



Research article

Bibliometric analysis of traditional Chinese medicine research on heart failure in the 21st century based on the WOS database

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ARTICLE INFO

Keywords:

Traditional Chinese medicine (TCM)
Heart failure (HF)
Bibliometrics
Knowledge mapping
Visual analysis
Systematic review

ABSTRACT

Introduction: Heart Failure (HF) is a key area of research in human medicine, and traditional Chinese medicine (TCM) is an important branch of this field. This study aimed to use bibliometric methods to sort out the trajectory of TCM research on HF in this century (2000–2022) from a high dimension and to analyze its characteristics, hotspots and frontiers.

Methods: In this study, the search formula “TS=(“traditional Chinese medicine”) OR (“Chinese medicine”) AND TS=(“heart failure”)” was used to find relevant studies included in the Web of Science Core Collection from 2000 to 2022. Targeted literature records were analyzed and mapped using CiteSpace and VOSviewer.

Results: The authors and collaborators of this study were still in the formation process, but several well-known scholars were included: YONG WANG, WEI WANG, etc. The main research institutions in this research area were Beijing Univ Chinese Med, China Acad Chinese Med Sc, etc. The main country of study was China. Current research hotspots and frontiers were Qili Qiangxin capsules, extracts (Tanshinone IIA, Panax ginseng, etc.), cardiac hypertrophy, ventricular remodeling, oxidative stress, signaling pathways, network pharmacology, etc. Influential journals that publish papers in this field were the Journal of Ethnopharmacology, Scientific Reports, Biomedicine & Pharmacotherapy, etc. The top 3 co-cited journals were Circulation, J ethnopharmacol, and J am coll cardiol.

Conclusions: We analyzed valuable details in TCM research on HF in the 21st century, which may help researchers identify potential collaborators and partner institutions, hotspots, and frontiers in the field.

1. Introduction

Heart failure (HF) is an acute and chronic progressive clinical syndrome caused by structural or functional cardiac abnormalities [1, 2,3,4]. The main clinical manifestations are signs and symptoms associated with systemic congestion and organ malperfusion, such as

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<https://doi.org/10.1016/j.heliyon.2022.e12770>

Received 20 June 2022; Received in revised form 28 November 2022; Accepted 29 December 2022

Available online 4 January 2023

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dyspnea, wet rales in the lungs, swollen limbs, and jugular venous dilatation. HF, one of the leading hospital admission diagnoses worldwide, affects tens of millions of people and has become a serious public health problem. According to foreign data, the incidence among people older than 65 years of age is close to 21 cases per 1000 people [5]. In developed countries, HF affects 2% of the adult population, and hospitalizations related to HF have tripled since the 1990s [1], with readmission rates of 24% and 50% within 30 days and 6 months, respectively, for patients with HF [6,7,8,9]. The figures for China are equally bleak. A recent study showed that China, the world's most populous country, has a staggering 1.10% and 275/100,000 person-years of age-standardized HF prevalence and incidence, respectively [10].

In recent years, the concept of treatment for HF has been constantly updated, and new drugs and devices for the treatment of HF have been used for clinical first-line applications, which shows that HF has been the focus of cardiovascular system research in recent years. Traditional Chinese medicine (TCM) has a long history in China and is still a very important part of the current Chinese medical system [11]. Practice has proven that TCM is a safe and effective treatment for HF [12]. It has become common to choose TCM as a complementary or alternative or even primary method to treat HF in China. Since the beginning of the new century, the practical application of TCM for HF has gained increasing attention, and a large number of relevant publications have been accumulated. Each year, the Web of Science (WOS) database accumulates an increasing number of high-quality, relevant works in TCM research on HF. Nevertheless, some questions are difficult to answer.

- 1) What are the publication trends of the related literature in this field?
- 2) Which authors, research institutions, and countries have had a substantial impact, and have any substantial collaborations formed?
- 3) Which journals publish the most articles? Which journals are most cited? Which articles have received more attention?
- 4) What are the research trajectories, current hotspots, and frontiers in this field? What are the future research trends?

It is impossible to answer these questions without bibliometrics. Bibliometrics is essentially a discipline that studies publications. Through quantitative statistical analysis of published studies in terms of authors, research institutions, countries, journals, keywords, etc., bibliometrics describes and summarizes the current historical development trajectory and research status of a topic or discipline in general and further reveals the hotspots of research and future development trends [13,14]. Quantitative analysis of the relatively scattered and large amount of literature in this field to condense research hotspots and trends is a pertinent need for relevant researchers. CiteSpace and VOSviewer are two citation visualization and analysis software programs developed based on scientometrics and data visualization that can model knowledge structures and map scientific knowledge based on comprehensive networks derived from publications and are widely used in bibliometrics [15,16,17,18].

To answer the above questions, this study aimed to use bibliometric methods to sort out the trajectory of TCM research on HF in this century (2000–2022) from a higher dimension and analyze its characteristics, hotspots and frontiers, to gain a comprehensive and extensive understanding of the field and provide relevant information for subsequent clinical practice and research among relevant researchers.

2. Methods

2.1. Data sources

The data sources and search strategy for this study were based on the WOS Core Collection. China is the birthplace of TCM and the main country for its research. The Chinese literature in this research area is mainly concentrated in the China National Knowledge Infrastructure (CNKI), but the CNKI mainly includes Chinese domestic journals and fails to include international journals or studies with greater influence, which cannot fully reflect the international trends in the research area; therefore, the CNKI was not an ideal choice for this study. WOS, as a world-renowned citation database, includes many influential and high-quality journals from all over the world, including China, is consistently updated and supplemented, and is authoritative in the field of medical research and highly recognized worldwide. The WOS Core Collection has up to 29 citation records for a single document, which is exhaustive and covers almost all the content needed for econometric analysis. In addition, the citation data format of the database is compatible with CiteSpace and VOSviewer, so that no important data are missed, and the analysis results are reliable. Therefore, the WOS Core Collection is often an important data source for bibliometric studies and scientific paper evaluations. In previous bibliometric studies, there have been many successful cases of bibliometric analysis using the WOS Core Collection as a data source [19,20,21,22].

2.2. Search strategy

WOS provides several search methods, of which topic searches are the most popular. This method of searching focuses primarily on the title, abstract, authors, keywords, and keywords plus. Thus, the topic search in WOS provides quick access to all corresponding documents in a certain field or subject area. Therefore, a topic search strategy was used in this study. Considering that the purpose of this study was to analyze the hotspots and other relevant aspects of the study of HF in Chinese medicine in this century, the topic is limited to "traditional Chinese medicine" or "Chinese medicine" and the dates of publication were customized from 2000 to 01-01 to 2022-05-20. An advanced search was conducted on the WOS official website. We chose the WOS Core Collection for "Search in" and the Social Sciences Citation Index (SSCI) and Science Citation Index Expanded (SCI-E) for "Editions". The search formula was "TS=(("traditional Chinese medicine") OR ("Chinese medicine")) AND TS=("heart failure)". A total of 441 records were obtained. To ensure the relevance of the retrieved results to this study, we further manually screened the retrieved studies. As a result, we excluded 4

articles that were not relevant to this study and ultimately obtained 437 accurate records. There were eight document types, including articles (348), review articles (78), editorial materials (5), letters (1), meeting abstracts (5), proceedings papers (1), book chapters (1), and early access articles (1). The proportion of articles and review articles ranked first and second, accounting for 79.63% and 17.85%, respectively. "Full record and cited references" were selected for the exported records and saved as plain text files. All data were downloaded on 2022-05-20.

2.3. Data processing

CiteSpace 5.8. R3 and VOSviewer 1.6.18 were used for the raw dataset analysis in this study. Considering the duplication of analysis objects such as authors, institutions and keywords, to prevent interference with the analysis results, the text data downloaded from WOS were sorted out, including conversion, deduplication, merging, cleaning and re-output. When data analysis was performed in CiteSpace, the time slice was selected as every 2 years, and the data were imported step by step. Different analysis methods were selected according to the analysis content. The main analysis included authors, institutions, countries, keywords, journals, references, etc., of the published literature. Appropriate adjustments were made to the content of the plots drawn by both software programs to improve data visualization. The whole data analysis process is shown in Fig. 1

2.4. Analysis methods

In CiteSpace mapping, each node represents an element being analyzed. The size of nodes and fonts is positively correlated with frequency. A colored ring represents the color of the nodes, and the color indicates the time when the analyzed element first appeared (Fig. 2); the warmer the color, the more recent the time. The red circle represents high emergence, and the wider the color of the rings, the higher the frequency. The intermediary centrality of an element is the number of times an element acts as a bridge for the shortest path between two other elements. The higher the intermediary centrality of an element is, the higher its importance. It can be regarded

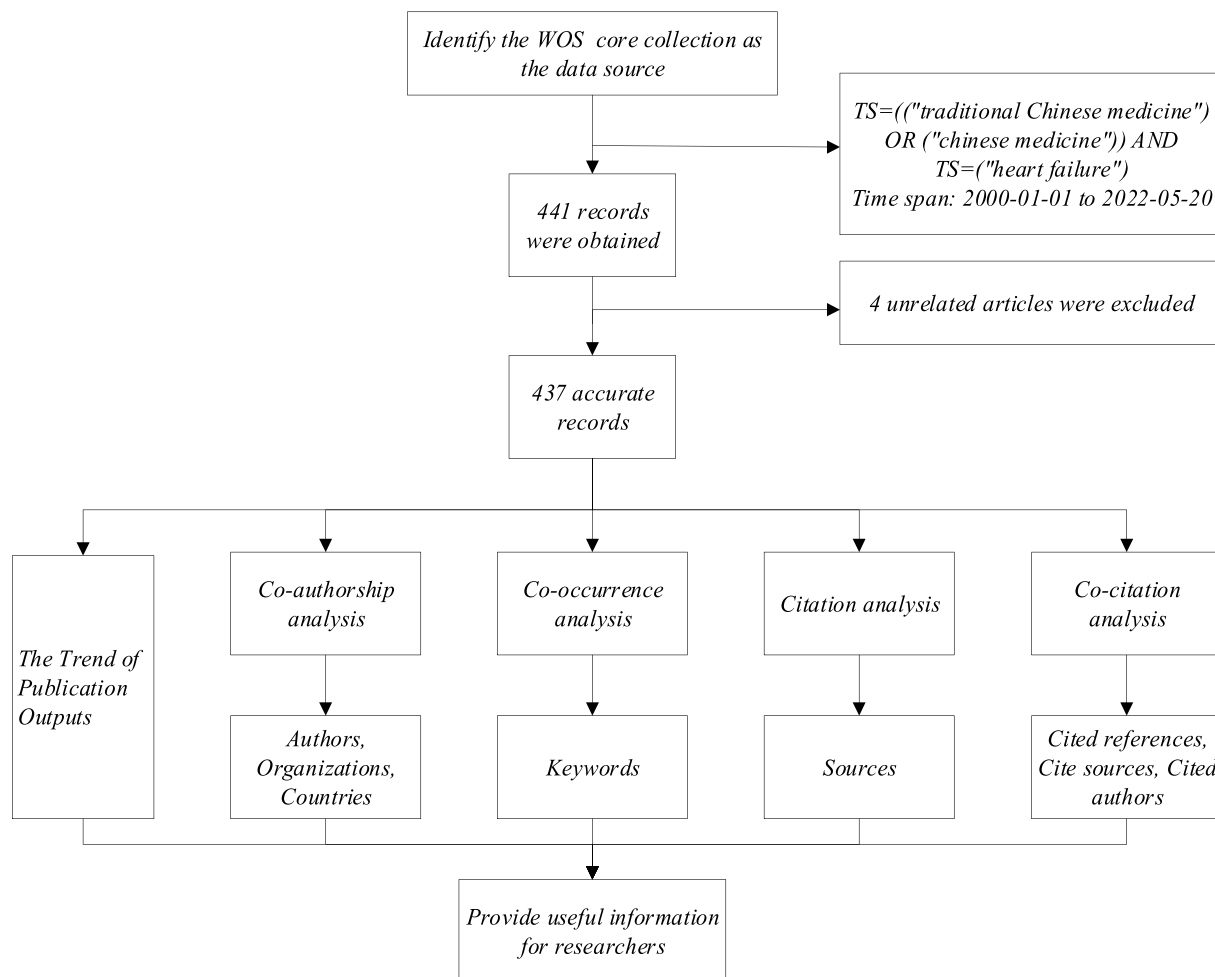


Fig. 1. The overview and flowchart of the study design.

as a pivotal node highly connected to other nodes, which is indicated by the purple outer circle on the mapping. The lines between nodes indicate the co-occurrence of two elements, and the color represents the time when the connection first occurred; the thicker the link line is, the more frequent the connection is. When performing cluster analysis, the Q-value and S-value were combined to determine the credibility of the cluster structure. In this study, the cluster structure was considered significant when the Q-value was greater than 0.3 and the S-value was greater than 0.5. The larger the nodes and labels in the clustering mapping drawn by VOSviewer, the more significant the hints of importance. The node's color represents the cluster to which it belongs, and different colors represent different clusters. The meaning of the line is the same as in CiteSpace. Since this study did not involve a comparative analysis, hypothesis testing and setting p values were unnecessary.

3. Results

3.1. Trend of publication outputs

The number of publications and citations can reflect the trend of research in a field (Fig. 3, Table 1). Between 2000 and 2022, the WOS Core Collection included 437 publications in TCM research on HF, with 4570 cited articles, 5832 citations, 13.48 per item on average, and an H-index of 37. Over the past 20 years, annual publications on TCM HF research have been characterized by a phased change. Between 2000 and 2010, there were fewer relevant publications, the upward yearly trend was not obvious, and TCM HF research was in the nascent research stage. The number of publications and citations grew evidently after 2010, with 77 publications in 2021 alone, representing 17.62% of the total literature, more than all publications from 2000 to 2010. More publications are expected to be published in 2022. This shows that in the last decade or so, an increasing number of scholars have started to pay attention to the potential of TCM for HF.

3.2. Authors

The author analysis showed that 2547 authors contributed to publications in the field of TCM research on HF. Among them, 36 authors have published more than 5 publications. The five most published authors were YONG WANG (20), WEI WANG (17), CHUN LI (17), JINGYUAN MAO (10), and HONGCAI SHANG (9). The top 5 authors by centrality were WEI WANG (0.06), JIAN ZHANG (0.06), JINGYUAN MAO (0.04), YONG WANG (0.03), and HONGCAI SHANG (0.03) (Table 2). The author map not only shows important researchers and coauthors in the field and the connections between them but also provides information on significant influential research groups and potential collaborators, which can help further build collaborations between research teams in the future. Most of the authors were in a complex mapping of longitudinal and cross-cutting co-occurrence networks, suggesting close relationships among scholars in the field. Future collaborations between these authors will generate more research on TCM studies of HF. On the map, the three authors WEI WANG, JIAN ZHANG and JINGYUAN MAO are relatively high in centrality, and their articles have a certain bridge role in the field and are more likely to promote the development of the discipline. However, the lack of nodes with significant purple outer circles on the map (usually, centrality needs to be greater than 0.1) suggests that scholars with significant vitality and influence in this field have not yet been formed. Cluster analysis revealed the 3 most prominent and still active academic communities (Fig. 4).

Community 1: The main members included BOLI ZHANG, LEI WANG, XIANLIANG WANG, JINGYUAN MAO, JIAN ZHANG, etc. The studies mainly included Qishen yiqi, randomized double-blinded multicenter studies, and Shenfu injection [23,24,25].

Community 2: The main members included CHUN LI, YONG WANG, WEI WANG, YONG JIANG, etc. The studies mainly included acute myocardial infarction (AMI)-induced HF rates, the AKT-p53 signaling pathway, myocardial apoptosis, and cyclooxygenase [26, 27,28].

Community 3: The core member was HONGCAI SHANG, and other team members included JING CHEN, JIAYUAN HU, XINLI LI, etc. The studies mainly included Citri reticulatae pericarpium, postmyocardial infarction HF, peroxisome proliferator-activated receptor (PPAR) gamma, integrating evidence, and TCM collateral disease theory [29,30,31].

When another publication simultaneously cites two (or more) authors, the two or more authors are said to constitute a co-citation relationship. The higher the co-citation frequency is, the closer the academic relationship. A total of 13454 authors were involved in this study, 37 of whom were cited more than 20 times. The top 5 authors by the number of citations were WANG Y, LI XL, ZHANG Y, YANCY CW and WANG J (Table 3).

3.3. Institutions and countries

In contrast to the micro cooperation between authors, the cooperation between institutions and countries is regarded as medium- and macrolevel cooperation. A total of 456 organizations have conducted in-depth research in this area. Most of the influential

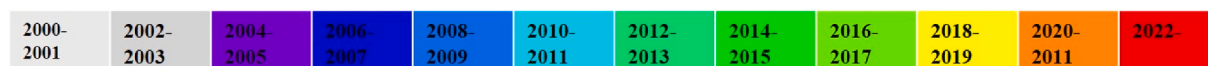


Fig. 2. Different colors represent different years in the mapping by CiteSpace. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

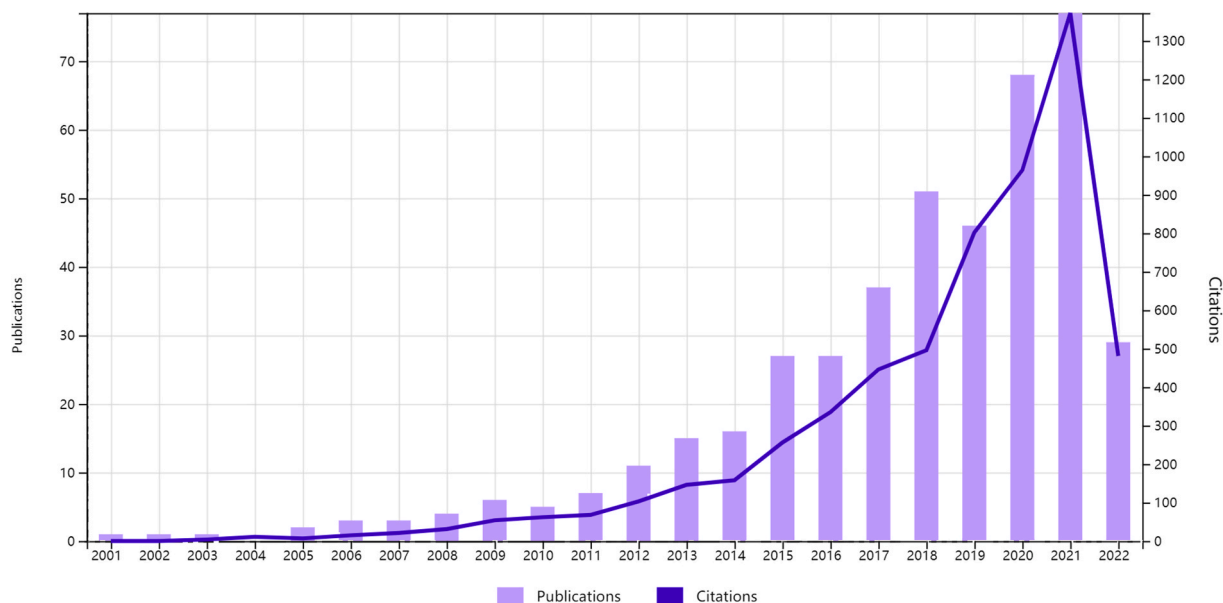


Fig. 3. Citations and publications over time.

Table 1
Annual publications and citations.

Years	Records (n,%)	
	Publications	Citations
2022 (01-01 to 05-20)	29 (6.34%)	481 (8.25%)
2020	68 (15.56%)	964 (16.53%)
2019	46 (10.53%)	802 (13.75%)
2018	51 (11.67%)	496 (8.50%)
2017	37 (8.47%)	446 (7.65%)
2016	27 (6.18%)	335 (5.74%)
2015	27 (6.18%)	256 (4.39%)
2014	16 (3.66%)	158 (2.71%)
2013	15 (3.43%)	146 (2.50%)
2012	11 (2.52%)	103 (1.77%)
2011	7 (1.60%)	68 (1.17%)
2010	5 (1.14%)	62 (1.06%)
2009	6 (1.37%)	54 (0.93%)
2008	4 (0.92%)	31 (0.53%)
2007	3 (0.69%)	21 (0.36%)
2006	3 (0.69%)	15 (0.26%)
2005	2 (0.46%)	7 (0.12%)
2004	0 (0.00%)	11 (0.19%)
2003	1 (0.23%)	4 (0.07%)
2002	1 (0.23%)	0 (0.00%)
2001	1 (0.23%)	0 (0.00%)
2000	0 (0.00)	0 (0.00)

research institutions come from Chinese universities. The top five institutions by the number of publications were Beijing Univ Chinese Med (80), China Acad Chinese Med Sci (55), Tianjin Univ Tradit Chinese Med (41), Peking Univ (20), and Guangzhou Univ Tradit Chinese Med (20). The top 5 institutions by centrality were Beijing Univ Chinese Med (0.36), China Med Univ (0.30), China Acad Chinese Med Sci (0.25), Tianjin Univ Tradit Chinese Med (0.21), and Peking Univ (0.20) (Table 4). Beijing Univ Chinese Med had the largest node with bright colors and a prominent purple outer ring and was intricately connected to other institutions, suggesting that this institution has a continuous strong research capacity, a significant position and a large academic influence in this research field. Direct observation and cluster analysis showed that Beijing Univ Chinese Med, China Acad Chinese Med Sci and Tianjin Univ Tradit Chinese Med are the most dynamic institutional groups in this field (Fig. 5). They have similar research directions, close cooperation, and many publications in recent years. These closely collaborating institutions have significant contributions and influence in TCM research on HF and are likely to produce even more important academic results in the future. In addition, China Med Univ and Guangzhou Univ Chinese Med have also conducted in-depth research in recent years and have become local core research institutes.

Table 2
Ranking of the top 10 authors by publications and centrality.

Rank	Authors	Rceords	Centrality	Rank	Authors	Centrality	Rceords
1	YONG WANG	20	0.03	1	WEI WANG	0.06	17
2	WEI WANG	17	0.06	2	JIAN ZHANG	0.06	5
3	CHUN LI	17	0.01	3	JINGYUAN MAO	0.04	10
4	JINGYUAN MAO	10	0.04	4	YONG WANG	0.03	20
5	HONGCAI SHANG	9	0.03	5	HONGCAI SHANG	0.03	9
6	GUANWEI FAN	9	0.01	6	JING CHEN	0.03	4
7	XIANLIANG WANG	8	0.01	7	BOLI ZHANG	0.02	6
8	YI ZHANG	7	0.01	8	LEI WANG	0.02	5
9	ZHIQIANG ZHAO	7	0.01	9	CHUN LI	0.01	17
10	QIYAN WANG	7	0.00	10	GUANWEI FAN	0.01	9

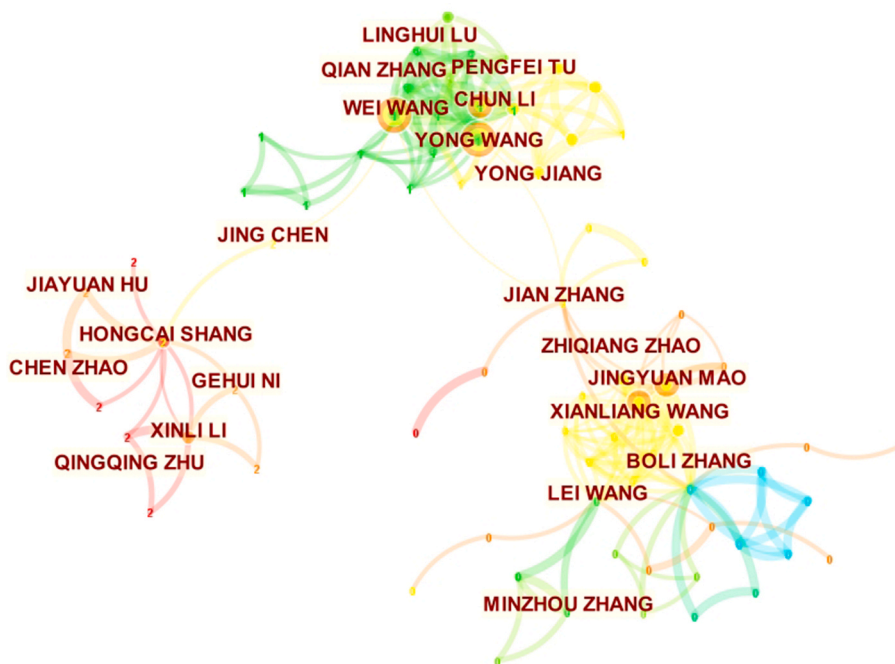


Fig. 4. Author co-occurrence cluster map by CiteSpace. Each node represents one author. Lines indicate co-occurrence relationships. The color corresponds to the time. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 3
The top 10 authors by number of citations.

Rank	Authors	Citations
1	WANG Y	105
2	ZHANG Y	74
3	LI XL	70
4	WANG J	58
5	HAO PP	48
6	YANCY CW	46
7	LI C	42
8	PONIKOWSKI P	42
9	ZAHNG L	41
10	LI L	36

The analysis of the distribution of countries can contribute to the promotion of global cooperation in this field. In total, 22 countries and regions have carried out studies in TCM research on HF. Most of the publications come from China, the birthplace of TCM. The top 3 countries (or regions) by the number of publications were PEOPLESRCHINA (383), USA (31), and TAIWAN (21). A total of 7 countries had centrality data, and the top 3 countries were PEOPLES R CHINA (0.81), USA (0.22), and ENGLAND (0.09) (Table 5). The number of publications from China exceeded the total number of publications from other countries. With a high centrality of 0.81,

Table 4
Top 10 institutions by publications and centrality.

Rank	Institutions	Records	Centrality	Rank	Institutions	Centrality	Records
1	Beijing Univ Chinese Med	80	0.36	1	Beijing Univ Chinese Med	0.36	80
2	China Acad Chinese Med Sci	55	0.25	2	China Med Univ	0.30	18
3	Tianjin Univ Tradit Chinese Med	41	0.21	3	China Acad Chinese Med Sci	0.25	55
4	Peking Univ	20	0.20	4	Tianjin Univ Tradit Chinese Med	0.21	41
5	Guangzhou Univ Chinese Med	20	0.14	5	Peking Univ	0.20	20
6	Shanghai Univ Tradit Chinese Med	19	0.07	6	Guangzhou Univ Chinese Med	0.14	20
7	China Med Univ	18	0.30	7	China Acad Sci	0.12	9
8	Capital Med Univ	17	0.03	8	Liaoning Univ Tradit Chinese Med	0.09	2
9	Chinese Acad Med Sci	16	0.07	9	China Pharmaceut Univ	0.08	15
10	China Pharmaceut Univ	15	0.08	10	Anhui Univ Chinese Med	0.08	5

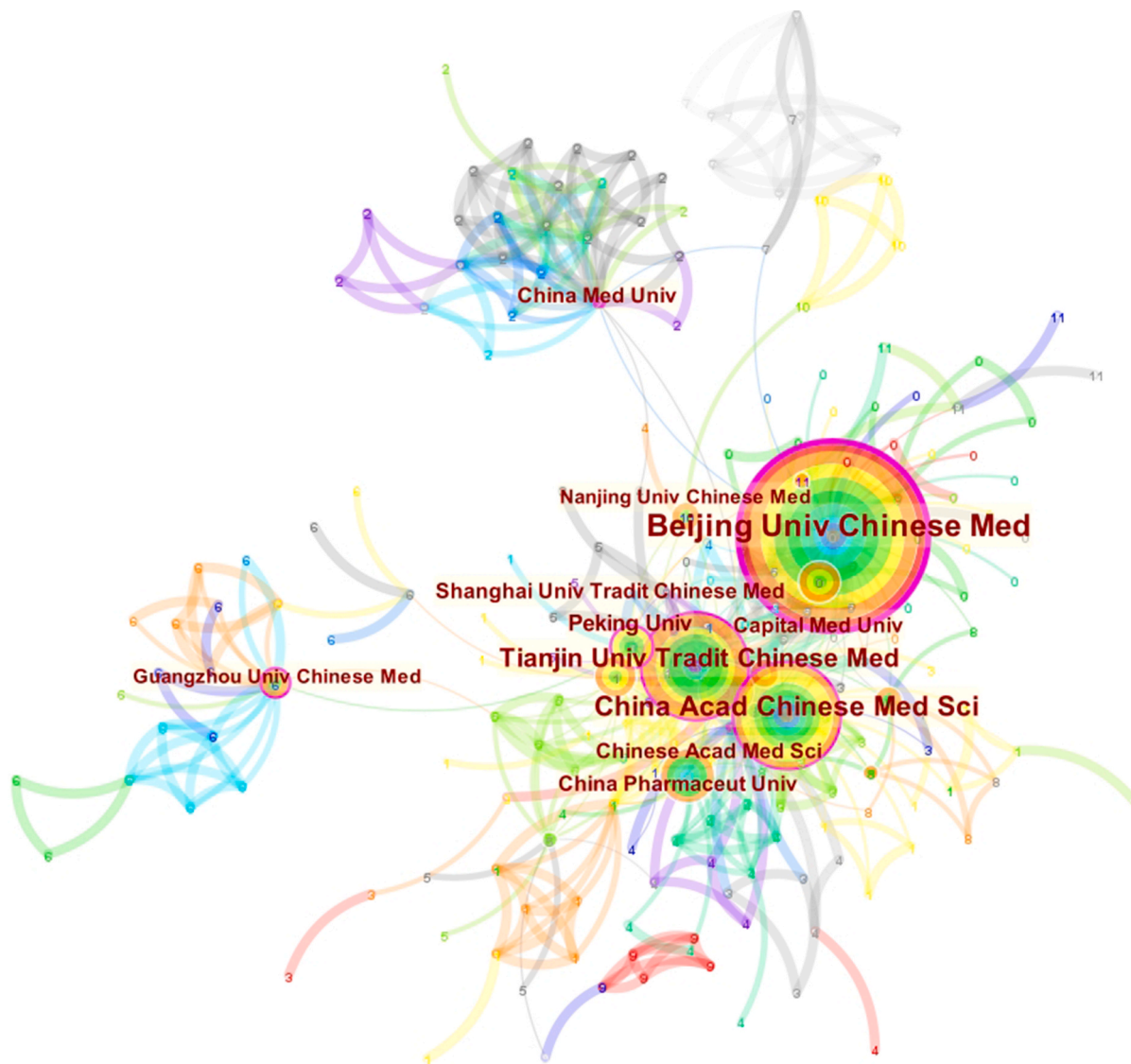


Fig. 5. Institutional co-occurrence clusters mapped by CiteSpace. Nodes indicate institutions, connecting lines indicate partnerships, and colors indicate time. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

China has a significant purple outer circle in the map, reflecting its dominant position in this research area (Fig. 6). The USA has the next highest centrality at 0.22, and there is also a clear purple outer circle on the map, indicating that the USA also plays a role as a link in the cooperative network between countries. JAPAN, CANADA, ITALY, and BRAZIL have published relevant publications but have not achieved centrality, indicating that the research results from these countries have not been taken seriously. Countries such as the UK, Germany, Australia, and India have centrality data, suggesting that these countries have gained some attention in this research area. In particular, although only 2 articles were published, Germany's centrality was higher than that of the Taiwan region, which published 21 papers, suggesting that Germany has more in-depth research in this field and is valued.

3.4. Keyword analysis

Keywords are an important part of the essay, which reflect the core idea of the essay and, to some extent, reflect the essay's disciplinary structure. Analyzing the frequency, co-occurrence and centrality of keywords can reflect the research hotspots in the field and predict the shift of the research frontier. The keyword analysis showed that the five most frequently used keywords were HF (247), TCM (140), oxidative stress (56), disease ([49]), and myocardial infarction ([46]). The keywords with the highest centrality were TCM (0.21), HF (0.16), activation (0.15), oxidative stress (0.13), and expression (0.13) (Table 6). These keywords identified research hotspots. CiteSpace generated 11 keyword clusters by cluster analysis with $Q = 0.468$ and $S = 0.7607$, showing good homogeneity of cluster analysis (Fig. 7). The clustering labels were all extracted from the keywords and did not represent the main meaning of the clusters. The clustering number started from 0. The lower the clustering number is, the higher the frequency of the keywords included, suggesting that the cluster is more important and has more research value. The first 5 types of cluster information are as follows.

Cluster #0 was mainly related to systems biology and adriamycin [32,33].

Cluster #1 was mainly associated with cardiovascular disease, induced cardiac hypertrophy, and cardiomyocytes [34,35].

Cluster #2 was mainly associated with randomized controlled trials, mortality, and network meta-analyses [36,37].

Cluster #3 was mainly associated with dysfunction, inhibition, and activation [38,39].

Cluster #4 was mainly associated with ventricular remodeling, molecular docking, ischemia–reperfusion, and network pharmacology [40,41,42,43].

The time zone map of keyword co-occurrence is designed based on the interaction effect between keywords in this domain in space and time, which helps to understand and discover the trajectory and stage characteristics of keyword development and transformation. Fig. 8 shows the time zone map of TCM research on HF based on CiteSpace software, which visually reflects the stage hotspots and development paths in the field from the time dimension. The position of the keywords corresponds to the time of the first occurrence, and the frequency is superimposed later on. From 2000 to 2005, the main research direction in this field was the study of the efficacy of TCM drugs and the modern mechanism of TCM revealed by animal experiments. Between 2005 and 2015, there was a significant change in this research area with a remarkable increase in research volume. Research during this period focused on oxidative stress, signaling pathways, apoptosis, activation, and fibrosis and was characterized by a diversity of disease types, such as myocardial infarction, cardiomyopathy, hypertension, and cardiac hypertrophy. In the last 5–7 years, scholars have started to explore herbal extracts (Salvia, Panax ginseng, etc.), acupuncture therapy, network pharmacology, molecular docking, and conducting multicenter double-blind trials in TCM to provide a high-quality evidence-based basis for the development of TCM.

"Burst words" refer to a sharp increase in the occurrence of keywords within a specific period and are indicators of changes in research frontiers or trends over time. The top 20 keywords with the strongest frequencies were obtained using CiteSpace's burst analysis function (Fig. 9). The following keywords were cited after 2016: tanshinone IIA (10 times), myocardial ischemia (8 times), risk (7 times), myocardial infarction (46 times), multicenter (12 times), failure (5 times), and cardiovascular disease (25 times). These are cutting-edge and hot topics in this research area. Therefore, researchers may want to consider these as directions for future research.

3.5. Journals and references

The 437 documents in this study were from 136 journals, 10 of which had 9 or more publications and 16 of which had 5 or more publications. Many of them were top journals, indicating that the research theme of TCM research on HF follows the frontiers of modern medical development and is internationally recognized. The top 3 journals in terms of the number of articles published were

Table 5
Ranking of country publications and centrality.

Rank	Countries	Centrality	Records	Rank	Countries	Records	Centrality
1	PEOPLES R CHINA	0.81	383	1	PEOPLES R CHINA	383	0.81
2	USA	0.22	31	2	USA	31	0.22
3	ENGLAND	0.09	6	3	TAIWAN (region)	21	0.03
4	GERMANY	0.04	2	4	ENGLAND	6	0.09
5	TAIWAN (region)	0.03	21	5	AUSTRALIA	5	0.02
6	AUSTRALIA	0.02	5	6	INDIA	4	0.01
7	INDIA	0.01	4	7	JAPAN	4	0.00
				8	NETHERLANDS	4	0.00
				9	ITALY	3	0.00
				10	SWEDEN	3	0.00

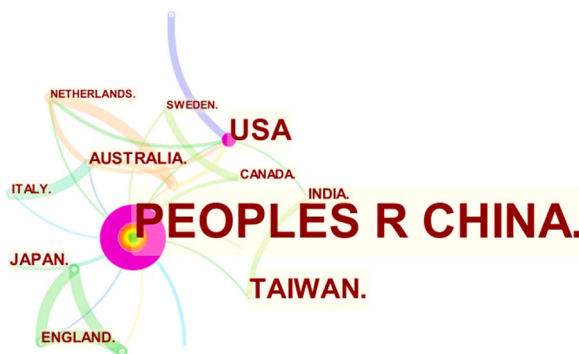


Fig. 6. Country co-occurrence network mapped by CiteSpace. PEOPLES R CHINA and the USA have a distinctive purple outer ring. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 6
Top 10 Keywords by frequency and centrality.

Rank	Keywords	Frequency	Centrality	Rank	Keywords	Centrality	Frequency
1	HF	247	0.16	1	TCM	0.21	140
2	TCM	140	0.21	2	HF	0.16	247
3	oxidative stress	56	0.13	3	activation	0.15	40
4	disease	49	0.11	4	expression	0.13	32
5	myocardial infarction	46	0.11	5	oxidative stress	0.13	56
6	rat	41	0.05	6	angiotensin ii	0.11	13
7	activation	40	0.15	7	disease	0.11	49
8	dysfunction	38	0.03	8	myocardial infarction	0.11	46
9	mechanism	37	0.05	9	nf kappa b	0.10	20
10	cardiac hypertrophy	35	0.08	10	cell	0.09	23

the Journal of Ethnopharmacology (40), Frontiers in Pharmacology (39), and Evidence-based Complementary and Alternative Medicine (36) (Table 7). After VOSviewer cluster analysis, 3 classes were formed, corresponding to the 3 colors in the figure (red, green, and blue) (Fig. 10).

Cluster 1 was represented by Journal of Ethnopharmacology. This is an interdisciplinary journal dedicated to indigenous medicines. It mainly publishes original articles on observational and experimental studies of the biological activity of plants and animals used in traditional medicine. Mechanisms of research action involving pharmacology and toxicology are particularly popular.

Cluster 2 was represented by Evidence-based Complementary and Alternative Medicine. As the journal’s name suggests, it aims to apply scientific rigor to the study of complementary and alternative medicine modalities. The journal is highly relevant to the content of TCM and is, therefore, an important choice for authors in this field to publish their articles.

Cluster 3 was represented by Journal of the American College of Cardiology. The journal is the top journal in the field of cardiovascular disease. A total of four articles in this research area have been published in this journal, representing a tremendous impact of research in this field. As a leader in the field, JACC publishes clinical and experimental reports on all aspects of cardiovascular disease. Topics include coronary and valvular disease, congenital heart defects, cardiomyopathies, new diagnostic techniques and therapeutic approaches, and many other cardiovascular topics.

The number of cited journals reached 3,859, and 173 of them were cited more than 20 times. The top 3 co-cited journals were Circulation (640 citations), J ethnopharmacol (524 citations), and J am coll cardiol (436 citations) (Table 8). After VOSviewer cluster analysis, 3 classes were formed, corresponding to the 3 colors in the figure (red, green, and blue) (Fig. 11).

Cluster 1 was represented by Journal of Ethnopharmacology. The publication content is as described above. This journal is both a highly published and highly cited journal in its field of study.

Cluster 2 was represented by Circ Res. This is a top journal in the cardiovascular field and belongs to the JCR1 region. It is one of the American Heart Association (AHA) series of journals. The journal publishes the highest quality manuscripts related to cardiovascular disease and encourages submissions that use state-of-the-art methods to elucidate the mechanisms of human disease.

Cluster 3 was represented by Circulation. This journal is part of the AHA series of journals along with Circ Res. Circulation publishes observational studies, clinical trials, epidemiology, and other cardiovascular health and disease literature.

The total number of references was 18310, of which 49 were cited more than 8 times. We listed 10 of the most frequently cited references related to the field of TCM research on HF (Table 9). These references were published in internationally recognized journals or even topical journals, which have generated a large impact and can be considered the most popular papers in this research field.

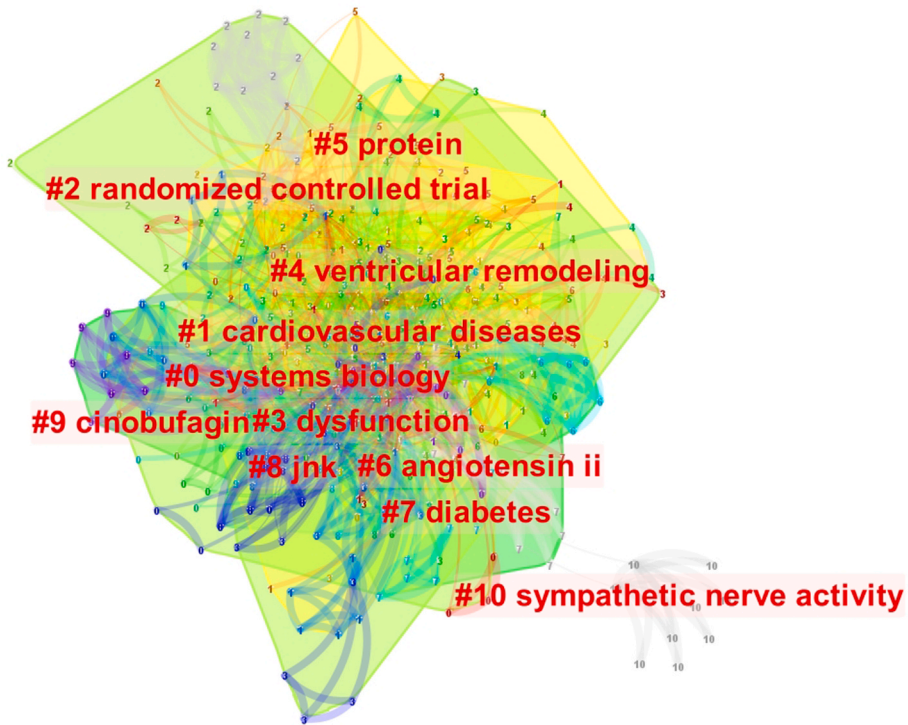


Fig. 7. Keyword co-occurrence clustering map drawn by CiteSpace. Different colors and numbers represent different clusters. The color of the cluster indicates the year in which the co-word relationship first appeared. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

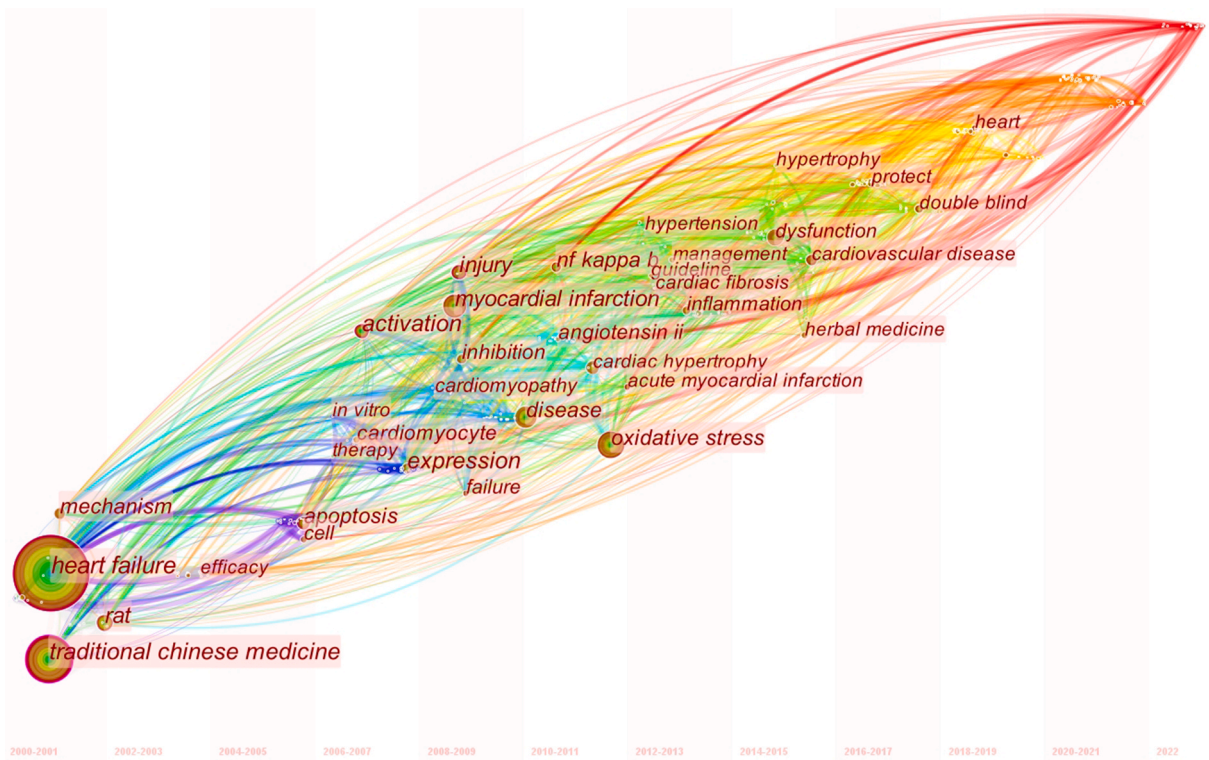


Fig. 8. The keyword time zone map drawn by CiteSpace. Each keyword corresponds to a vertical line of time.

Top 20 Keywords with the Strongest Citation Bursts

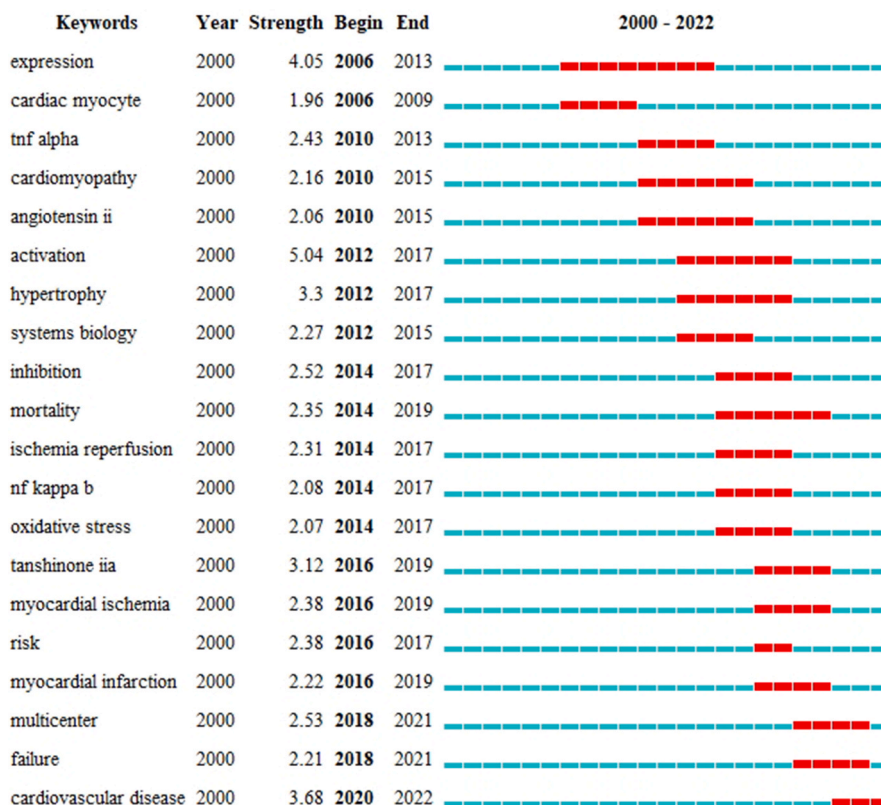


Fig. 9. Burst words drawn by CiteSpace. The red line represents the year of occurrence. Each small line represents one year. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 7
Top 10 journals in terms of number of publications published.

Rank	Source	Publications	Citations	Average Citation/publication
1	journal of ethnopharmacology	40	909	22.73
2	frontiers in pharmacology	39	305	7.82
3	evidence-based complementary and alternative medicine	36	179	4.97
4	Chinese journal of integrative medicine	21	89	4.23
5	medicine	20	53	2.65
6	biomedicine & pharmacotherapy	17	162	9.53
7	scientific reports	14	597	42.64
8	Phytomedicine	10	86	8.6
9	trials	9	82	9.11
10	journal of traditional Chinese medicine	9	49	5.44

3.5.1. The top 3 co-cited references were

- 1). Li XL, 2013, J AM COLL CARDIOL, V62, P1065, DOI 10.1016/j.jacc.2013.05.035. Cited 62 times. This article, published as a randomized controlled trial, focused on evaluating the efficacy of Qili qiangxin capsules for patients with chronic HF and recommended the combination of Qili qiangxin capsules for the treatment of chronic HF in the context of standard therapy.
- 2). Hao PP, 2017, J AM COLL CARDIOL, V69, P2952, DOI 10.1016/j.jacc.2017.04.041. Cited 37 times. The article, published in J Am Coll Cardiol, is a review that systematically evaluates the efficacy and safety of Chinese herbal medicine in the treatment of cardiovascular disease, as well as the pharmacological effects and potential mechanisms of the active ingredients of Chinese medicine on the cardiovascular system. TCM is recommended as a complementary and alternative approach to primary and secondary prevention of cardiovascular disease.
- 3). Ponikowski P, 2016, EUR HEART J, V37, P2129, DOI 10.1093/eurheartj/ehw128. Cited 28 times. The article, published in Eur Heart J, is a 2016 ESC guideline for the diagnosis and treatment of acute and chronic HF.

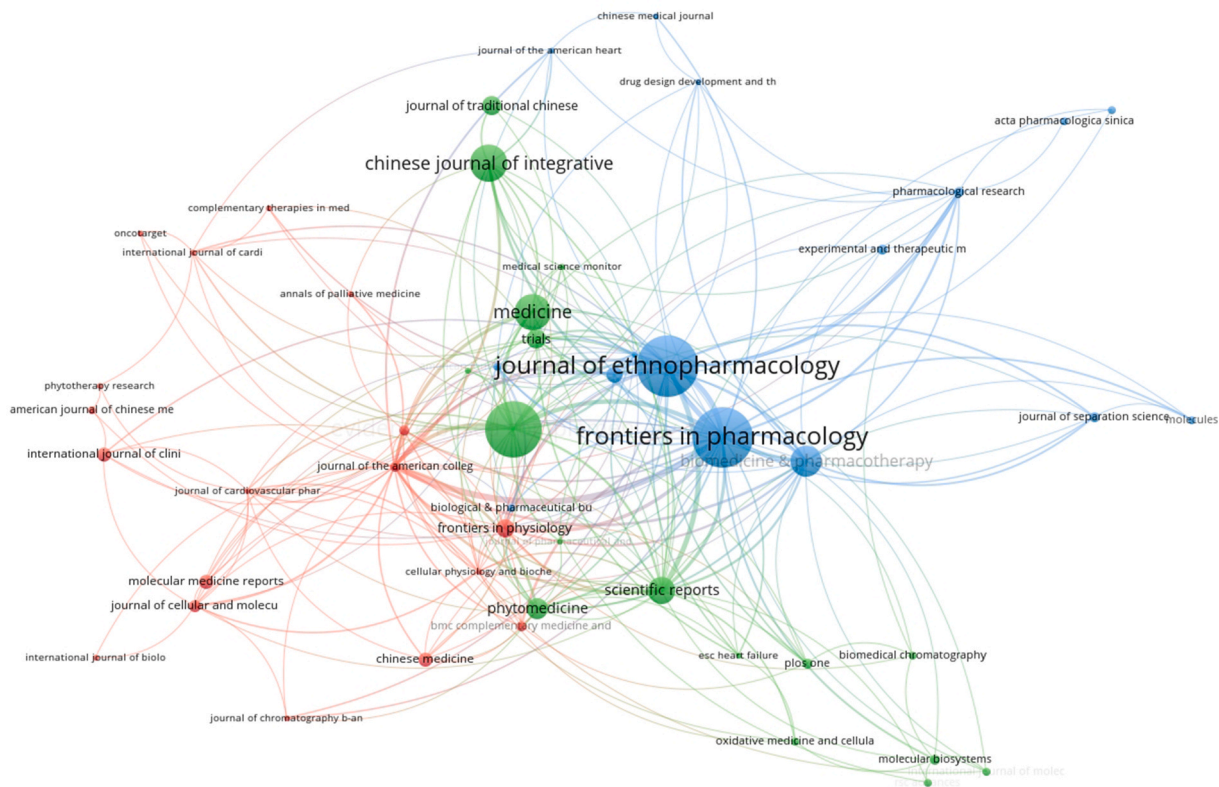


Fig. 10. Clustering map of journal sources drawn by VOSviewer.

Table 8
Top 10 journals in terms of number of citations.

Rank	Source	Citations
1	circulation	640
2	j ethnopharmacol	524
3	j am coll cardiol	436
4	circ res	397
5	evid-based compl alt	393
6	plos one	319
7	cardiovasc res	280
8	j mol cell cardiol	249
9	sci rep-uk	223
10	new engl j med	201

4. Discussion

The problem of information overload creates difficulties for people in obtaining valuable information. It has become a major challenge to find the frontiers and research hotspots in the vast literature. Bibliometrics is a cross-cutting science that integrates mathematics, statistics, and bibliography to quantitatively analyze knowledge carriers and has been widely used in the medical field. Bibliometrics uses citation and co-citation analysis, word frequency and co-occurrence analysis, burst word analysis, cluster analysis and other methods to identify the research trajectory, current research hotspots and frontiers in a certain field. This will help researchers quickly and comprehensively understand the development of this field and determine the research direction. Both CiteSpace and VOSviewer are citation visualization and analysis software programs that were gradually developed in bibliometrics and data visualization, which present the structure, pattern and distribution of scientific knowledge utilizing visualization (mapping). Mapping is an innovative research method that synthesizes a variety of dry literature data and incorporates visual analysis, contributing to a better understanding of the scientific field.

HF, characterized by high morbidity and mortality, is one of the major diseases endangering human health in the 21st century and an important issue in global public health. Traditionally, the treatment of HF has been based mainly on modern medicine. Although modern concepts and treatments for HF continue to improve, readmission and mortality rates remain high, and the side effects of long-

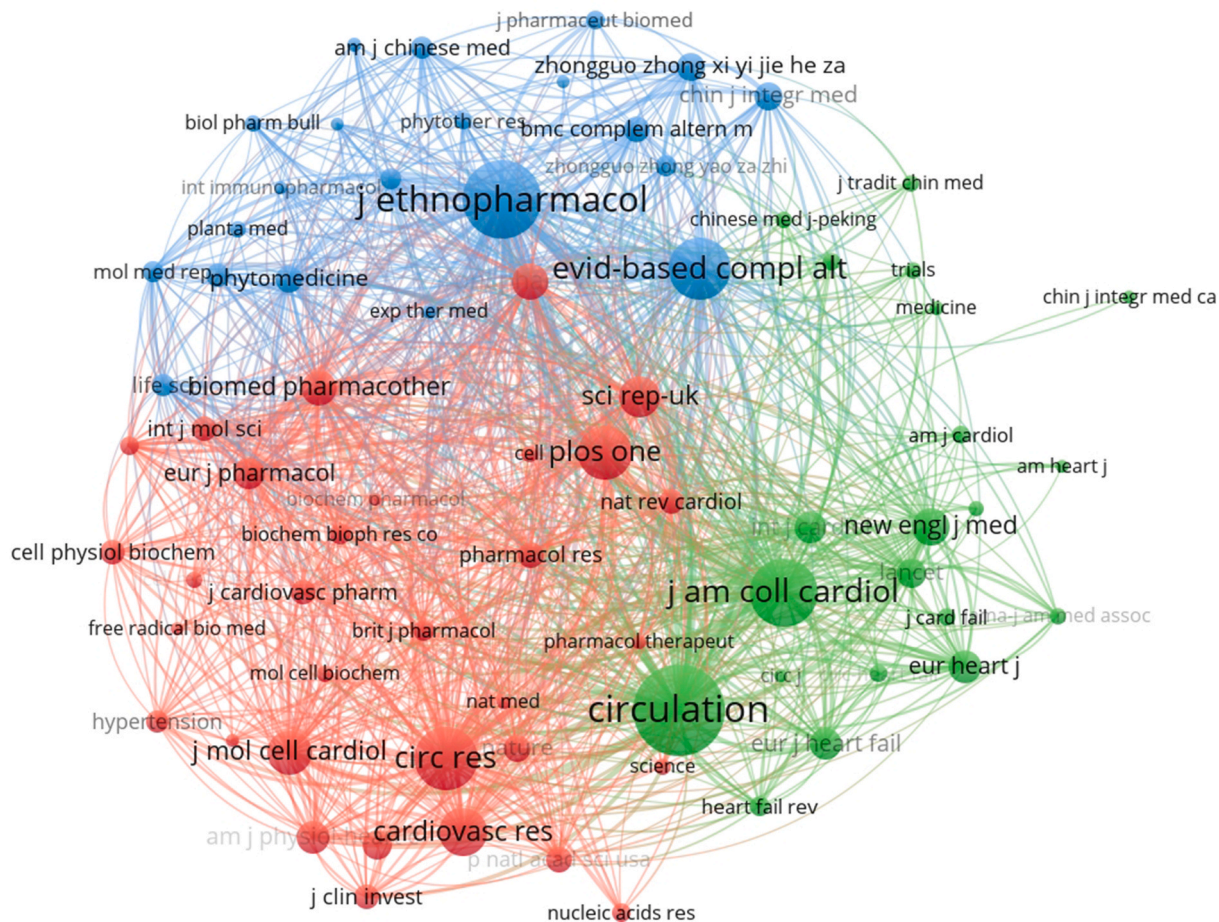


Fig. 11. Clustering map of cited journals drawn by VOSviewer.

Table 9
Top 10 of the most frequently cited references.

Rank	Cited references	Citations
1	Li XL, 2013, J AM COLL CARDIOL, V62, P1065, DOI 10.1016/j.jacc.2013.05.035	62
2	Hao PP, 2017, J AM COLL CARDIOL, V69, P2952, DOI 10.1016/j.jacc.2017.04.041	37
3	Ponikowski P, 2016, EUR HEART J, V37, P2129, DOI 10.1093/eurheartj/ehw128	28
4	Tao LC, 2015, SCI REP-UK, V5, DOI 10.1038/srep08374	20
5	Zou YZ, 2012, J CARDIOVASC PHARM, V59, P268, DOI 10.1097/FJC.0b013e31823f888f	18
6	Li C, 2014, PLOS ONE, V9, DOI 10.1371/journal.pone.0104255	18
7	Tang WHW, 2013, J AM COLL CARDIOL, V62, P1073, DOI 10.1016/j.jacc.2013.05.028	17
8	Wang Y, 2017, CURR PHARM DESIGN, V23, P5115, DOI 10.2174/1381612823666170925163427	17
9	Xian SX, 2016, J ETHNOPHARMACOL, V186, P136, DOI 10.1016/j.jep.2016.03.066	17
10	Yancy CW, 2013, J AM COLL CARDIOL, V62, pE147, DOI 10.1016/j.jacc.2013.05.019	16

term oral chemotherapy are inevitable. Apparently, the demand for modern medicine to control HF has not been satisfied, and people are now considering the possible role of traditional medicine in preventing and treating HF. Since its birth, TCM has a long history of serving the health of the Chinese people and is still an important part of the current medical system in China. In China, more than 71.2% of patients who experienced Western medicine, Chinese medicine and combined Western and Chinese medicine preferred a combination of Western and Chinese medicine, with 18.7% choosing Chinese medicine as their favorite [44]. In addition, TCM is becoming increasingly popular in some developed countries, such as the United States and Japan. The research and development of TCM have provided more possibilities for the treatment of HF patients. Chinese medicine has certain advantages over modern medicine in some aspects of HF treatment and is an important complement to modern medicine.

This study shows that Qili Qiangxin capsules have a high degree of attention in this field. Under the guidance of the theory of TCM, this medicine is a kind of Chinese patent medicine composed of 11 kinds of Chinese herbs, and its main pharmacological active

ingredients are astragali radix and aconiti lateralis radix preparata. The medicine has been widely used for the treatment of HF in China for nearly 20 years. The clinical efficacy and mechanism exploration of the drug in the intervention of HF is a hotspot in the current research field. In the context of standard HF treatment, Qili Qiangxin capsules can further reduce N-terminal pro B-type natriuretic peptide levels, restore cardiac function, and reduce mortality in patients with HF. Herbal extracts (tanshinone IIA, Panax ginseng, etc.) are increasingly used in the field of HF. These extracts have positive ameliorating effects on HF and are the focus of current research. In addition, the clinical research of TCM decoction on HF has gradually entered people's vision, but the relevant literature is limited, and there is still a lack of high-quality evidence-based medical evidence [45]. Mechanism research has always been the focus and key in the field of medicine. Through the analysis of keywords and burst words, the mechanism of TCM intervention on HF mainly involves myocardial hypertrophy, ventricular remodeling, oxidative stress, signaling pathways, cell apoptosis, activation and fibrosis, and inflammation. These hotspots and frontiers deserve attention at present and even in the future. In recent years, the literature on network pharmacology, molecular docking technology and metabolomics on TCM has been emerging, which is also one of the current research hotspots. In the future, high-quality TCM clinical trials and mechanistic exploration of TCM intervention in HF will be important topics in the field of HF research.

Coronavirus disease 2019 (COVID-19) is still circulating worldwide and has brought a series of unique challenges to patients with HF. In fact, TCM has been introduced to treat COVID-19, and some high-quality evidence has been obtained. Data show that the total global mortality rate for COVID-19 in 2019 was approximately 6.9%. Patients with cardiovascular disease typically have a worse prognosis, with some reported mortality rates exceeding 10% [46,47]. Severe infections also increase the risk of HF among COVID-19 patients, and the mechanisms involved may include cardiac stress, increased thrombotic activity, direct viral damage to the heart, and cytokine storms. TCM can not only improve the clinical symptoms and quality of life of HF patients but also regulate the function of all body systems, enhance immune function, prevent HF and reduce the chance of recurrence of HF. The level of clinical evidence for the treatment of HF with TCM has gradually improved, and the clinical efficacy continues to be recognized [12,48,49]. The intervention of TCM in COVID-19 complicated with HF has gradually formed a new research direction.

TCM is an ancient and constantly renewed discipline, and its development can be considered a microcosm of the changes in the entire natural sciences. Research on HF of TCM has developed very rapidly in this century, and the research hotspots are constantly changing. This study analyzed the research related to HF in TCM during the 21st century based on CiteSpace and VOSviewer software, systematically reviewed the development trend of the field, verified the applicability of bibliometrics in the field, and explored and analyzed the influential authors, institutions, countries, journals, keywords, and other analysis elements in the research field. This will provide useful information for subsequent scholars to explore the core research in this field and help them to grasp the core content, overall framework and development trend of this field faster.

This study also has some limitations. The bibliometric analysis software has high specifications and standards for data, and the quality and completeness of the collected data are the basis for conducting the analysis, but it was difficult to find the best balance between checking the complete and refined literature, and there may have been some studies that already had some influence in the field or will have influence in the future that were not included in this study. In addition, there may be some articles whose topics were only labeled as "complementary medicine", "alternative medicine", or "translational medicine" by WOS, resulting in these articles not being included in this study. Therefore, our study may not fully represent all the results in this research area. In addition, quantitative analysis requires the analysis and interpretation of data, which requires researchers to have a deeper and more comprehensive understanding of the territory and inevitably carries some subjectivity.

5. Conclusions

We used bibliometric and visual methods to analyze valuable details in TCM research on HF in the 21st century, which may help researchers identify potential collaborators and partner institutions, hotspots, and frontiers in the field.

Author contribution statement

Yun-Hu Chen, Li-Hua Fan conceived and designed the experiments; Mo-Qing Yin performed the experiments; Yun-Hu Chen, Xue-Chun Jiang, Hong-Feng Xu analyzed and interpreted the data; Tao Zhang, Xing-Yu Zhu contributed reagents, materials, analysis tools or data; Yun-Hu Chen, Mo-Qing Yin wrote the paper.

Funding statement

This work was supported by the 2019 Suzhou (Taicang) Science and Technology Development Plan (the fourth batch of basic research on people's livelihood, science and technology, and medical and health applications). Project name: Applied research on diuretic resistance of Zhuling decoction. Project number: SYSD2019201, TC2019JCYL13.

Data availability statement

The data in this paper can be obtained from the corresponding author.

Additional information

No additional information is available for this paper.

Declaration of competing interest

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.

Acknowledgments

We thank Professor Shoupeng Chen of Nanjing University of Traditional Chinese Medicine for providing information retrieval services in this experiment.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.heliyon.2022.e12770>.

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