzing association rules, and the "arulesViz" package for visualization of association rules. The "NbClust," "parameters," and "factoextra" functions were used to determine the number of clusters, with "ward.D" for distance calculation, and the "heatmap" and "pheatmap" functions for dendrogram and heatmap analysis [19, 20].

3 RESULTS

3.1 Analysis of Web of Science Data

3.1.1 Annual publication volume

Analysis of 308 documents collected from the Web of Science and imported into Citespace showed an overall upward

trend in publication volume (Figure 1). From 1995 to 2003, there was a steady increase in publications, followed by a decline between 2003 and 2005 before rising again until 2009. Years 2010-2011, 2013-2014, and 2019-2020 showed declining trends, while other years experienced growth. A downward trend in 2023 was observed, attributed to incomplete data inclusion for the year.

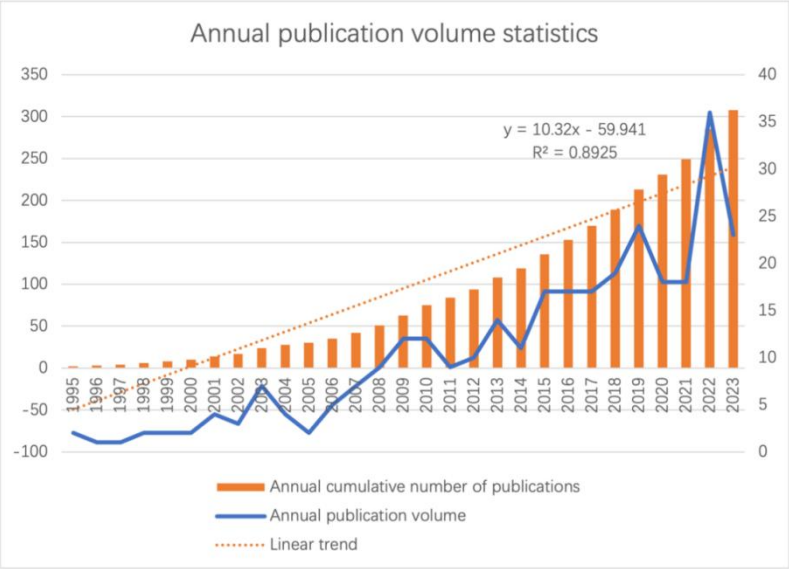

Figure 1 Line Chart of Annual Publication Volume for Acupuncture Treatment of Spinal Cord Injury

3.1.2 Author statistics

The analysis of authors included in the literature revealed collaboration networks as seen in Figure 2, with 589 nodes and 1058 links, and a network density of 0.0061. This formed multiple research teams centered around core individuals like Ding Ying and Guo Yi, showing close intra-team collaboration. Ding Ying was the most prolific author with 9 publications. There were 23 authors with more than 3 publications, totaling 86 publications, accounting for 27.92% of the total, indicating the need to expand the core group of authors and improve publication output. The top 10 authors are listed in Table 1.

Figure 2 Author Collaboration Network Map in Acupuncture Treatment of Spinal Cord Injury Research Literature (Nodes represent authors, with larger nodes indicating more publications; lines between nodes indicate collaborative relationships between authors, with more lines indicating closer collaboration.)

Table 1 Top 10 Authors by Publication Volume on Acupuncture Treatment for Spinal Cord Injury

Number	Author	Number of publications	Starting publication time
1	Ding,Ying	9	2009
2	Guo,Yi	6	2013
3	Wang,Ting-Hua	6	2007
4	Chen,Bo	4	2019
5	Jiang,Song-He	4	2014
6	Fan,Wen	4	2020
7	Gong,Yinan	4	2020
8	Wu,Yaochi	4	2017
9	Li,Ningcen	3	2021

10	Dou,Baomin	3	2021

3.1.3 Institution statistics

Analysis of institutions involved in the included literature, depicted in the institutional collaboration network seen in Figure 3, showed 344 nodes and 469 links, with a network density of 0.0079. This indicates that 344 institutions are researching acupuncture treatment for spinal cord injuries, with low network density suggesting limited collaboration between them. The top five publishing institutions were Kyung Hee Univ (14 publications), Beijing Univ Chinese Med (12 publications), Sun Yat Sen Univ (10 publications), Shanghai Jiao Tong Univ (10 publications), and China Acad Chinese Med Sci (10 publications).

Figure 3 Institutional Collaboration Network Map in Acupuncture Treatment of Spinal Cord Injury Research (Nodes represent institutions, with node size indicating the volume of publications; lines represent collaborative relationships between institutions.)

3.1.4 Keyword statistics

(1) Keyword Co-occurrence Analysis

The analysis included 503 keywords, with 503 nodes and 2645 links, showing a network density of 0.0209 (Figure 4). "Neuropathic pain" and "expression" were among the high-frequency keywords related to SCI symptoms. The top ten high-frequency keywords are listed in Table 2.

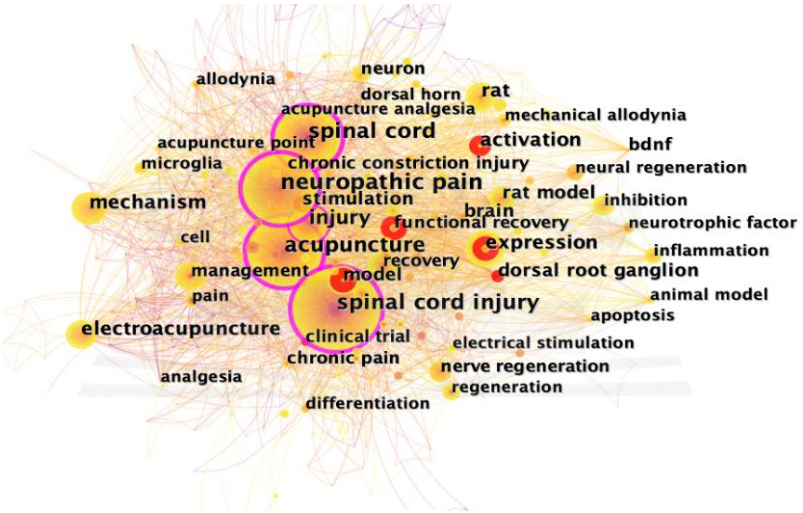

Figure 4 Keyword Co-occurrence Analysis Map in Acupuncture Treatment of Spinal Cord Injury Research Literature (Nodes represent keywords, with larger nodes indicating higher frequency of occurrence; lines represent co-occurrence relationships, with the closeness of relationships indicated by the number of lines, and colors transitioning from red to yellow indicating from more recent to older.)

Table 2 High-Frequency Keywords in Acupuncture Treatment for Spinal Cord Injury Research Literature (Top 10)

Number	Keywords	Centrality	Frequency
1	spinal cord injury	0.34	110
2	acupuncture	0.23	90

3	neuropathic pain	0.34	69
4	spinal cord	0.23	53
5	expression	0.07	40
6	injury	0.16	31
7	mechanism	0.09	29
8	activation	0.08	27
9	electroacupuncture	0.09	26
10	model	0.03	21

(2) Keyword Clustering

Keywords within the same cluster have strong relevancy, forming 11 clusters representing different research domains in acupuncture treatment for SCI (Figure 5). The clustering quality metrics, with a modularity Q value of 0.4805 and a silhouette S value of 0.7776, indicate a reasonable clustering structure [21]. The clusters are categorized into 1) SCI mechanisms, 2) literature types, 3) SCI-related symptoms, and 4) acupuncture prescriptions.

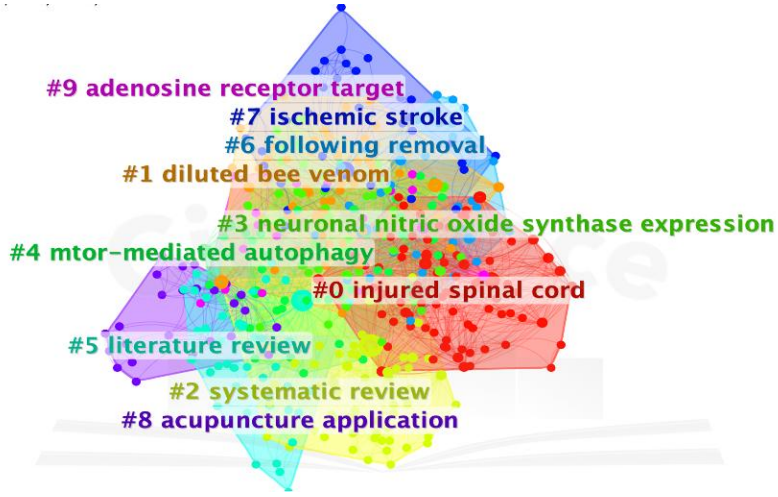

Figure 5 Keyword Clustering Analysis Map in Acupuncture Treatment of Spinal Cord Injury Research Literature (Different color blocks represent different clusters, with nodes within a block representing keywords in that cluster; smaller cluster numbers indicate larger cluster sizes.)

(3) Keyword Timeline Visualization

This visualizes the research focus over time, with high-frequency keywords before 2000 including "neuropathic pain," "spinal cord injury," and "acupuncture," shifting towards "electroacupuncture," "expression," and "model" after 2000, indicating a research focus on specific therapies and mechanisms (Figure 6).

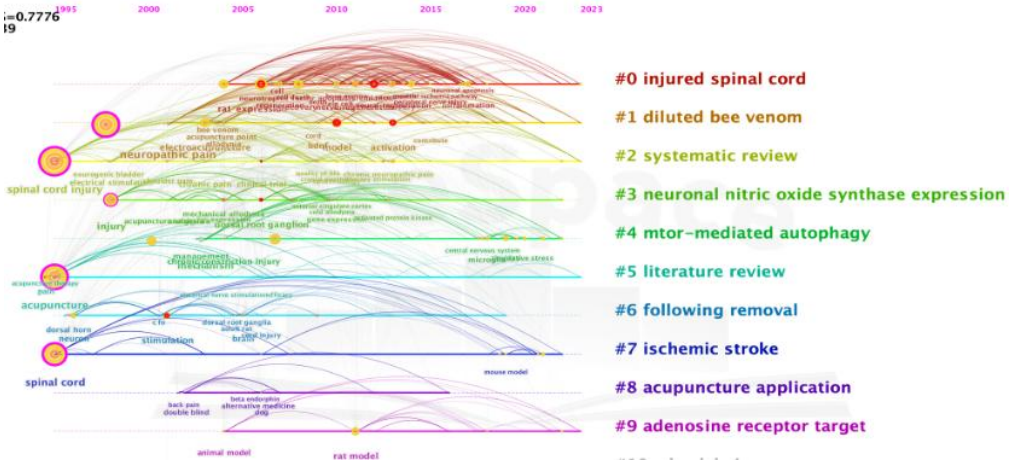

Figure 6 Timeline Map of Acupuncture Treatment for Spinal Cord Injury Research Literature (Y-axis nodes represent the year keywords first appeared, with node size indicating frequency of occurrence; smaller cluster numbers indicate larger cluster sizes.)

3.2 Acupuncture Prescription Findings and Overview

In five databases, 949 articles were found and imported into Note Express 3.7 for selection. After exclusion criteria were applied, 373 documents were included for further analysis (Figure 7).

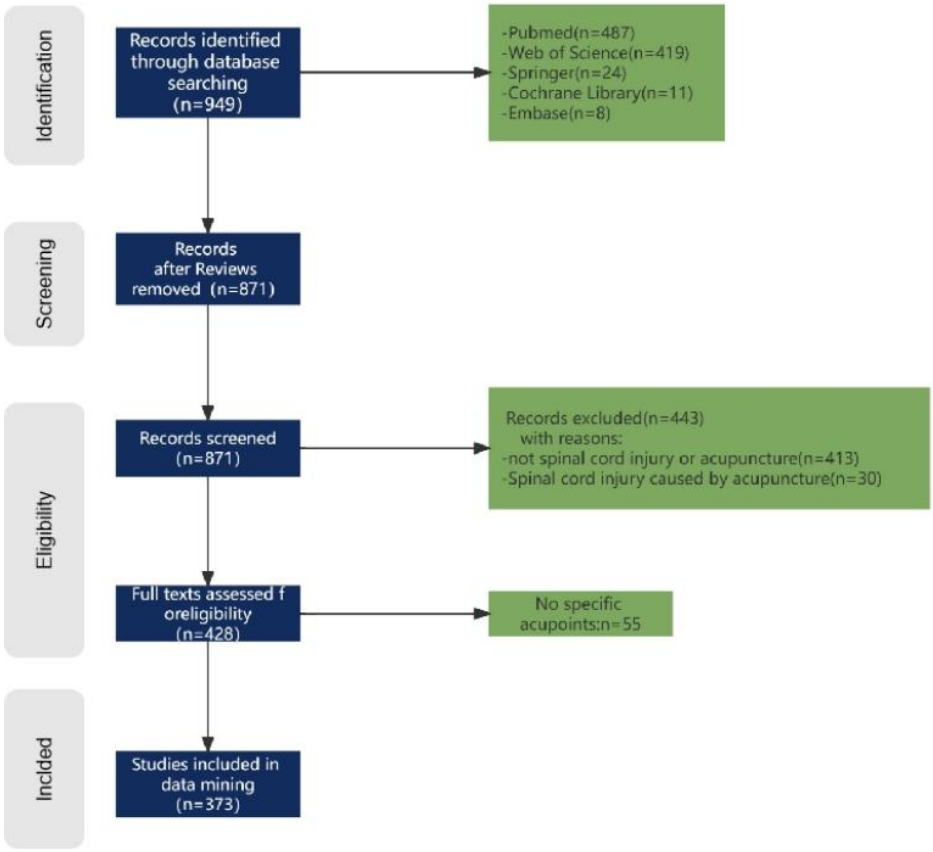

Figure 7 Literature Screening Process for Acupuncture Treatment of SCI

3.2.1 Application of acupoints

Among 368 prescriptions, 84 meridian acupoints and 3 extra-meridian points were recorded 959 times. Table 3 lists the 20 most commonly used acupoints, with ST36, EX-B2, SP6, GV14, and GV4 being the top five (Figure 8).

Table 3 The Top Twenty Acupoints for SCI Treatment

Number	Acupoints	Frequency	Proportion(%)
1	ST36	132	13.75
2	EX-B2	65	6.77
3	SP6	61	6.35
4	GV14	61	6.35
5	GV4	52	5.42
6	GB30	40	4.17
7	GB34	39	4.06
8	GV6	39	4.06
9	BL32	36	3.75
10	GV9	35	3.65
11	BL40	20	2.08
12	GB39	20	2.08
13	BL54	19	1.98
14	ST32	19	1.98
15	CV3	18	1.88
16	GV2	17	1.77
17	CV4	16	1.67
18	ST28	16	1.67
19	BL33	16	1.67
20	GV3	15	1.56

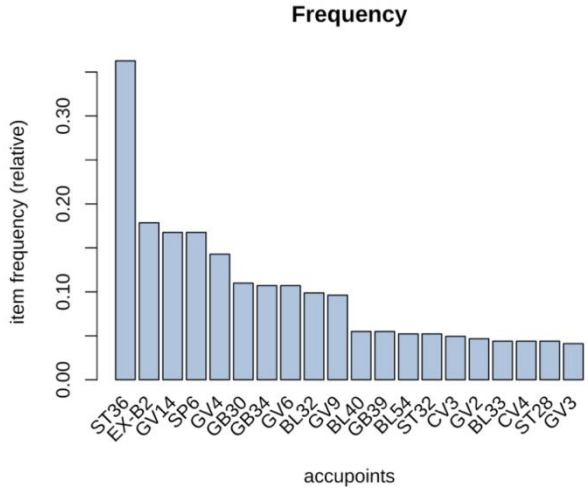

Figure 8 Frequency Chart of High-Frequency Acupoints for SCI

3.2.2 Application of meridians and acupoints

Analysis revealed 87 acupoints used for treating SCI, distributed among the 14 meridians (12 main meridians, GV, CV) and 3 extras. Table 4 shows the frequency and proportion of each meridian used, with GV, ST, BL, GB being the most frequently used meridians. In terms of yin-yang balance, yang meridian acupoints accounted for 72.61%, and yin meridian acupoints for 27.38%.

Table 4 Association Analysis of Meridians and Acupoints Used in SCI Treatment

Number	Meridian	Frequency	Proportion (%)*	Acupoints in Each Meridian		
				Number	Proportion (%)#	Acupoints (Frequency)
1	GV	262	27.29	12	13.79	GV14(61),GV4(52),GV6(39),GV9(35),GV2(17),GV3(15),GV1(14),GV20(12),GV26(9),GV16(5),GV12(2),GV29(1)
2	ST	176	18.33	6	6.90	ST36(132),ST32(19),ST28(16),ST25(7),ST41(1),ST40(1)
3	BL	146	15.21	19	21.84	BL32(36),BL40(20),BL54(19),BL33(16),BL23(13),BL34(9),BL31(8),BL60(5),BL20(4),BL62(3),BL28(3),BL35(2),BL13(2),BL15(1),BL21(1),BL24(1),BL59(1),BL11(1),BL57(1)
4	GB	101	10.52	5	5.75	GB30(40),GB34(39),GB39(20),GB21(1),GB20(1)
5	EX	69	7.19	3	3.45	EX-B2(65),EX-UE9(2),EX-LE10(2)
6	SP	65	6.77	2	2.30	SP6(61),SP9(4)
7	CV	54	5.63	7	8.05	CV3(18),CV4(16),CV6(11),CV12(4),CV8(2),CV2(2),CV17(1)
8	LI	25	2.60	5	5.75	LI4(14),LI11(7),LI10(2),LI16(1),LI14(1)
9	SI	14	1.46	9	10.34	SI3(6),SI4(1),SI11(1),SI13(1),SI10(1),SI15(1),SI9(1),SI14(1),S12(1)
10	SJ	11	1.15	5	5.75	SJ2(4),SJ14(3),SJ5(2),SJ6(1),SJ15(1)
11	KI	10	1.04	1	1.15	KI3(10)
12	PC	10	1.04	4	4.60	PC6(6),PC5(2),PC2(1),PC7(1)
13	LR	6	0.63	1	1.15	LR3(6)
14	HT	6	0.63	4	4.60	HT7(2),HT3(2),HT8(1),HT1(1)
15	LU	5	0.52	4	4.60	LU7(2),LU1(1),LU2(1),LU10(1)

3.2.3 Application of specific acupoints

Of the 87 acupoints used, 45 were specific, constituting 51.72% of the total. The most commonly used specific acupoints were the Five-shu points (31.1%), followed by Lower he-sea points, EX, and Front-mu points for treating SCI (Table 5).

Table 5 Association Analysis of Specific Acupoints Used in SCI Treatment

Number	Specific Acupoints	Frequency	Proportion (%)*	Acupoints in Each Specific Acupoints		
				Amount of Acupoints	Proportion (%)#	Acupoints (Frequency)
1	Five-shu points	225	38.66	14	31.1	ST36(132),GB34(39),BL40(20),LI11(7),SI3(6),BL60(5),SP9(4),SJ2(4),HT7(2),HT3(2),PC(2),LU10(1),HT8(1),ST41(1)
2	Lower he-sea points	152	26.12	2	4.44	ST36(132),BL40(20)
3	EX	69	11.86	3	6.67	EX-B2(65),EX-UE9(2),EX-LE10(2)
4	Front-mu points	35	6.01	3	6.67	CV3(18),CV4(16),LU1(1)
5	Yuan-primary points	32	5.50	5	11.11	LI4(14),KI3(10),LR3(6),SI4(1),PC7(1)
6	Eight-influential points	25	4.30	3	6.67	GB39(20),CV12(4),BL11(1)
7	Back-shu points	24	4.12	6	13.33	BL23(13),BL20(4),BL28(3),BL13(2),BL15(1),BL21(1)
8	Eight-confluent points	14	2.41	5	11.11	SI3(6),BL62(3),SJ5(2),LU7(2),SI10(1)
8	Luo-connecting points	5	0.86	3	6.67	SJ5(2),LU7(2),ST40(1)
9	Xi-cleft points	1	0.17	1	2.22	BL59(1)

3.2.4 Application of acupoints on different body parts

We analyzed the distribution of acupoints in acupuncture prescriptions. Table 6 displays the frequency and percentage of acupoint distribution, along with the names and frequencies of the acupoints. The back and lumbar area had the highest frequency of acupoint usage (43.65%), with 26 acupoints used 419 times. The upper limbs were the body part with the most acupoints used (7.08%), with 27 acupoints used 68 times.

Table 6 Association Analysis of Body Parts and Acupoints Used in SCI Treatment

Body Part	Frequency	Proportion (%)*	Acupoints in Each Body Part		
			Amount of Acupoints	Proportion (%)#	Acupoints (Frequency)
Back and lumbar	419	43.65	26	29.89	EX-B2(65),GV14(61),GV4(52),GV6(39),GV9(35),BL32(36),BL54(19),GV2(17),BL33(16),GV3(15),GV1(14),BL23(13),BL34(9),BL31(8),BL20(4),BL28(3),GV12(2),BL35(2),BL13(2),BL15(1),BL21(1),SI11(1),BL24(1),SI15(1),SI14(1),BL11(1),
Lower limbs	365	38.02	17	19.54	ST36(132),SP6(61),GB30(40),GB34(39),GB39(20),BL40(20),ST32(19),KI3(10),LR3(6),BL60(5),SP9(4),BL62(3),EX-LE10(2),ST41(1),BL59(1),ST40(1),BL57(1)
Chest and abdomen	80	8.33	12	13.79	CV3(18),ST28(16),CV4(16),CV6(11),ST25(7),CV12(4),CV8(2),CV2(2),LU1(1),LU2(1),PC2(1),CV17(1)
Upper limbs	68	7.08	27	31.03	LI4(14),LI11(7),PC6(6),SI3(6),SJ2(4),SJ14(3),SJ5(2),LI10(2),HT7(2),HT3(2),LU7(2),PC5(2),EX-UE9(2),SJ6(1),LU10(1),SI4(1),SJ15(1),HT8(1),SI13(1),SI10(1),LI16(1),SI9(1),GB21(1),HT1(1),PC7(1),SI12(1),LI14(1)
Head, face, and neck	28	2.92	5	5.75	GV20(12),GV26(9),GV16(5),GV29(1),GB20(1)

3.2.5 SCI high-frequency acupoints-specific points-body parts chord diagram

We selected the top ten acupoints by frequency, along with related specific acupoint attributes and body part distributions, to create an SCI high-frequency acupoints-specific points-body parts chord diagram (Figure 9) using the Microbio platform.

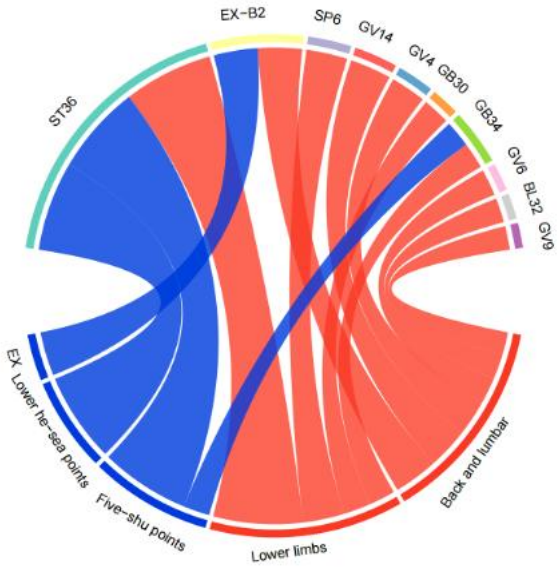

Figure 9 Chord Diagram of High-Frequency Acupoints with Specific Points and Body Parts

3.2.6 SCI acupoint combination rules

Table 7 summarizes the top 10 acupoint combinations in SCI acupuncture prescriptions by support. The top three combinations by support were ST36 with SP6, GV4 with GV14, and GV14 with GV4, consistent with the association rules matrix visualization. The primary combination was ST36 with SP6, which had the highest support of 17.64% and a confidence of 73.40%. We then generated association rule scatter plots and network diagrams using the "plot" function in R and created complex network diagrams of acupoint combinations using IBM SPSS Modeler18.0 (Figure 10-12).

Table 7 The Top Ten Acupoint Combinations in SCI Treatment

Number	Combination of Acupoints	Support (%)	Confidence (%)	Lift
1	ST36 →SP6	17.64	73.40	2.12
2	GV4 →GV14	15.76	69.05	5.18
3	GV14→GV4	13.32	81.69	5.18
4	ST36→GB34	10.88	68.97	1.99
5	GV9→GV6	9.76	88.46	9.82
6	GV6→GV9	9.01	95.83	16.32
7	ST28→BL54	5.25	64.29	16.92
8	ST32→GB39,ST36	5.25	85.71	5.47
9	SP6→GB39,ST36	5.25	96.43	2.88
10	GB30→BL40	5.07	70.37	16.92

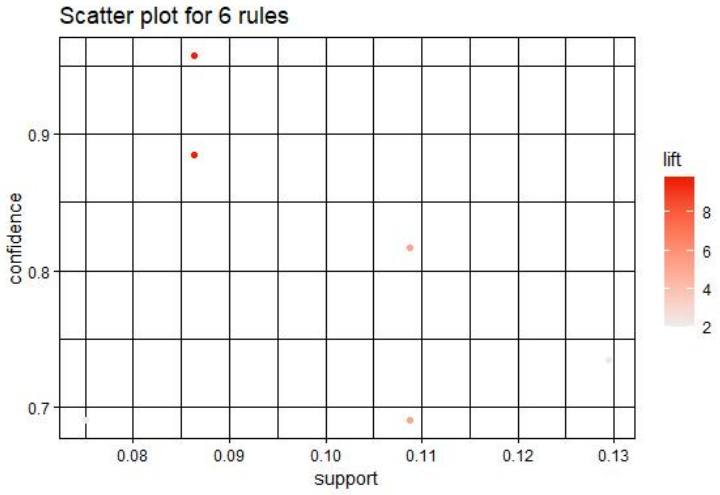

Figure 10 Scatter Plot of Association Rules

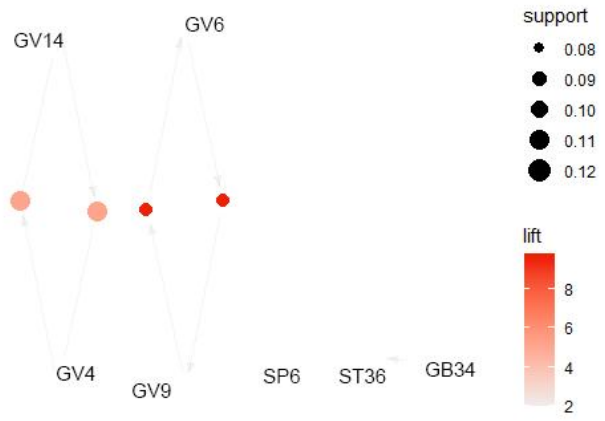

Figure 11 Network Diagram of Association Rules

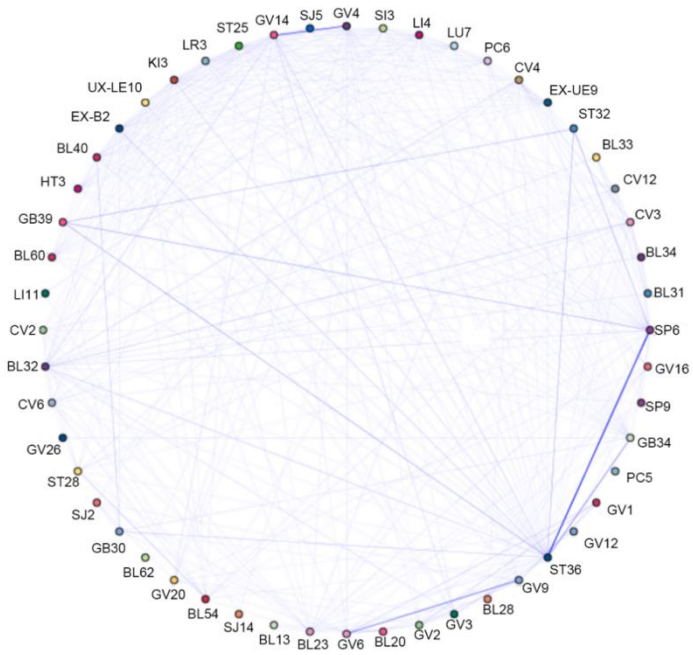

Figure 12 Complex Network Map of Association Rules in Acupuncture Treatment for SCI

3.2.7 SCI acupoint cluster analysis

We conducted a hierarchical cluster analysis on the top fifteen high-frequency acupoints used for SCI treatment using R, resulting in dendrograms and heat maps. Based on clinical experience, the high-frequency acupoints for acupuncture treatment of SCI can be divided into four categories: the first category includes GV9 and GV6; the second category includes GB39 and ST32; the third category includes GV14 and GV4; the fourth category comprises BL40, GB30, GB34, ST36, SP6, EX-B2, BL54, BL32, and CV3 (Figure 13-14).

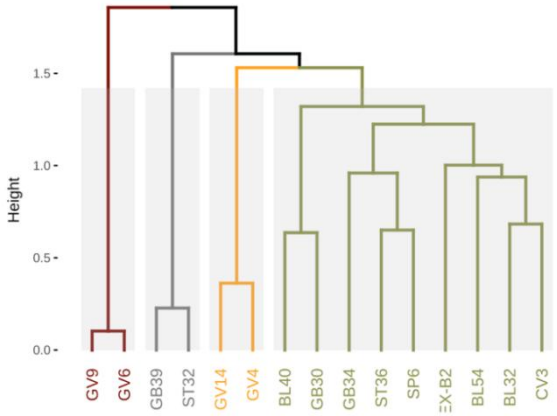

Figure 13 Dendrogram of Acupoint Clustering in Acupuncture Treatment for SCI

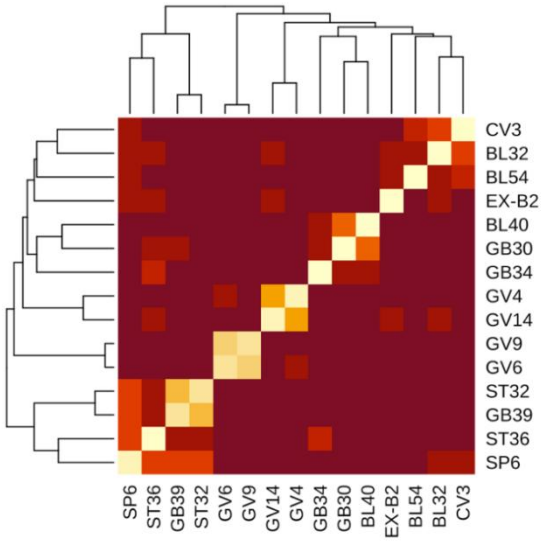

Figure 14 Heatmap of Acupoint Clustering in Acupuncture Treatment for SCI

4 DISCUSSION

Spinal cord injury causes neurological dysfunction in patients, with severe cases leading to paralysis of the lower limbs [22]. The remodeling and integrity of neural circuits are crucial for the functional recovery of the spinal cord [23]. Dysfunction in neural circuits following SCI is primarily due to axonal breakage and neuronal death. Therefore, the plasticity of neural circuits is the basis for neurological function recovery. Current treatments mainly focus on promoting the regeneration and extension of the corticospinal tract (CST) to re-establish connections with distal neurons [24]. Additionally, reducing adverse factors in the microenvironment that affect neural regeneration, such as glial scarring [25] and neuroinflammation [26], is critically important.

Acupuncture, as an essential part of Traditional Chinese Medicine, has been widely applied in neurological diseases and serves as a significant non-surgical alternative and adjunct therapy for SCI [27]. The efficacy of acupuncture in the treatment of SCI has been confirmed in numerous studies [28]. Research indicates that acupuncture can promote the survival and synaptic plasticity of hippocampal neurons [29]. Electroacupuncture has been shown to induce the synthesis and secretion of endogenous neurotrophic factors in spinal cord cells in SCI, creating a favorable microenvironment for neuronal survival and axonal regeneration [30]. Furthermore, acupuncture inhibits the activation of astrocytes and microglia following SCI [31-32], preventing the formation of glial scars and the occurrence of neuroinflammation, thus removing adverse factors for neural regeneration.

This study first utilized Citespace software to visually analyze literature related to acupuncture treatment for SCI in the Web of Science. The results indicate a stable upward trend in overall publication trends, with significant contributions from teams led by Ding Ying and Guo Yi. There is close cooperation within research teams but less between teams. Before 2000, the focus was on general research on SCI, shifting towards basic research and specific mechanisms from 2000 onwards. From the collaboration network diagram of research institutions, China dominates, but there is insufficient cooperation among institutions. Research institutions should establish connections, enhance result exchange, and further deepen the field of acupuncture treatment for SCI. High-frequency keywords and clusters in the field of acupuncture treatment for SCI involve adenosine receptor targets, mtor-mediated autophagy, neuropathic pain, etc.

Respiratory complications common in SCI patients negatively impact quality of life. Adenosine receptor antagonists can induce the recovery of diaphragm function after rat SCI [33]. Research by Zhou et al [34], suggests that autophagy flux impairment induced by SCI leads to neuronal death. Neuropathic pain following SCI is a complex condition, with its definition, manifestations, and related treatments under extensive study [35, 36].

In terms of acupoint frequency, acupuncture treatment for Spinal Cord Injury most commonly utilizes ST36, EX-B2, SP6, GV14, and GV4. ST36 is associated with the stomach meridian, serving as a crucial point for harmonizing the stomach and as a lower he-sea point. EX-B2, an extra-meridian point adjacent to GV, is known for its efficacy in activating blood circulation, removing stasis, and relieving pain [37]. SP6, often used in conjunction with ST36, is instrumental in nourishing qi and blood, playing a vital role in improving the local microenvironment for SCI treatment [38]. Acupuncture at GV14 and GV4 directly benefits by warming yang, invigorating the governing vessel, strengthening the kidneys, and nourishing qi and blood [39].

From the perspective of meridian distribution, GV, ST, and BL are predominantly chosen for treating SCI. GV acts as the sea of yang meridians, governing the body's yang qi, distributed to the trunk and limbs. In SCI, when GV is compromised, it leads to qi and blood stagnation, yang qi obstruction, and malnourishment of muscles and tendons. Thus, dredging GV and facilitating the flow of yang qi are key to treating SCI [40]. The "Huang Di Nei Jing Su Wen" mentions that treating flaccidity involves primarily selecting yangming, with the stomach meridian being the sea of the five zang and six fu organs. Its harmonization ensures the smooth flow of qi and blood, nourishment of organs, and relaxation of tendons and ligaments [41]. The thoracic and lumbar spine, warmed by the qi of the foot taiyang bladder meridian, shows signs of neurogenic bladder and urinary incontinence when the bladder meridian is impaired [2].

In acupuncture treatment for SCI, specific acupoints such as Five-shu points, Lower he-sea points, and EX play a dominant role. "Ling Shu: The Nine Needles and Twelve Source Points" states that the transformation and regulation of bladder qi depend on the harmony of the Five-shu points [42]. Among the Lower he-sea points, ST36, as the lower he-sea point of the stomach, is a key point for treating paralysis of the lower limbs, facilitating the flow of meridian qi [43]. EX points are selected for their proximal effects in improving SCI [44].

Acupuncture treatment for SCI primarily selects acupoints on the back and lumbar area and the lower limbs, with GV points mainly chosen for the back and lumbar area, and the foot yangming meridians for the lower limbs. The yang qi, distributed through yang meridians, can be regulated and nourished by selecting yang meridians, which helps improve the musculoskeletal system [45].

Association rules indicate that ST36-SP6 and GV14-GV4 are the combinations with the highest support. ST36 and SP6, commonly used together for SCI treatment, have been shown in modern research to effectively reduce inflammation and oxidative stress at the injury site and inhibit the proliferation of astrocytes, thereby improving SCI [46]. Both GV14 and GV4, as key points on the GV meridian, warm yang and facilitate qi flow. Modern research has validated that their combined use can promote autophagy to improve neural functions in SCI [39].

Cluster analysis yielded four effective clusters, with the first cluster including GV6 and GV9, key choices for acupuncture treatment of SCI, shown to benefit the regeneration of axonal neurons post-SCI [47]. The second cluster, combining GB39 and ST32, complements each other to nourish the liver and kidney, unblock meridians, and warm kidney yang [48]. The third cluster, GV14-GV4, vital points on the GV meridian, can restore yang and facilitate the flow of qi. Research by Guan et al. proved that electroacupuncture at GV14 and GV4 improves the microenvironment in SCI rats, restoring peripheral and central nervous system functions [27]. The fourth cluster includes ST36, SP6, GB34, and others, working together to nourish qi and blood, strengthen muscles and bones [49], with EX-B2 and GV points also promoting blood circulation and nourishing essence, collectively treating SCI from various aspects.

Treating SCI poses challenges and significantly impacts patients' lives. Clinical acupuncture treatment for SCI has shown effectiveness, yet a unified standard for selecting acupoints is still under development. Data mining enables the integration and analysis of content from large samples, making it feasible to explore acupoint selection patterns in acupuncture treatment for SCI. This study aimed to analyze acupoint selection in SCI treatment from relevant literature to summarize patterns and provide clinical experience. However, limitations include uneven acupoint distribution in the collected data, affecting pattern analysis, and the study's focus on literature reporting effective treatment without considering negative impacts or acupoints for complications. Further research is needed to standardize acupuncture treatment protocols for SCI.

5 CONCLUSION

This study utilized Citespace to analyze the research hotspots and frontiers in acupuncture treatment for Spinal Cord Injury (SCI). The findings indicate that targeting adenosine receptors, mTOR-mediated autophagy, and neuropathic pain are the focal points of acupuncture research in SCI treatment, with significant contributions made by researchers such as Ding Ying and Guo Yi. Through data mining, we have identified the frequency and characteristics of acupoint selection in the treatment of SCI. The most frequently used acupoints are ST36, EX-B2, SP6, GV14, and GV4, with the GV, ST, and BL meridians being the most commonly applied. The Five-shu points, Lower he-sea points, and EX points are the specific acupoints most used, with a preference for selecting acupoints on the back and lumbar area as well as the lower limbs. The combinations of ST36-SP6 and GV14-GV4 are among the most common. However, further expansion of data and clinical research is needed to substantiate the significance of these findings.

ABBREVIATIONS

Full name	Abbreviations
Spinal Cord Injury	SCI
Excerpta Medica Database	Embase
Web of Science Core Collection	WOS
Randomized Controlled Trials	RCTs
Clinical Controlled Trials	CCTs
Hand Tai Yin Lung Meridian	LU
The Large Intestine Meridian of Hand-yangming	LI
Foot Yangming Stomach Meridian	ST
Spleen Meridian of Foot Taiyin	SP
The heart channel of Hand-Shaoyin	HT
Hand Sun Small Intestine Meridian	SI
The urinary bladder channel of Foot-Taiyang	BL
The Kidney Channel of foot-Shaoyin	KI
Hand Jueyin Pericardium Meridian	PC
Hand Shaoyang Triple Jiao Meridian	SJ
Gallbladder meridian of foot shaoyang	GB
Foot Jueyin Liver Meridian	LR
Governor's pulse	GV
Ren channel	CV
Extra nerve points	EX
Orticospinal tract	CST

COMPETING INTERESTS

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AUTHOR CONTRIBUTIONS

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas.

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