Bibliometric Analysis of China's Contribution to the Knowledge System of Cerebrovascular Intervention

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Research

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Abstract

Background: Cerebrovascular disease has become the leading cause of death in China. The purpose of this article is to analyze China's contribution to interventional treatment of cerebrovascular diseases.

Methods: Bibliometric analysis was used for evaluating the quantity, quality, research hotspots, and cooperation network of publications from China. Articles were acquired from the database of Web of Science Core Collection. The authors, publication years, citation times, original regions, and source journals were recorded by EXCEL 2019. Network analysis and visualization were performed on Citespace5.6.

Results: From 1991 to 2019, totally 5,052 articles regarding cerebrovascular intervention were published by Chinese researchers. The number of publications from China grew fastest annually in the latest five years among countries. These publications were totally cited 61,216 times, with 12.12 average citations per item. The h-index was 82. Affiliated hospitals of Capital Medical University contributed most articles. Cerebral ischemia and intracranial aneurysm were the most popular keywords over the three decades. The timeline view of keywords indicated that cerebral ischemia was always a hot spot. Stent techniques were the main treatment tools and still had a strong developing trend. Basic researches of cerebrovascular intervention had a preference for neural regeneration and neuroprotection.

Conclusions: The number of publications from China grows fast in recent years, but research quality needs further enhancement. The highly targeted researches are continuously promoting the clinical practice of CVDs. More valuable clinical evidence would be provided.

Background

Cerebrovascular diseases (CVDs) are a critical health problem worldwide, consisted of conditions that affect cerebral blood supply[1]. Disparities in the incidence of CVDs are growing, with a decrease in high-income countries and an increase in low-income and middle-income countries (LMICs) such as China[2]. According to the Global Burden of Disease Study, CVDs are the leading cause of death in China[3]. Over the past three decades, development in cerebrovascular intervention techniques has provided a new treatment strategy for CVDs[4]. Interventional surgery now has become the most common therapeutic approach for cerebrovascular conditions[5]. Chinese researchers have made great efforts in the development of the cerebrovascular intervention in past decades. The practice of this technique has brought meaningful benefits to many patients[6]. But China's contribution to cerebrovascular intervention has not been well evaluated.

Bibliometric analysis is a useful approach to evaluate the development of a certain scientific field[7]. The circumstance of one scientific field over a period is evaluated by analyzing the quantity and quality of publications, journals, keywords, citation, cooperation networks, and other valuable information of literature in this field. Based on the analysis results, researchers can draw experience from the past, predict the trends in development, and get inspiration for future research[8].

This is the first bibliometric study to evaluate China's contribution to cerebrovascular intervention, we retrospectively analyzed the publications of cerebrovascular intervention from China searched on Web of Science Core collection. For the first time, we use the approach of bibliometrics to evaluate the contribution of China's research in the cerebrovascular intervention field and employ the statistics analysis instrument Citespace 5.6 to visualize the literature information[9].

Methods

Literature retrieve

To select Chinese cerebrovascular intervention research with high global influence, we chose Science Citation Index Expanded (SCI-EXPANDED) database from Web of Science Core Collection as a literature source. Studies regarding cerebrovascular intervention were retrieved by topic search, which included the title, abstract, and keywords of the articles. Search terms were acquired from Medical Subject Headings (MeSH).

In the first part, we searched the literature regarding cerebrovascular diseases. The core subject term "cerebrovascular disorders" and its subordinate subject terms which were "Basal Ganglia Cerebrovascular Disease", "Brain Ischemia", "Carotid Artery Diseases", "Cerebral Small Vessel Diseases", "Cerebrovascular Trauma", "Intracranial Arterial Diseases", "Intracranial Embolism and Thrombosis", "Intracranial Hemorrhages", "Leukomalacia, Periventricular", "Sneddon Syndrome", "Stroke", "Vascular Headaches", "Vasculitis, Central Nervous System" and "Vasospasm, Intracranial" were searched. Besides, all the affiliate terms of above subordinate subject terms such as "Intracranial Aneurysm" and" Brain Infarction" were included. We also searched for the relevant entry terms of all the subject terms. In the second part, researches related to interventional treatment were searched from the perspective of interventional radiography, interventional operation techniques, and interventional devices, with searched terms including "interventional radiography", "endovascular treatment" and "stent" respectively.

The intersection of the above two parts was finally retrieved as research results. Papers only regarding cardiovascular disease were eliminated by using exclusionary words such as "percutaneous coronary intervention" and "myocardial Ischemia". The literature type was restricted to "article". Country/region was refined as "Peoples R China" or "Taiwan". The Year of publication was set from 1990 to 2019. Literatures records were screened by 2 reviewers independently. The duplicated and unrelated articles were removed.

Data collection and bibliometric analysis

Bibliometric indicators including the number of publications cited times, years, authors, country and regions, journals, and keywords were extracted and recorded in Excel 2019. The citation report tool of Web of Science was used to analyze cited times and h-index. Literature records were downloaded from Web of Science and imported into citespace 5.6 software. The number of publications among countries was analyzed and contrasted. The quality and influence of publications were mainly measured by cited frequency and h-index which was a common evaluation index for literature [10]. Network analysis and

visualization were performed on Citespace by knowledge mapping. Cooperation network analysis was based on information of authors, institutions, and countries. The hotspots of the research field were reflected by the keywords co-occurrence network. After acquiring the hotspots, we analyzed the articles belong to these hot topics in the literature retrieved to show their proportion and development situation. The valuable articles, authors, and journals with high influence in the field were selected by co-citation analysis. We set the top 50 most cited or occurrence items each year as statistics selection criteria. Cluster visualization was generated to reflect the relationship between items. The emerging trend of hotspots was visualized by timeline view, in which the solid line indicated the persist of new attention in this cluster. The fast increase in the co-occurrence of certain keywords and the burst in co-citation of specific articles over a period were identified by burstness detection. On the visualization figures, citation counts or occurred times were measured by the thickness of the “tree ring” with different colors. The wide of color bands reflected the strength of the indicators at the year that the color represented. The relationship between key nodes was reflected in different lines. The color of the line indicated the year of first cooperation between two nodes and the thickness of the line represented the strength of their relationship. The lines with small nodes were partly omitted by the pathfinder algorithm for better visualization. Purple rings around nodes indicated high centrality. Cluster labels were extracted from keywords using latent semantic index (LSI) algorithm.

Results

Contribution in publications

Totally 44,779 articles regarding cerebrovascular intervention from 1990 to 2019 were retrieved, in which 5,052 publications were from Chinese researchers, including 2,805 (55.5%) articles published in the last five years. The top five contributed countries to the global research of cerebrovascular intervention were as follows: The United States, Japan, China, Germany, and France. (Fig.1A) The United States published 14,913 articles, accounting for 33.3% of the total publications, and still maintained a high growth rate in new publications. Since 2010, the annual amount of publication from China had come to second place. Furthermore, the average increasing number of publications from China in the latest five years was 82.4, which was much higher than that in the United States (2.75), Japan (9.25), Germany (26), and France (16.5). (Fig.1B)

Publications from the United States had the most cumulative citation times (530,712), with average citation times of 35.58 and h-index of 241. Germany came in second place in terms of citation times and h-index, which were 129,613 times and 132 respectively. Canada, England, and Netherland were less in the number of publications but more in the number of high cited articles. The h-index of Canada, England, and Netherland were 124, 121, and 97 respectively. There were 46.46 citations on average for each article published from Canada. This data ranked first in all countries, followed by England (41.16) and Netherland (36.26). In contrast, publications from China were totally cited 61,216 times, ranking seventh. The h-index of China was 82, ranking ninth. The number of publications of China was the third most, but each article had only 12.12 citations on average. (Fig.1C) Considering the papers from China were mainly

published within the latest 5 years, the citation information was further analyzed from 2015 to 2019. Although the average citations of each paper were only 5.44, the sum of citation (15,260 times) had come to the fourth place and the h-index was 39, ranking fifth in all countries. There was a small improvement of articles' quality(Fig. 1D) To evaluate the high influence publications, 2,006 of 44,779 articles cited more than 100 times were considered as high-qualified. Thereinto, 47 articles involved with Chinese researchers, including 2 published in the 1990s, 28 published in the 2000s, and 17 published in 2010s. We regard the first author as the most contributed person in one article. In the 30 articles published before the 2010s, only 8(26.7%) articles' first authors were from mainland China. Six (12.8%) were from Taiwan. Three (6.4%) were from Hong Kong. Thirteen(27.6%) were from other countries. For those published after 2010, the first authors in 10 of the 17 articles were Chinese researchers (9 were from mainland China). The contribution of China in high-qualified articles was partly improved.

Articles from Chinese researchers were distributed in 631 journals. The journals that would like to publish articles from China were listed in table I. The Top 10 journals published most articles from China were *World Neurosurgery*(IF=1.723, 229 articles), *Interventional Neuroradiology* (IF=1.450, 133 articles), *Stroke*(IF=6.046, 123 articles), *Chinese Medical Journal* (IF=1.555, 119 articles), *Plos One*(IF=2.776, 114 articles), *American Journal of Neuroradiology* (IF=3.256, 114 articles), *Journal of Stroke & Cerebrovascular Diseases* (IF=1.646, 99 articles), *International Journal of Clinical and Experimental Medicine*(IF=0.181, 99 articles), *Medicine* (IF=1.87, 96 articles), and *Brain Research* (IF=2.929, 95 articles). These journals were included in 9 JCR categories.

Cooperation network analysis focusing on China

The cooperation network of institutions, authors, and countries based on the 5,052 articles was visualized by knowledge mapping of Citespace 5.6.(Fig.2A) Capital Medical Univ (685 articles, 13.56%) was the most prolific institution of China, followed by Shanghai Jiao Tong Univ (276, 5.5%), Fudan Univ (263, 5.2%), Second Mil Med Univ (226, 4.5%) and Beijing Neurosurgical Institute (198, 3.92). The top 10 authors having published most articles were: "XINJIAN YANG", "YOUXIANG LI", "XINFENG LIU", "JIANMIN LIU", "QINGHAI HUANG", "XUNMING JI", "BO HONG", "ZHONGXUE WU", "CHUHAN JIANG", and "GELIN XU". Interestingly, our result suggested that prolific authors were usually centralized in a few institutions. For instance, XINJIAN YANG and YOUXIANG LI were from Capital Medical Univ, XINFENG LIU and GELIN XU were from Nanjing General Hospital, and JIANMIN LIU and QINGHAI HUANG were from Second Mil Med Univ. (Fig.2B) Most of these institutions were distributed in east coast regions, especially in Beijing and Shanghai, whereas the prevalence, incidence, and mortality of stroke in these regions were low compared with other provinces. The interventional treatment resource in China was unbalanced. (Fig.2C) As for the cooperation with other countries, the USA, Australia, Germany, Japan, and Canada were the five countries most frequently cooperated with China. (Fig.2D)

Reference co-citation analysis

The articles cited by the included 5,052 articles were analyzed through co-citation analysis. The top 10 most co-cited literature were listed. (Table II) The top five articles were all randomized clinical trials

regarding thrombectomy treatment of ischemic stroke in 2015, followed by one randomized clinical trial regarding stent treatment of carotid artery stenosis, two clinical guidelines or consensus, one meta-analysis about thrombectomy treatment, and one epidemiologic survey about Chinese intracranial atherosclerosis. Seven of the above 10 articles were published in the latest five years, indicating the burst of attention in cerebrovascular intervention researches. Six articles were concentrated on mechanical thrombectomy for ischemic stroke. On the visualization map, the co-cited articles were divided into 15 visualize clusters which were labeled by the LSI algorithm. These labels reflected the general topics of the cited literature included in one cluster. The top five clusters including the most co-cited articles were: “covered stent”, “stenosis”. “stent-assisted coiling”, “acute ischemic stroke”, “inflammation” and “digital subtraction angiography”. (Fig.3) The timeline view suggested that the researches about “acute ischemic stroke” attracted comprehensive attention from 2015 until now. Studies about “inflammation” and “rupture” also attracted great attention until recently. (Fig.4)

Keywords co-occurrence analysis

The hot spots of cerebrovascular intervention in China were detected by the knowledge mapping of keywords. Fifty most occurred keywords each year in the past three decades were selected to construct the keywords co-occurrence network. “Stroke”, “endovascular treatment”, “intracranial aneurysm”, “ischemic stroke”, “cerebral ischemia”, “ischemic stroke”, “cerebral ischemia”, “aneurysm”, “angiography” and “neuroprotection” were 10 keywords that occurred mostly in the network. Eleven clusters were identified by the “found cluster” function of Citespace 5.6 and labeled by the LSI algorithm. (Fig.5) The cluster label names ordered as the number of keywords in the clusters were as following: “neural regeneration”, “cerebral ischemia”, “stent”, “aneurysm”, “dural arteriovenous fistula”, “hyperbaric oxygen”, “moyamoya disease”, “carotid stenosis”, “tissue plasminogen activator”, “covered stent”, “smooth muscle cell”, and “cerebral blood flow”. Five names of disease were selected as labels. All the articles regarding these diseases were retrieved from our above search results. We found 2,525(50.0%) articles related to cerebral ischemia, 1,255(24.8%) for intracranial aneurysm, 105(2.1%) for dural arteriovenous fistula, 131(2.6%) for moyamoya disease, and 584(11.6%) for carotid stenosis. The timeline view showed that “cerebral ischemia” is always a research hotspot since 1991 until now, and “covered stent” is another continuous research hotspot since the 2000s. (Fig.6) Five keywords with the strongest citation burst were “carotid artery”, “restenosis”, “nitric oxide”, “MR angiography” and “arteriovenous malformation”. (Table III)

Discussion

Our bibliometric study analyzed the contribution of each country to the development of cerebrovascular interventional research, especially the contribution of China. The contribution and cooperation of Chinese institutions and authors were evaluated and ranked. The co-citation analysis presented valuable researches in this field and primarily showed promising research directions. The co-occurrence analysis of keywords further pointed out the research hotspots and the future research directions in this field.

The status quo of the development of Chinese cerebrovascular interventional research

China is one of the largest developing countries, where stroke is the leading cause of death and disability, with 11 million cases of stroke annually[11, 12]. It used to be considered that China was a country with a high stroke burden but a low amount of cerebrovascular disease researches[13]. In the last five years, the amount of publications from China regarding the interventional treatment of stroke inclined the most rapidly among countries. This might attribute to the reforms of China's health-care system which extended the sources of clinical cases[14]. Since the establishment of the Ministry of Health China Stroke Prevention Project Committee in April 2011, more stroke centers were constructed nationally and more people could accept endovascular treatment in time [6]. However, the sum of publications citations, average publication citations, and h-index were all still low in the ranking. In the 2,006 articles cited more than 100 times, 47 articles were involved with Chinese researchers, which just accounted for 2.3%. Very few journals in Q1 (First quartile in JCR Category) were in the list of journals that Chinese researchers most published. These data denoted that cerebrovascular interventional research in China has reached a considerable scale, but its quality needs further improvement.

The contributions of researchers and medical institutions of China are critical for the blossom of cerebrovascular interventional research. Early in the 1990s, Wu ZX, Ling F, etc. began to report their experience of treating intracranial aneurysms, traumatic carotid cavernous fistulas, and arteriovenous malformation with endovascular techniques widely.[15-17] For the blank of interventional techniques and materials in China, they produced self-made tungsten coils to treat aneurysms and have favorable outcomes[18]. The first cerebrovascular intervention training institution was established in 1996, which attracted many Chinese doctors to learn and popularize endovascular treatment nationally. Cooperation network analysis suggested that institutions including Capital Medical Univ, Shanghai Jiao Tong Univ, Second Mil Med Univ, and their affiliated hospitals have made a significant contribution to the cerebrovascular interventional research of China. Yang XJ, Li YX, etc. leadingly reported the application of Neuroform stent in intracranial aneurysm[19]. Liu JM, etc. first reported stent-assisted electrical detachable coil embolization in vertebral artery aneurysms and intracranial ruptured aneurysms in China[20]. In 2004, embolization with onyx in AV-shunt and arteriovenous malformation was widely applied [21]. The primary experience of Wingspan stent in Chinese patients was reported by Fan XY, Liu XF, etc [22]. However, most of these researches are case reports or case series rather than clinical researches with larger scales. Furthermore, these early exploratory works from China were mainly reported on domestic journals in Chinese, and not many papers were published in international journals, which limited their global influence. This phenomenon might attribute to the lack of systemic clinical case statistics. Recently, with the improvement of the medical condition and the incentive of patients' demands, Chinese cerebrovascular interventional research is rapidly developing. Chinese researchers can raise and answer focus issues. Results of the DRICT-MT trial first showed that in large vessel occlusion, endovascular thrombectomy with or without intravenous alteplase had similar outcomes, within a 20% margin of confidence [23]. The BASILAR trial proved that in patients with acute basilar artery occlusion, endovascular treatment administered within 24 hours was associated with better functional outcomes and reduced mortality than standard medical treatment alone [24]. The BEST trial showed no evident

favorable outcomes of patients receiving endovascular therapy compared with those receiving standard medical therapy alone in vertebrobasilar artery occlusion [25]. These high-ranked trails are eminent representatives of the Chinese contributions to the global cerebrovascular interventional research.

Basing on the cooperation networks of institutions and authors, we inferred that the interregional imbalanced development of the medical condition and the lack of institutional cooperation might be the hampers of the cerebrovascular interventional research of China. Most of the authors with high citations were from a few institutions that were distributed in east coast regions, especially in Beijing and Shanghai [26]. This phenomenon reflects the reality of the imbalanced distribution of medical resources. To thoroughly settle this dilemma, further investment from the government and more efforts from clinical practicians are needed, which will be a “protracted war” [11]. Enhancing the inter-institutional cooperation may be a cost-effective way to improve the general research level of China. Looking back to the success of Chinese clinical trials including BEST, BASILAR, and DIRECT-MT, it is obvious that multi-center cooperation is the necessity of high-ranked clinical trials. The cooperation is not only limited to sharing clinical data but also involves discussing research protocols and raising clinical questions. Besides that, the cooperation in the research field may also facilitate collaboration in clinical practice. Currently, the stroke centers in China are ranked as “Primary stroke center”, “Senior stroke center”, and “National model senior stroke center”. Interventional practicians from primary centers can engage in advanced studies in senior centers, and experience and techniques of endovascular treatment can be more accessible. This model of collaboration can enhance the development of clinical research in return.

The research trend of cerebrovascular intervention in China

The result of reference co-citation analysis indicated the burst of attention in cerebrovascular intervention researches in the last five years. Chinese researchers paid specific attention to thrombectomy treatment of ischemic stroke, which suggested the great potential of this direction. The keyword analysis pictured the research directions and hotspots currently and prospectively of cerebrovascular interventional research in China. From the most occurred 10 keywords, we can find that “intracranial aneurysm” and “cerebral ischemia” were two important topics in cerebrovascular intervention. Keywords were divided into 11 clusters by algorithm, which represented the different research directions. The clusters were ordered as the number of keywords it contains. Cluster #0 labeled by “neural regeneration” was the one comprised most keywords. The highly occurred keywords in this cluster, such as “neuroprotection”, “apoptosis”, and “oxidative stress” were mainly involved in basic experimental researches, which denoted the close relationship between clinical and basic research in the cerebrovascular intervention field. Chinese researchers contributed a lot in this direction. For example, the study from Wang B et al., which was totally cited 112 times, illustrated that low-concentration CO manifested a neuroprotective effect on cerebral ischemia by activating the Nrf2 pathway[27]. One of the special contributions of China was the exploration of the neuroprotective effect of traditional Chinese medicine, such as Sanhua Decoction and QiShenYiQi[28, 29]. Many trials about neuroprotection failed to translate their protective effects from animal models to humans. We could see that the solid line of cluster#0 halted in recent years on timeline view, which meant a fall of attention. Still, approximately half of the patients who suffered from ischemic

stroke do not regain independent function after successful endovascular recanalization, which is a critical issue deserving further investigation [30]. Cluster#1 was labeled as “cerebral ischemia”. Timeline span suggested this was the only cluster with continuous attention throughout the three decades. The key nodes in this cluster, such as “stroke”, “artery occlusion”, and “middle cerebral artery” tended to be large, and their emerging time was uniformly distributed on the timeline. According to the result of the co-citation mentioned above, cerebral ischemia would still be a substantially important research trend in future years. Cluster#2 and #9 were labeled by “stent” and “covered-stent” respectively, suggesting the importance of stent in interventional techniques. “Stenosis” and “carotid endarterectomy” were two keywords with large nodes in the network, which might due to the long-time discussion about the strategy selection of stenting or endarterectomy in different cases. The time span of the cluster#2 and #9 extended to 2017 or later, indicating the persistent attention of the stent. The wide application of stent, including stent-assisted embolization, stent-assisted angioplasty, and the outspring of novel stents such as flow diverters and stent retrievers, made stents popular for endovascular treatment. Cluster#3 was labeled by “aneurysm”. Key nodes in this cluster, such as “intracranial aneurysm”, “cerebral aneurysm”, and “subarachnoid hemorrhage”, were all intensely related to the management of aneurysm. Timeline view showed that these nodes intensely emerged in the 1990s, denoting that at that time the traditional interventional therapy such as coil embolization had been introduced to China and well-studied. Later, researchers realized that stent with high material coverage could become a stand-alone device to embolize aneurysms by changing the hemodynamics. Chinese researchers invented the Tubridge flow diverter and demonstrated a significantly higher obliteration rate of large and giant aneurysms during a 6-month follow up with this device than stent-assisted coiling[31]. Flow diverter treatment for aneurysm became a hotspot in recent years. Timeline span suggested topics in cluster#4, cluster#5, and cluster#6 were not mainstay topics in recent years. Endovascular embolization had become a first-line treatment for dural arteriovenous fistula, direct carotid cavernous fistula, and arteriovenous malformation. The cure rates with Onyx was considerably acceptable[32]. Breakthrough progress in hyperbaric oxygen and clinical management for moyamoya disease was not evident. Keywords in cluster#7 “ carotid stenosis” suggested the key nodes regarding interventional radiology, such as “angiography” and “magnetic resonance angiography”, were often co-occurred with carotid stenosis, indicating the frequent application of interventional techniques in carotid stenosis.

Conclusions

The number of researches for cerebrovascular intervention grew rapidly in China but researches quality still needs further enhancement. Chinese researchers made their ways to introduce advanced methods and techniques from western countries in the past decades and tried to explore optimal endovascular strategies specifically for the Chinese population. Much of the attention was paid to the diseases with high incidences, such as cerebral ischemia and intracranial aneurysm. With the construction and development of stroke centers in China, more and more researchers will devote to solve the global critical questions of cerebrovascular intervention.

List Of Abbreviations

CVDs Cerebrovascular diseases

LMICs low-income and middle-income countries

MeSH Medical Subject Headings

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors' contributions

Author Hongyu Ma, author He Li and author Pengfei Yang have given substantial contributions to the conception or the design of the manuscript, author Peng Liu and author Pei Liu to acquisition, analysis and interpretation of the data, author Yongxin Zhang and author Lei Zhang to preparation of the figures and tables. Author Hongyu Ma, author He Li, author Zifu Li and author Rui Zhao have participated to drafting the manuscript. Author Pengfei Yang, author Bo Hong and author Jianmin Liu provided critical review of the manuscript. All authors read and approved the final version of the manuscript.

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Tables

Table I. 10 Journals with most publications from China

Journals	JCR Category	Quartile in Category	IF	Number of publications
World Neurosurgery	Clinical Neurology	Q4	1.732	229
	Surgery	Q3		
Interventional Neuroradiology	Clinical Neurology	Q4	1.45	133
	Radiology, Nuclear Medicine & Medical Imaging	Q4		
Stroke	Clinical Neurology	Q1	6.046	123
	Peripheral Vascular Disease	Q1		
Chinese Medical Journal	Medicine, General & Internal	Q3	1.555	119
Plos One	Multidisciplinary Sciences	Q2	2.776	114
AJNR	Clinical Neurology	Q2	3.256	114
	Neuroimaging	Q2		
	Radiology, Nuclear Medicine & Medical Imaging	Q2		
J Stroke Cerebrovasc	Neurosciences	Q4	1.646	99
	Peripheral Vascular Disease	Q4		
IJCEM	Medicine, Research & Experimental	Q4	0.181	99
Medicine	Medicine, General & Internal	Q2	1.87	96
Brain Research	Neurosciences	Q2	2.929	95

AJNR: American Journal of Neuroradiology; IJCEM: International Journal of Clinical and Experimental Medicine

Table II. 10 articles most co-cited by the retrieved articles from China

Rank	Co-cited times	year	Journal	Country	Title
1	154	2015	NEJM	Canada	Randomized assessment of rapid endovascular treatment of ischemic stroke.
2	146	2015	NEJM	Netherland	A randomized trial of intraarterial treatment for acute ischemic stroke.
3	142	2015	NEJM	Australia	Endovascular therapy for ischemic stroke with perfusion-imaging selection.
4	133	2015	NEJM	US	Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke.
5	131	2015	NEJM	US	Thrombectomy within 8 hours after symptom onset in ischemic stroke.
6	81	2011	NEJM	US	Stenting versus aggressive medical therapy for intracranial arterial stenosis.
7	67	2015	Stroke	US	2015 American Heart Association/American Stroke Association Focused Update of the 2013 Guidelines for the Early Management of Patients with Acute Ischemic Stroke Regarding Endovascular Treatment
8	58	2013	Stroke	US	Recommendations on angiographic revascularization grading standards for acute ischemic stroke: a consensus statement.
9	58	2016	Lancet	Canada	Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials.
10	49	2014	STROKE	China	Prevalence and outcomes of symptomatic intracranial large artery stenoses and occlusions in China: the Chinese Intracranial Atherosclerosis (CICAS) Study.

NEJM: The new England journal of medicine

Table III. Top 20 Keywords with the Strongest Citation Bursts

Keywords	First occurred	Strength	Burst Begin	End
carotid artery	1991	17.5523	1996	2011
restenosis	1991	15.7391	2001	2012
nitric oxide	1991	13.4386	2001	2011
mr angiography	1991	11.8505	1997	2009
arteriovenous malformation	1991	11.802	2000	2012
malformation	1991	10.2963	1998	2009
guglielmi detachable coil	1991	9.9596	2001	2010
ultrasonography	1991	9.6952	1996	2009
dural arteriovenous fistula	1991	8.8745	2004	2011
gene expression	1991	6.2523	2004	2009
embolization	1991	6.1641	1998	2001
smooth muscle cell	1991	5.9877	2000	2009
thrombosis	1991	5.7673	1998	2008
angiography	1991	5.3289	1993	1999
transcranial doppler	1991	5.021	2003	2009
ct	1991	4.9913	2003	2007
cerebral infarction	1991	4.7254	2003	2008
artery stenosis	1991	4.6447	1996	2003
diagnosis	1991	4.2921	2003	2007
ischemic preconditioning	1991	3.4546	2003	2006

Figures

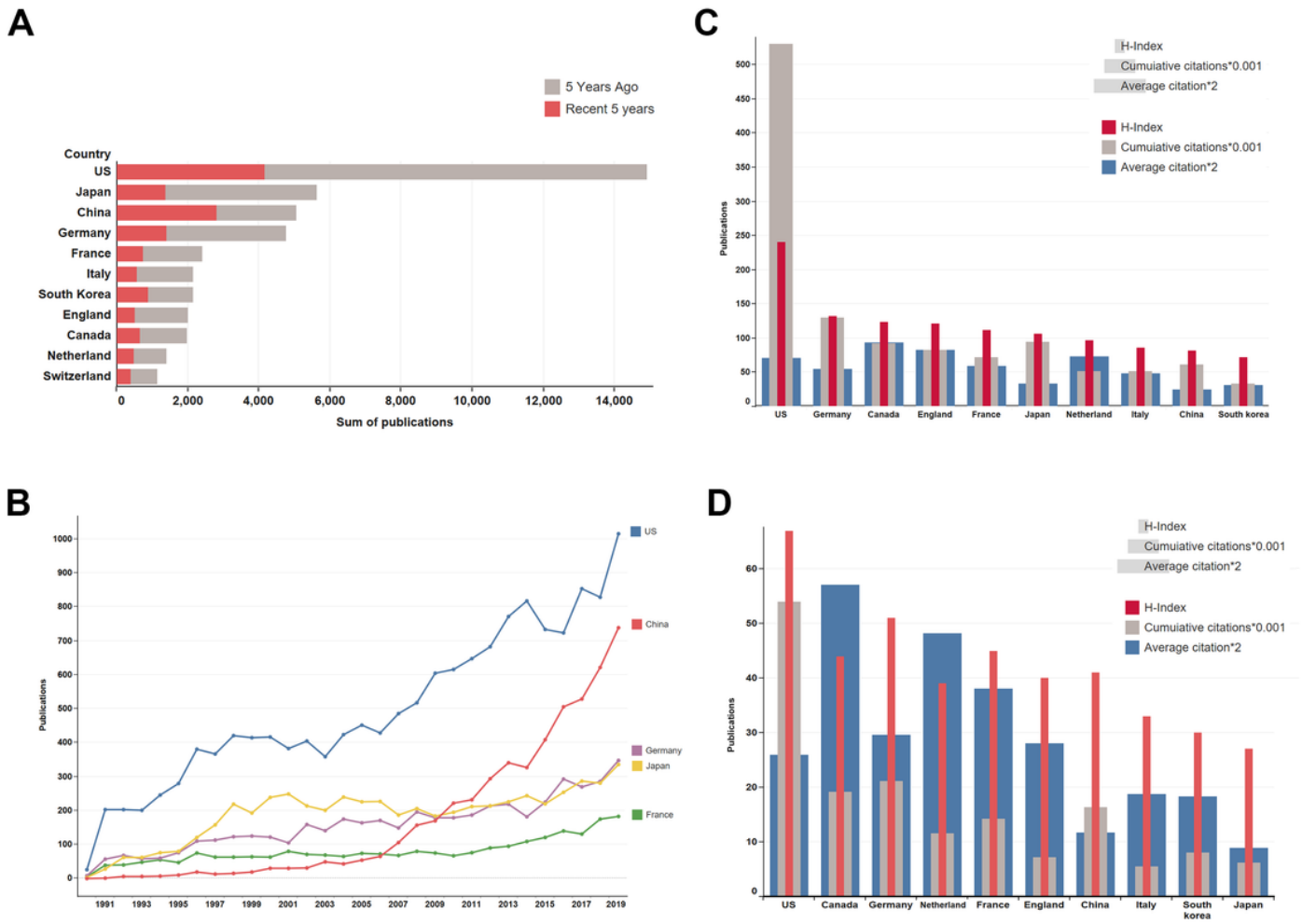

Figure 1

Publications in cerebrovascular intervention A. The top 10 countries that publish most articles regarding cerebrovascular intervention. The red part represents the number of articles that were published in the last 5years. China ranks third and more than half of the articles were published in the last 5 years. B. The trend in the number of publications of the five most published countries. Publications from China increase fastest in recent years and reach second place. C. The quality of publications over the three decades in the 10 most published countries. The quality of the publications is evaluated by h-index, accumulated citations, and average citations. D. The quality of publications in the past 5years in the most published 10 countries.

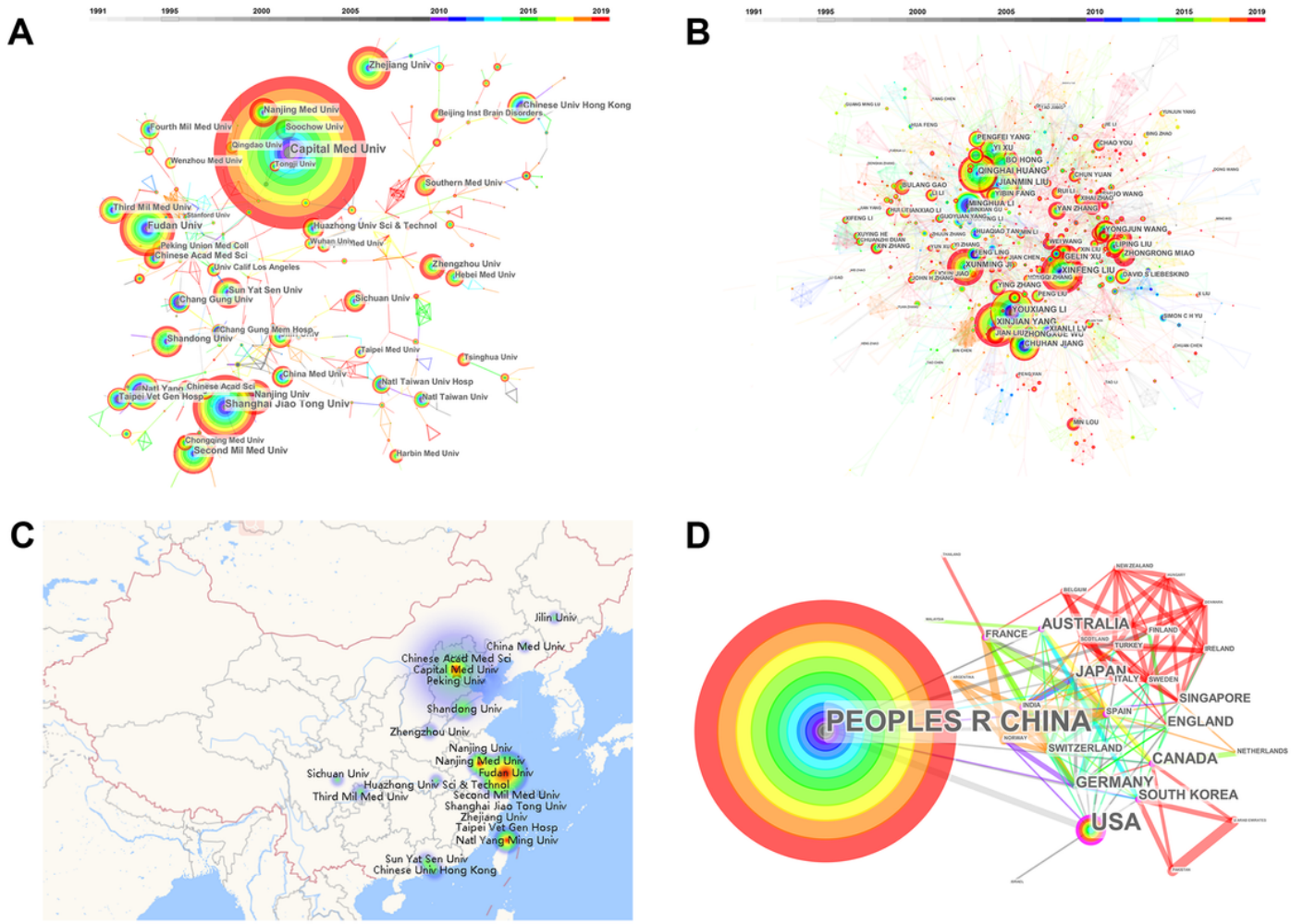

Figure 2

Cooperation network of the publications from China A. Institutions co-occurred network. The size of nodes represents the counts that institutions occurred in articles retrieved. The thickness of the lines represents the co-occurred counts of the connected two institutions. Time is reflected in different colors. B. Authors co-occurred network. The size of nodes represents the counts that authors occurred in articles retrieved. The thickness of the lines represents the co-occurred counts of the connected two authors. Time is reflected in different colors. C. The geological distribution of the ten most published institutions in China. Most of the institutions are located in east coast regions. D. Countries co-occurred network. The size of nodes represents the counts that countries occurred in articles retrieved. The thickness of the lines represents the co-occurred counts of the connected two countries. Time is reflected in different colors. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

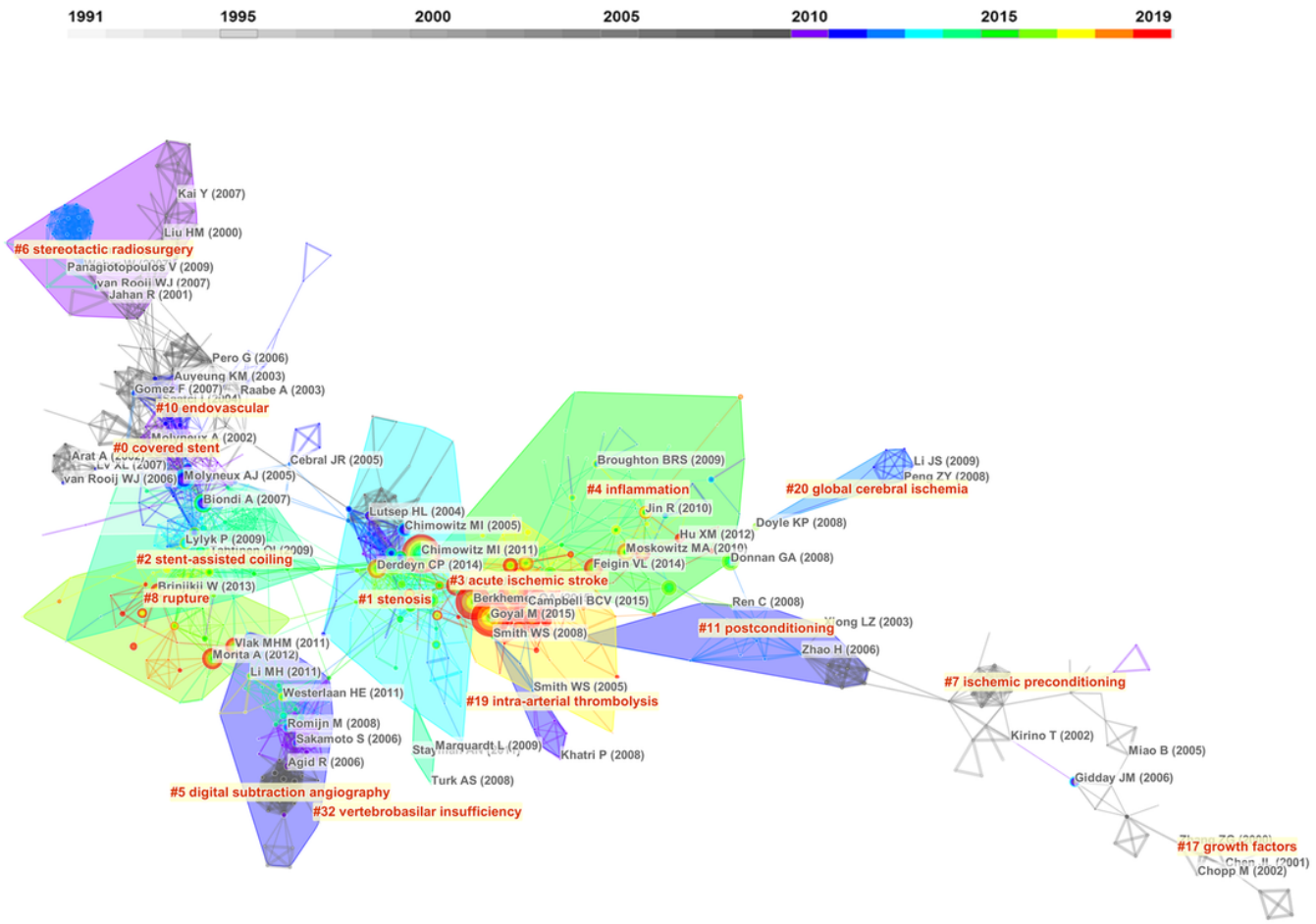

Figure 3

The network of the articles co-cited by retrieved articles from China. The size of the nodes represents the co-cited times of one article. The articles that are co-cited at the same time are connected with lines. The thickness of the lines reflects the co-cited counts. All the articles belong to one cluster are covered by regions with different colors. Time is reflected in different colors.

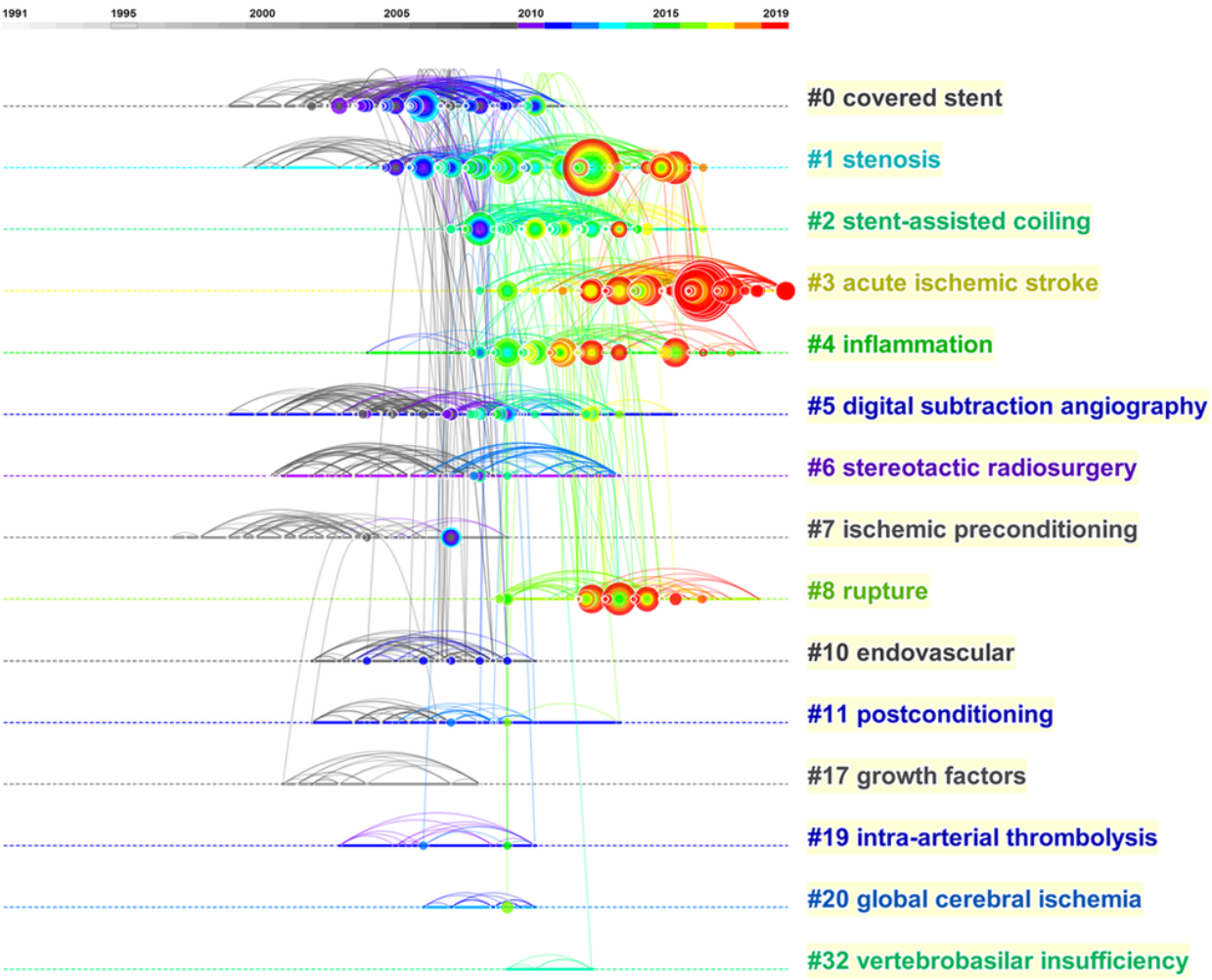

Figure 4

A timeline view of co-cited analysis. Papers with high cited counts are reflected by the nodes in the timeline axle of their clusters. Articles regarding acute ischemic stroke are most co-cite by Chinese researchers in recent years.

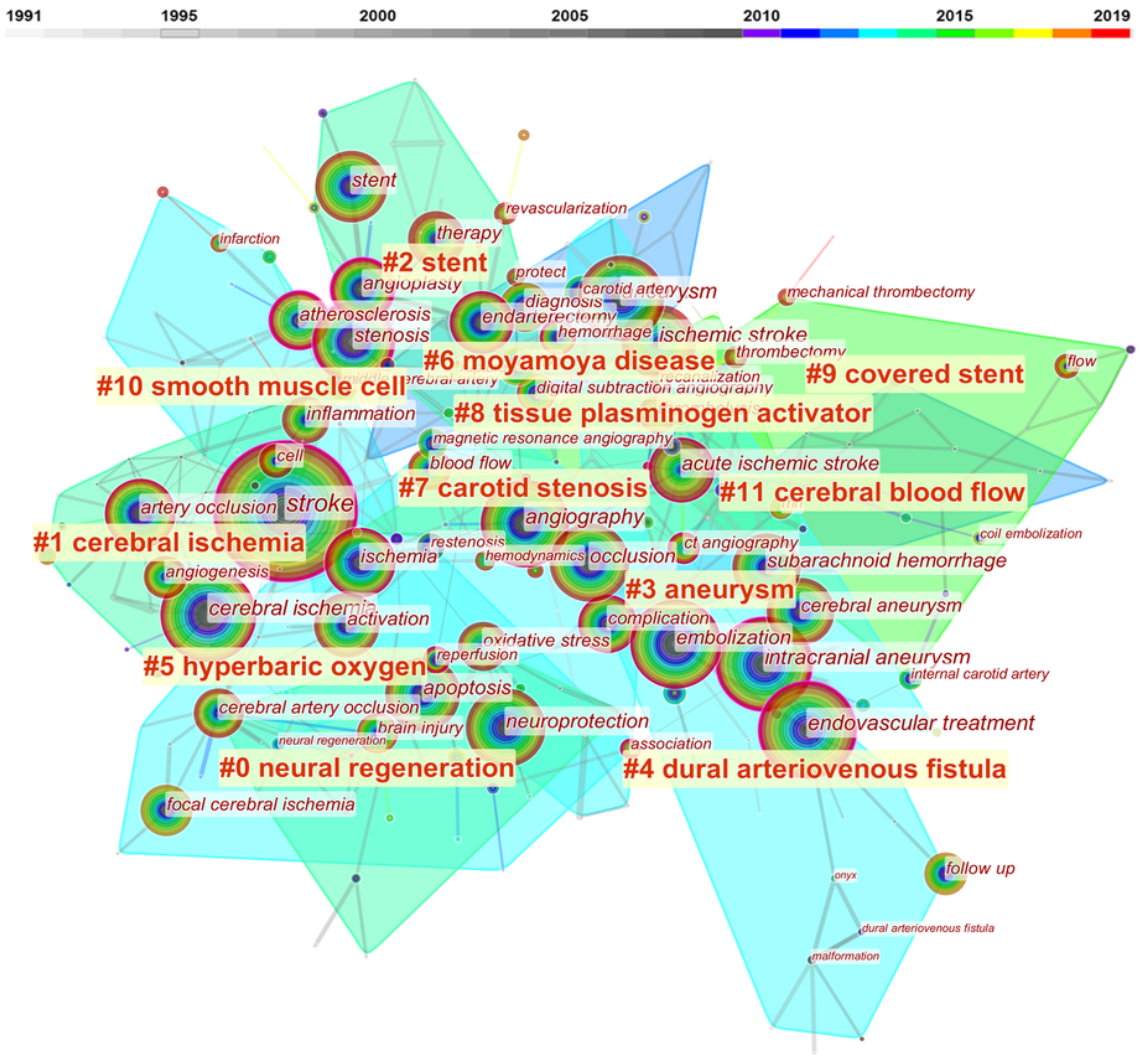

Figure 5

Co-occurrence network of keywords. The size of the nodes represents the co-occurred counts of keywords. The keywords that are co-cited at the same time are connected with lines. All the keywords that belong to one cluster are covered by regions with different colors. Time is reflected in different colors.

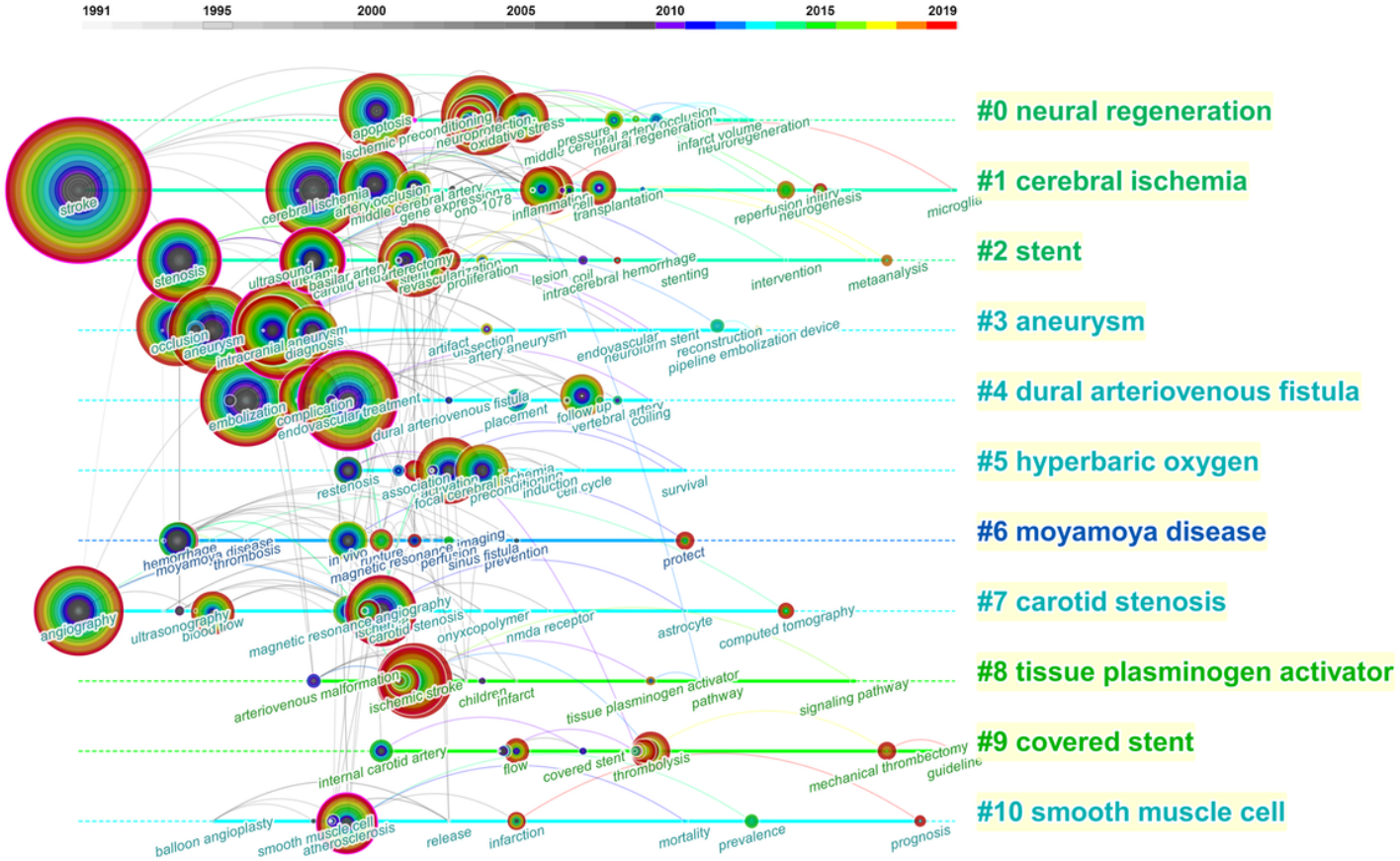

Figure 6

Timeline view of keywords analysis Hot spots of one cluster were reflected by the nodes in the timeline. Clusters with more large nodes reflected the hot field of cerebrovascular intervention.