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Review article

Research focus and theme evolution on enhanced external counterpulsation: A bibliometric analysis

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ABSTRACT

Aims: The study delved into the identification of key research areas and evolving trends within the domain of Enhanced External Counterpulsation, aiming to gain comprehensive insights into the subject matter.

Methods: Utilizing the sophisticated search parameter of 'topic' (TS) on the Web of Science (WoS) database, the necessary information was retrieved. This research employed an array of tools for effective data extraction, analysis, and visualization, which included Microsoft Excel for tabular management, HistCite Pro for citation analysis, GunnMap for geographical mapping, BibExcel for bibliometric assessments, and VOSviewer for network visualization purposes.

Results: From its establishment up until March 31, 2024 a total of 535 entries were recorded in the WoS database, with 491 of these relevant to the specified subject matter. The USA was the most prolific country, and China ranked second. Sun Yat Sen University was the most productive institution, which was from China. And 80 % of the top 10 institutions were from the USA. A keyword co-occurrence analysis was conducted, revealing four distinct research foci. And they were the application of EECP in cardiovascular disease, the main indications of EECP, the mechanism of EECP and the therapeutic effect of EECP, respectively. Researchers paid the most attention to the application of EECP on the cardiac cardiovascular system. Professor Lawson WE, Hui JCK and Kennard ED were the top three prolific authors. Lawson WE, Henry TD, Braith RW and Zheng ZS were identified as the core authors in the author co-citation network analysis.

Conclusion: A comprehensive analysis was conducted on the literature surrounding improved enhanced external counterpulsation in this investigation, which can help researchers understand the theme trend better and grasp the research gap, to carry out further research and promote the progress of the topic.

Enhanced external counterpulsation (EECP) is a kind of non-invasive therapy, which is a pulsation-type auxiliary circulation method based on electrocardio signals [1]. EECP works by triggering inflation of the cuff wrapped around the lower extremity during diastole and deflation during systole, which can increase blood flow to vital organs [2,3]. EECP has been approved by the U.S. Food and Drug Administration (FDA) for treating patients with cardiogenic shock and stable angina [4,5]. The first external counterpulsation (ECP) device, based on the principle of fluid dynamics, was developed by Birtwell, Soroff and other colleagues in 1963 [6]. Research

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conducted by Soroff et al. has evaluated the effectiveness of ECP in the treatment of patients diagnosed with cardiogenic shock [7]. The study indicated that ECP can effectively maintain systolic blood pressure in patients with cardiogenic shock, but it has not been popularized due to its disadvantages. For example, it is time-consuming to initiate ECP therapy for patients suffering from cardiogenic shock [7]. In 1976, Zheng and his colleagues transformed the ECP apparatus into sequential ECP, which is based on pneumatic system and further evolved into EECP in 1983 [8,9]. In the 1980s, Zheng and colleagues at Sun Yat Sen University in China first reported the benefits of external counterpulsation through the use of pneumatic counterpulsation device in a sequential manner [8]. In 2007, the first work of EECP in vascular endothelial protection was published in "Circulation" by Dr Guifu Wu's team, which was the basis of EECP application in cardiovascular rehabilitation [10].

EECP is a safe and effective treatment. With the in-depth study of the therapeutic mechanism of EECP, the application scope of EECP has been gradually expanded, both cardiac conditions [11,12] and noncardiac conditions [13,14]. In the early years, researchers mainly explored the central hemodynamic mechanisms of EECP and the application of EECP focused on patients with angina pectoris and heart failure [5,15]. Later, researchers found that EECP could work not only via central mechanisms, but also via peripheral mechanism [16]. With the attention paid to the peripheral mechanism, the application population of EECP has gradually expanded and has been used in more areas, such as cerebrovascular disease [17], diabetes [18], erectile dysfunction [19], psychological and psychiatric diseases [20], etc. Concerning the research focus, researchers have mainly devoted themselves to exploring the safety of EECP treatment [21], the mechanism of EECP benefits [22], influencing factors of benefits with EECP treatment [23], and EECP treatment effect [24]. The mechanism of EECP benefits and treatment effects have been paid the most attention to. The benefit mechanism of EECP for patients can be divided into two categories. One is immediate hemodynamics [25–27] and the other is vascular biology [10,28]. Through the above mechanism, EECP could ameliorate endothelial dysfunction [29], improve vascular state [30], improve peripheral perfusion in patients with coronary artery disease (CAD), and promote the establishment of collateral circulation in patients with coronary artery occlusive [31]. Under the benefit mechanism of EECP, patients' symptom burden could be relieved [32], exercise tolerance could be elevated [33], and psychological state and quality of life could be all improved [32]. With the development of research, the mechanism of EECP benefit has been further studied. Researchers have concentrated on exploring the treatment strategy of different EECP frequencies [34,35], different doses of EECP [36], and different sequential levels [37]. In general, researchers began to evaluate the mechanism of EECP influence on hemodynamics from a quantitative perspective, and some researchers even began to develop numerical calculation models [38].

With the continuous verification of EECP benefits and the in-depth study of the mechanism of EECP benefits, EECP has caught the attention of more and more researchers. In recent years, the literature related to EECP has been growing. Therefore, we carried out a bibliometric analysis, a powerful statistical analysis tool, to have a comprehensive understanding of the research domain of EECP and help researchers grasp the research gap more quickly.

1. Method

1.1. Search strategy

Diverse search engines can be used to obtain bibliometric data. For this investigation, the WoS database was employed due to its extensive, trustworthy, and all-encompassing nature as a bibliographic resource. The search was conducted within the Web of Science Core Collection, encompassing six distinct databases. The central theme employed in the literature retrieval process was "TS=((“Enhanced External Counterpulsation”) OR (“EECP”) OR (“External Counterpulsation”) OR (“External Counter-pulsation”))". The literature search was performed for all literature on EECP from its inception to 31 March 2024. The analysis in this research has exclusively focused on documents written in English, due to its status as a global lingua franca. And the literature type was limited to article and only. 535 documents concerning EECP were included, and they were imported into HisCite for further filtering. Literature was eliminated if it did not meet the research theme. Ultimately, this study encompassed 491 entries retrieved from the database. The 2022 Journal Citation Reports (JCR) covers 21,762 journals across 254 scientific disciplines spanning 112 countries.

1.2. Data analysis and visualization

Software tools such as Microsoft Excel, GunnMap version 2, HistCite Pro, BibExcel, and the VOSviewer java application was instrumental in facilitating data analysis and visualization processes. All information related to articles, such as author, country, journal et al., was exported in text format from the WoS database. Statistical scrutiny and graphic representation of publication year, nationalities, yearly production, journals, contributors, academic institutions, linguistic usage, and highly quoted papers were executed utilizing HistCite Pro2.1 and Microsoft Excel 2010. To manifest visualization of bibliometric maps, BibExcel software was employed for data extraction, while VOSviewer version 1.6.9 facilitated the construction of these maps and the calculation and analysis of term co-occurrence networks derived from article abstracts. Furthermore, it enabled the portrayal of collaboration networks among authors and nations.

BibExcel and VOSviewer v.1.6.9 software were used to extract and construct bibliometric maps, visualize, calculate and analyze the co-occurrence network of the keywords extracted from the title and abstract, and visualize the country co-authorships, and author co-citation network. GunnMap 2 (http://lert.co.nz/map/) was put into use to generate the world map to show the global geographic distribution of the total number of documents by country.

2. Result

2.1. Descriptive analysis

535 documents were retrieved about EECP, indexed in the WoS from its inception to March 31, 2024. Upon exclusion of those entries that did not align with the study focus, 491 articles were incorporated into the analysis.

2.1.1. Publication distribution across time and countries

Fig. 1 depicts annual publications spanning from 1963 through 2024, as of March 31, 2024. It reveals a pattern of inconsistent yet progressive growth in the number of publications, with a significant acceleration in document growth since 1998. This suggests heightened interest in EECP within the research community in recent times. A substantial majority, 472 documents (95.7 %), are indexed under SCI-Expanded, while 15 (3.0 %) find their place in SSCI. Furthermore, 20 documents (4.1 %) are indexed in ESCI, and 9 papers (1.8 %) are listed in CPCI-S. Notably, no articles are indexed in A&HCI or CPCI-SSH.

The analysis revealed that 44 nations engaged in EECP research. Displayed in Fig. 2 is a global map pinpointing these countries, where the quantity of scholarly papers serves as the basis. A total of 25 countries contributed less than five publications. Each pattern's hue signifies the overall count of articles, with deeper red indicating a higher volume. Leading the list was the United States with 212 publications, trailed by China (105), Germany (32), Japan (17), and India (15). To discern collaborative networks between nations, a graphical representation of joint authorship among countries was employed. Fig. 3 depicts cooperation networks for countries with at least one publication. Evidently, the U.S., China, and Germany had the largest nodes, signifying their strongest collaboration with other nations.

2.1.2. Publication analysis based on journals

This study pinpointed 264 core journals that delved into the subject matter of EECP. To assess these journals, a set of five key performance indicators were adopted: Journal Impact Factor (JIF), Total Number of Articles (TA), Total Global Citation Score (TGCS), Global Citation Score Per Article (GCSA), and Journal's Country (JC). As illustrated in Table 1, the top 10 most active journals contributed 123 papers, making up 25 % of all articles on the subject. The American Journal of Cardiology led the pack with 27 publications (5.5 %), followed closely by Clinical Cardiology with 26 (5.3 %), then Journal of The American College of Cardiology (14, 2.8 %), American Heart Journal (11, 2.2 %), Cardiology (10, 2.0 %), and International Journal of Cardiology (10, 2.0 %). Circulation also held significant weight due to its high GCSA (93) and JIF (37.8). Remarkably, 70 % of the top 10 prolific journals had a JIF of 3.0 or more. Furthermore, half of these top journals hailed from the USA, while the remaining were from Switzerland, Ireland, and China.

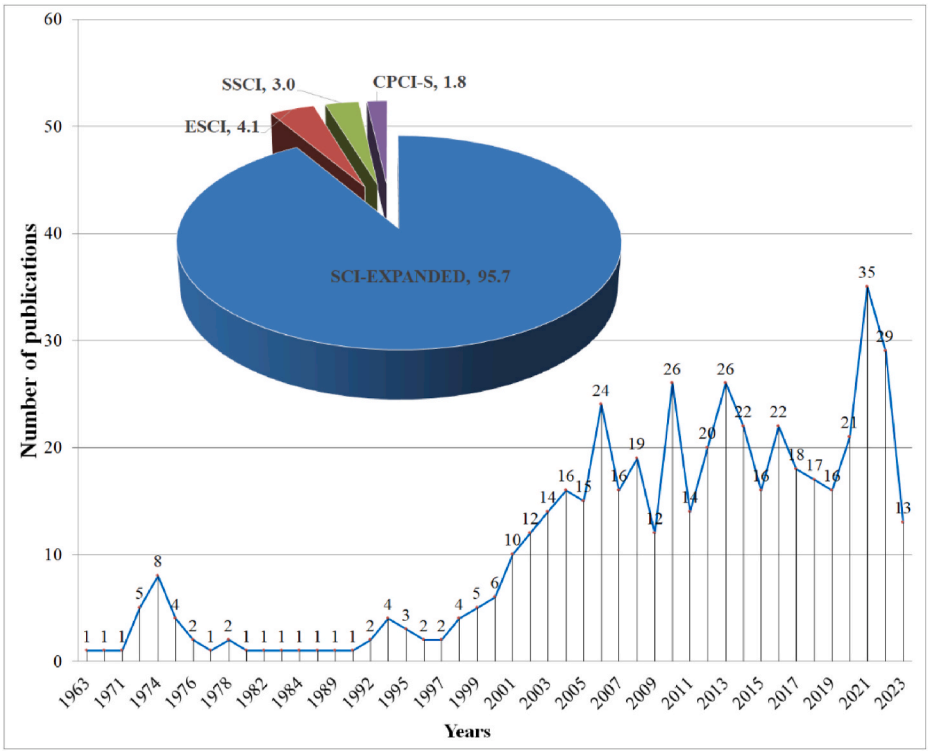

Fig. 1. Evolutionary pattern of "Enhanced External Counterpulsation" studies in the Web of Science corpus during the past six decades.

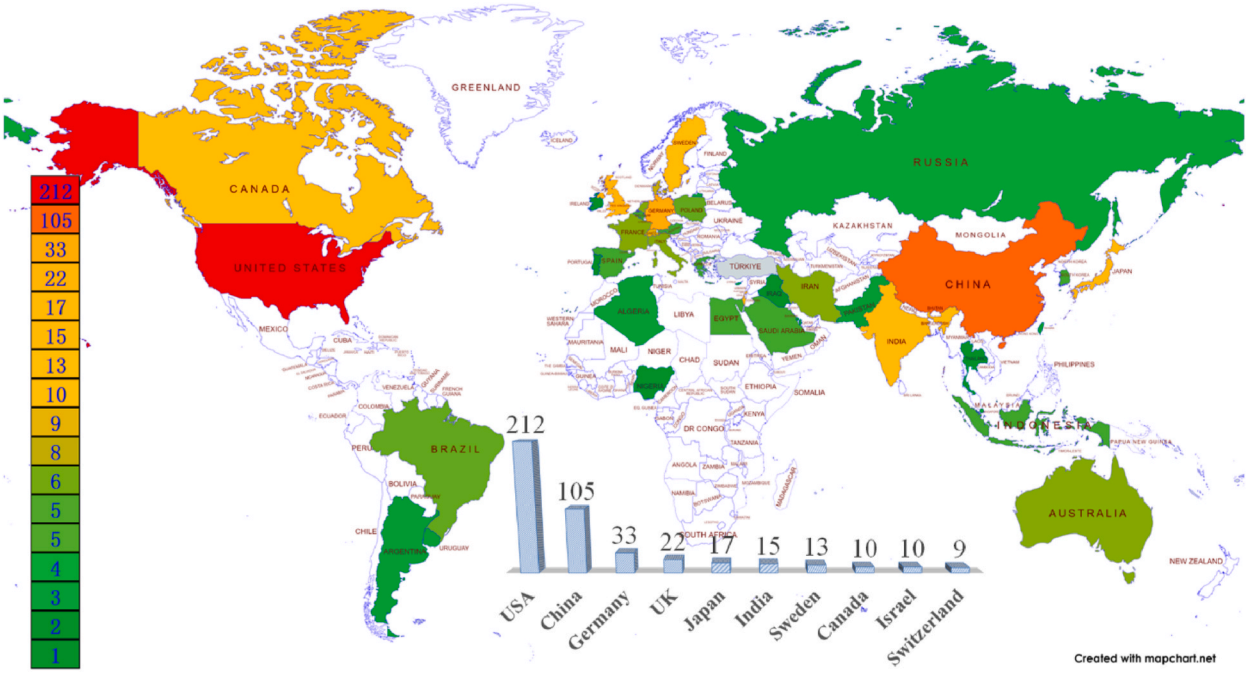

Fig. 2. (a) The worldwide distribution of total documents across nations and (b) An enumeration of the top 10 countries with the highest volume of publications concerning "Enhanced External Counterpulsation" studies.

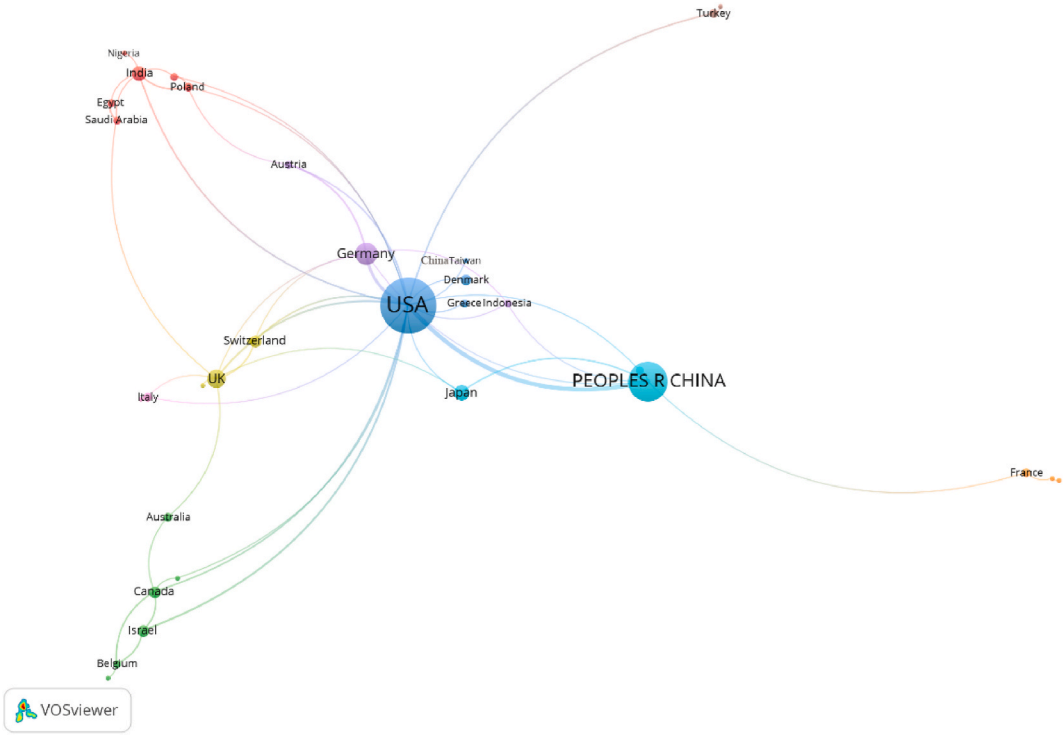

Fig. 3. Network visualization map of country co-authorships (Wider connections denote more robust collaborative ties). Nations depicted with bigger circle dimensions or typography indicate a higher volume of published works.).

Table 1
Quantitative assessments of periodicals disseminating studies on "Enhanced External Counterpulsation" research.

Rank	Source Title	JIF2022 (R)	TA (%)	TGCS	GCSA	JC
1	American Journal of Cardiology	2.8	27 (5.5 %)	910	33.7	USA
2	Clinical Cardiology	2.7	26 (5.3 %)	562	21.6	USA
3	Journal of The American College of Cardiology	24.0	14 (2.8 %)	2661	190.1	USA
4	American Heart Journal	4.8	11 (2.2 %)	195	17.7	USA
5	Cardiology	1.9	10 (2.0 %)	249	24.9	Switzerland
6	International Journal of Cardiology	3.5	10 (2.0 %)	125	12.5	Ireland
7	Frontiers in Cardiovascular Medicine	3.6	8 (1.6 %)	6	0.8	Switzerland
8	Frontiers in Physiology	4.0	7 (1.4 %)	36	5.1	Switzerland
9	Chinese Medical Journal	6.1	5 (1.0 %)	20	4.0	China
10	Circulation	37.8	5 (1.0 %)	465	93.0	USA

Note: JIF: Journal Impact Factor; TA: Total Articles; TGCS: Total Global Citations Score; GCSA: Global Citation Score Per Article; and JC: Journal Country.

Table 2
Numerical assessments of institutions engaged in "Enhanced External Counterpulsation" scholarly publications.

Rank	Institution	Country	TA	TA (%)	TGCS	GCSA
1	Sun Yat Sen University	China	38	7.7	441	11.6
2	Pennsylvania Commonwealth System of Higher Education	USA	37	7.5	1178	31.8
3	State University of New York Suny System	USA	37	7.5	1128	30.5
4	University of Pittsburgh	USA	37	7.5	1178	31.8
5	State University of New York Suny Stony Brook	USA	36	7.3	1117	31.0
6	Mayo Clinic	USA	25	5.1	1016	40.6
7	University of California System	USA	25	5.1	1006	40.2
8	State University System of Florida	USA	23	4.7	563	24.5
9	University of Florida	USA	23	4.7	563	24.5
10	Chinese University of Hong Kong	China	21	4.3	330	15.7

Note: TA: Total Articles; TGCS: Total Global Citations Score; and GCSA: Global Citation Score per Article.

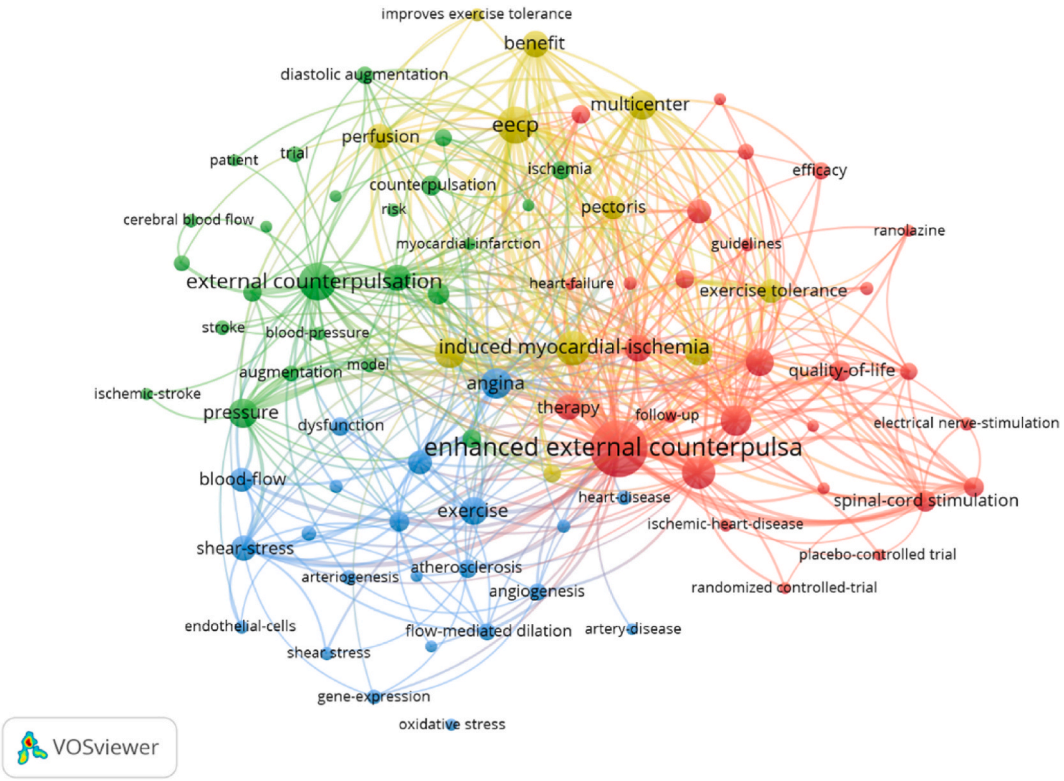

Fig. 4. Co-occurrence network of the terms with occurrences of 9 or more extracted. The larger circle size or font size indicates a higher occurrence.

2.1.3. Publication analysis on the basis of institutions

Table 2 depicts the leading 10 institutions with the highest output of EECP-related documents, quantified by their publication count. Concerning the number of articles published, the Sun Yat Sen University (n = 38, 7.7 %) ranked first, followed by Pennsylvania Commonwealth System of Higher Education (37 articles, 7.5 %), State University of New York Suny System (37 articles, 7.5 %) and University of Pittsburgh (37 articles, 7.5 %). Furthermore, certain institutions, despite having a lower volume of publications, exhibited an impressively high Global Citation Score per Article (GCSA). Notably, the Mayo Clinic ranked first in GCSA among the top 10 most productive establishments, despite its article count placing sixth in terms of quantity. Moreover, four-fifths of the top 10 institutions were based in the USA, with the remaining one-fifth originating from China.

2.2. Investigating thematic analysis through keyword co-occurrence and research category

Keywords serve as a reflection of the core themes within a research domain; hence, their co-occurrence analysis is instrumental in deciphering research priorities and evolutionary patterns. This work identified and analyzed terms that appeared nine times or more. Ultimately, 85 qualifying terms emerged, depicted in Fig. 4. The outcome revealed four distinctive clusters: a red group (Cluster 1), a green group (Cluster 2), a blue group (Cluster 3), and a yellow group (Cluster 4). The primary focus of studies was the utilization of EECP in cardiovascular ailments (Cluster 1), primary indications for EECP therapy (Cluster 2), the underlying mechanisms of EECP (Cluster 3), and the therapeutic outcomes of EECP treatment (Cluster 4).

A comprehensive analysis of the leading 10 research domains, as depicted in Fig. 5, was conducted to gain a deeper insight into the subject matter. The Cardiac Cardiovascular System took the lead with a share of 217 studies (44 %), closely trailed by Peripheral Vascular Disease accounting for 41 (8.3 %) entries. Medicine General Internal secured third place with 38 studies (7.7 %), while Pharmacology Pharmacy also registered an identical count of 38 studies (7.7 %).

2.3. Top 10 cited articles analysis

Table 3 depicts the top 10 most referenced articles, ranked according to their Total Citation (TC). Among the top 10 articles, they were published from 1992 to 2014, which may contribute to the influential factor of high citation. In addition, the first and the fifth articles are guidelines [39,40], and the fourth and the ninth articles were reviews. And the above two article types usually have high citations [41,42].

The top 10 referenced articles predominantly revolved around Cardiovascular Disease (CVD). The most frequently cited work delved into heart failure patients, detailing the application of EECP therapy in managing heart failure cases [39]. The second most cited paper centered on Coronary Artery Disease (CAD), assessing the safety and effectiveness of EECP for individuals experiencing angina symptoms [11]. Following closely, the third most cited study examined the impact of EECP on endothelial function in subjects with coronary artery disease [43].

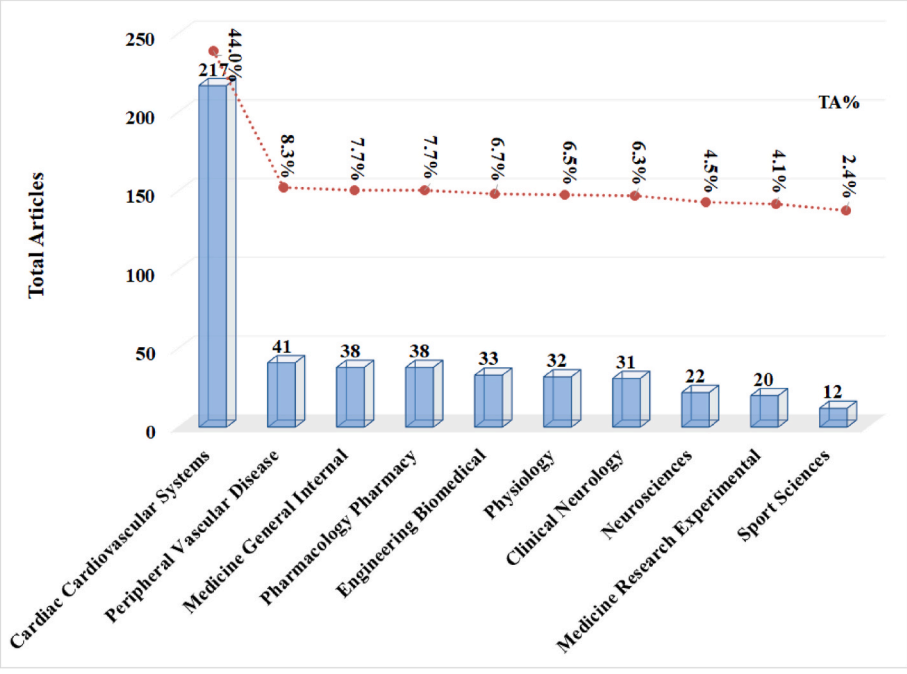

Fig. 5. The top 10 research categories ranked by count.

Table 3
The leading ten most referenced publications on "Enhanced External Counterpulsation" research from the inception of the searched databases to 2024.

Rank	Article	Author(s)	Journal	TC	TC/Y	Year
1	2009 Focused Update Incorporated Into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines Developed in Collaboration With the International Society for Heart and Lung Transplantation [39]	Hunt, SA	Journal of The American College of Cardiology	1423	94.87	2009
2	The multicenter study of enhanced external counterpulsation (MUST-EECP): Effect of EECP on exercise-induced myocardial ischemia and anginal episodes [11]	Arora, RR	Journal of The American College of Cardiology	339	13.56	1999
3	Enhanced external counterpulsation improves endothelial function in patients with symptomatic coronary artery disease [43]	Bonetti, PO	Journal of The American College of Cardiology	320	15.24	2003
4	The human coronary collateral circulation: development and clinical importance [41]	Seiler, C	European Heart Journal	178	16.18	2013
5	2014 ACC/AHA/AATS/PCNA/SCAI/STS Focused Update of the Guideline for the Diagnosis and Management of Patients With Stable Ischemic Heart Disease A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines, and the American Association for Thoracic Surgery, Preventive Cardiovascular Nurses Association, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons [40]	Fihn, SD	Circulation	155	15.5	2014
6	Left ventricular systolic unloading and augmentation of intracoronary pressure and Doppler flow during enhanced external counterpulsation [26]	Michaels, AD	Circulation	129	5.86	2002
7	Enhanced external counterpulsation improved myocardial perfusion and coronary flow reserve in patients with chronic stable angina - Evaluation by N-13-ammonia positron emission tomography [45]	Masuda, D	European Heart Journal	119	5.17	2001
8	Enhanced external counterpulsation improves exercise tolerance, reduces exercise-induced myocardial ischemia and improves left [44] ventricular diastolic filling in patients with coronary artery disease	Urano, H	Journal of The American College of Cardiology	115	5	2001
9	Enhanced external counterpulsation for ischemic heart disease - What's behind the curtain? [42]	Bonetti, PO	Journal of The American Col lege of Cardiology	105	5	2003
10	Efficacy of enhanced external counterpulsation in the treatment of angina-pectoris [5]	Lawson, WE	American Journal of Cardiology	101	3.16	1992

Note: TC: Total Citation; TC/Y: Average Citations per Year, which is the TC divided by the Year.

Regarding the subject matter, nine out of the top ten most cited publications centered on Coronary Artery Disease (CAD) [40,44]. Within this group, a quarter of these articles delved into angina patients [5,11,40,45]. As for the research themes, half of the top ten articles concentrated on the mechanisms of EECP [41–43,45], specifically addressing improvements in endothelial function [43], and the facilitation of collateral circulation development [41]. A third of these prominent studies assessed therapeutic outcomes [5,11,44], highlighting how EECP can alleviate anginal symptoms, decrease reliance on anti-anginal medications, and enhance exercise capacity, patient symptoms, and myocardial perfusion in individuals with stable angina [5,44]. The remaining pair of highly cited articles investigated the appropriateness and scope of EECP application [39,40].

2.4. Author analysis

2.4.1. Influential authors

To some extent, the following measurement indexes, such as total number of articles published (TA), Total Global citation Score (TGCS), and Global citation score per article (GCSA), could be considered as representative of the author's contribution.

Table 4 highlights the leading 10 contributors in the field of EECP research. A total of 1783 researchers have dedicated their efforts to this subject, with 48 of them authoring over five publications. The most prolific author, Lawson WE, holds a remarkable record of 30 articles, followed closely by Hui JCK with 29 articles and Kennard ED with 24 articles. Notably, two out of the top three authors, Lawson WE and Hui JCK, are affiliated with the State University of New York Suny Stony Brook. Among the top 10 contributors, 8 researchers were from the USA, the other two were from China. Furthermore, the results showed that the articles of Zheng ZS and Cohn PF were cited with high frequency, though the number of their articles was small. What's more, the global citation score per article of Cohn PF and Zheng ZS ranked first and second respectively among the ten authors, which indicated that the area they focused was with high attention.

2.4.2. Author co-citation network analysis

Of the 1783 authors, 6.0 % constituted 264 authors who garnered over 100 citations each, with a notable 2.3 % comprising 101 authors who amassed a minimum of 300 citations, and an impressive 1.7 % consisting of 76 authors who exceeded 500 citations.

The study employed an author co-citation network analysis to depict the interconnections among scholars. In the outcome of this analysis, authors with identical colors signify a cluster. In this study, four clusters were formed and the results are shown in Fig. 6. The primary contributors to the four distinct clusters, as indicated by the largest circle dimensions or text size, were Lawson WE, Henry TD,

Table 4
Top 10 contributing authors in terms of articles.

Rank	Author	Affiliation	Country	TA	TA (%)	TGCS	GCSA
1	Lawson WE	State University of New York Suny Stony Brook	USA	30	6.1	1031	34.4
2	Hui JCK	State University of New York Suny Stony Brook	USA	29	5.9	959	33.1
3	Kennard ED	University Pittsburgh	USA	24	4.9	563	23.5
4	Soran O	University Pittsburgh	USA	21	4.3	464	22.1
5	Wu GF	Sun Yat Sen University	China	21	4.3	290	13.8
6	Kelsey SF	University Pittsburgh	USA	19	3.9	447	23.5
7	Zheng ZS	Sun Yat-sen University	China	19	3.9	696	36.6
8	Braith RW	University of Florida	USA	16	3.2	414	25.9
9	Michaels AD	The University of Utah	USA	16	3.2	499	31.2
10	Cohn PF	State University of New York Suny Stony Brook	USA	12	2.4	534	44.5

Note: TA: Total Articles; TGCS: Total Global Citations Score; and GCSA: Global Citation Score per Article, which is the TGCS divided by the TA.

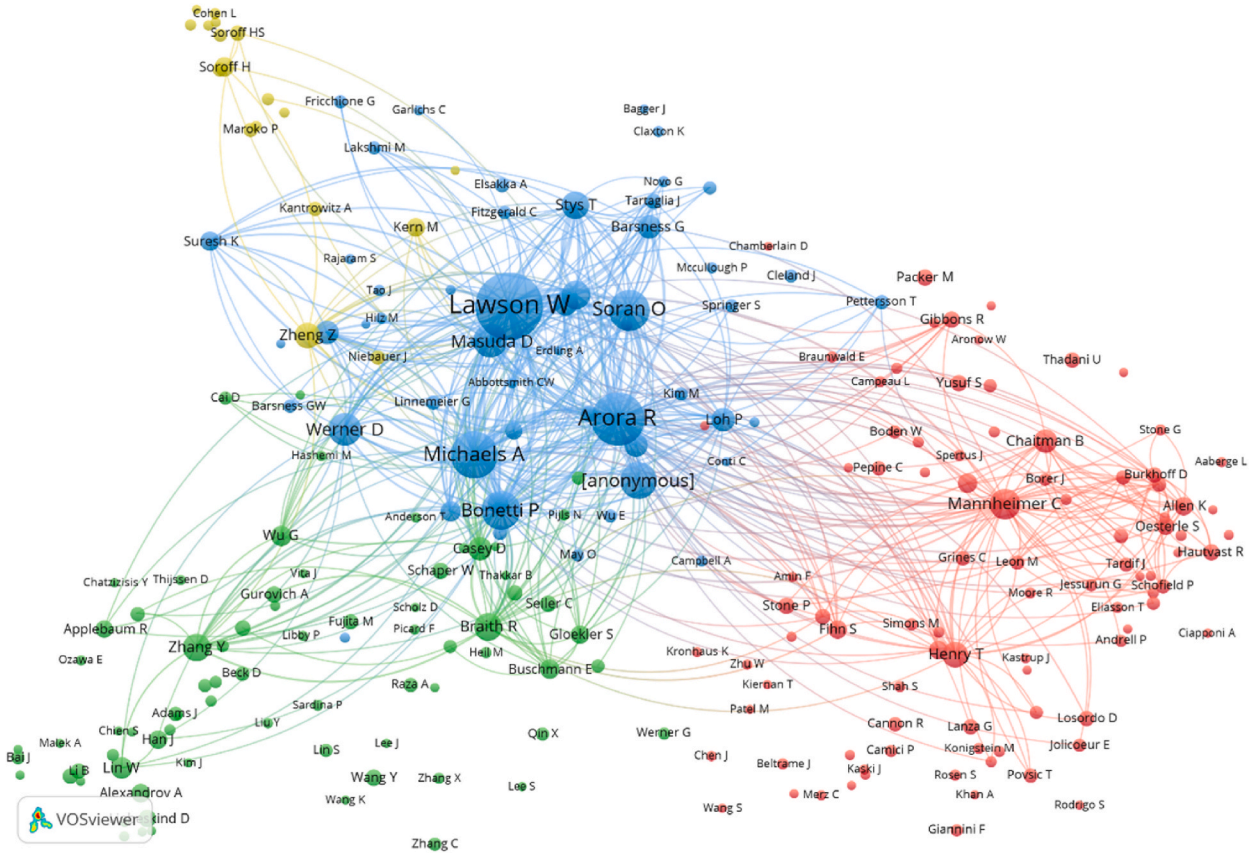

Fig. 6. Author co-citation network analysis in the field of "enhanced external counterpulsation" research.

Braith RW, and Zheng ZS in respective order. The results indicated that the above four authors have made outstanding contributions to the field.

3. Discussion

EECP was a low-cost noninvasive therapy, and its safety and effect have been proven globally [36,46,47]. In recent years, researchers have paid more attention to EECP, which will catch much more attention of individuals as the incidence of chronic diseases increases and the development of rehabilitation discipline. In the past 60 years, the literature concerning EECP has been increasing. To comprehensively understand the research trend, a bibliometric analysis was conducted in this study. The results will serve to capture the hot topic and research gap quickly for researchers.

The first article concerning EECP was published in 1963. The number of articles was with fluctuant growing, which might be attributed to the tortuous development of EECP [6–9]. The literature was with rapid growth after 1998, which may be related to the

establishment of the international EECP patient Registry in the United States [48] and approval of EECP by FDA. Most of the prolific countries, journals, institutions, and authors were from the USA and China. In general, the USA and China made significant contributions to the area of EECP, both the breaking and promoting of the area [49–51].

To gain a comprehensive insight into the current research landscape of EECP, an analysis was conducted on keyword co-occurrences, the top 10 most-cited publications related to EECP, and the scholarly focus of prominent authors. The keyword network revealed that researchers have kept an eye on the application of EECP in cardiovascular diseases, such as heart failure [52], angina pectoris [21], etc. Concerning research content, they kept an eye on the indications of EECP. For example, some researchers have carried out research on the application of EECP on patients diagnosed with stroke [34]. And we also found that researchers also concentrated on the mechanism and effect of EECP from the co-occurrence of keywords [35]. They found that EECP could influence the gene-expression [53]. Both the exercise tolerance [29] and endothelial function [54] could be improved. Within the ten most referenced papers, a significant 90 % of these works delved into the utilization of EECP for cardiovascular ailments, with a notable 40 % specifically concentrating on angina pectoris. This aligns closely with the findings from keyword co-occurrence analysis.

In order to thoroughly examine the essence of EECP studies, the works of the three most productive authors, key contributors from the author co-citation network analysis, and the three most referenced authors were meticulously studied. The top-ranking authors in this category were Lawson WE, Hui JCK, and Kennard ED. Remarkably, the research focus of Lawson WE closely paralleled that of Hui JCK, both of whom predominantly centered their investigations on the utilization of EECP in the treatment of angina pectoris patients [47,55], such as the effect of EECP [55,56], the economic benefit of EECP [4,47], etc. In addition, they both kept an eye on the predicted factors of the therapy effect of EECP [57], factors influencing EECP treatment and compliance [58] and the EECP benefit mechanism [59]. The study of Kennard ED has similarities with Lawson WE and Hui JCK. Besides, Kennard ED also paid attention to the therapy effect of EECP on patients diagnosed with angina pectoris with diabetes [60], the effect of BMI and secondhand smoke exposure on the efficacy of EECP in angina pectoris [61,62], and the effect of EECP on heart rate variability [63]. The primary contributors to the field of author co-citation network analysis were identified as Lawson WE, Henry TD, Braith RW, and Zheng ZS, each playing a significant role in its development. Henry TD was similar to Lawson WE, who paid much attention to the application of EECP on patients with angina pectoris and mainly focused on the effect and safety of EECP [64]. Braith RW and Zheng ZS both kept an eye on the benefit mechanism and therapy efficacy of EECP. And there were some differences between them. Braith RW paid more attention to the effect of EECP on patients diagnosed with diabetes [65] and Zheng ZS concentrated more on the long-term benefits of EECP [4]. The top 3 cited authors all paid much attention to the application of EECP on patients diagnosed with heart failure [39,66,67].

From the above analysis, we find that researchers have carried out much more research on the application of EECP on cardiovascular disease. And most of them paid much attention to patients with angina [68,69]. This might reflect that angina was an important clinical condition that needed to be solved. According to statistics, refractory angina pectoris (RAP) is an increasingly common chronic condition, with an annual incidence of 50,000–100,000 in the United States and 30,000 to 50,000 in Europe [70,71]. The prevalence of RAP in patients with coronary heart disease (CAD) ranges from 5 % to 10 % [72]. The characteristic of this condition is that the symptom of angina still exists despite the medical intervention having been adopted [70,73]. Despite the prognosis of RAP improving, with an annual mortality rate of 3–4%, this condition remains a challenging clinical issue, impairing an individual's quality of life (QoL) significantly [70].

This study will help researchers have a holistic understanding of EECP research, such as the prolific countries, influential authors, and important institutions. In addition, researchers can have a comprehensive guideline of research trends, which can help them catch the research hotspots and important researchers quickly. Overall, this investigation offers a degree of guidance for future researchers. It furnishes an all-encompassing examination, albeit with a few caveats. Primarily, the reliance on the WoS database exclusives, excluding literature not indexed by it, might limit the scope of the findings. Secondly, the restriction to English-language articles narrows the linguistic inclusivity, which limits the number of studies conducting EECP. In the future, researchers can include regional non-English language (Chinese, Russian, etc.) publications, which may widen the direction of EECP. Thirdly, there is no in-depth analysis of EECP study according to study type. For example, this study hasn't analyzed the proportion of randomized studies among all publications, which will be meaningful for future research. It is also unknown for the relationship between the ratio of active EECP devices and scientific publications in different countries. Lastly, temporal factors could create discrepancies between real research scenarios and bibliometric outcomes, considering the continuous updating nature of databases.

4. Conclusion

EECP is an effective therapy for patients and researchers have concentrated more on it, recently. However, the number of publications was still small, which indicated that more researchers should pay attention to this area. To help researchers understand the EECP research better, we have carried out a comprehensive analysis. This research will help researchers grasp the core authors, important articles, core institution and main research trend. The examination revealed a significant focus among researchers on the utilization of EECP for angina pectoris patients, the therapeutic efficacy and safety of EECP, predictive elements influencing treatment outcomes, and the underlying mechanisms of EECP's benefits. Future research directions should emphasize the following points. Firstly, fostering increased international collaboration among prolific nations is crucial. Secondly, there is a need for greater scholarly input in the field of EECP, as only a minority of authors, specifically 48 out of 1783, have produced five or more publications. Lastly, considering the rising prevalence of chronic disease co-morbidities, investigators might explore the application of EECP in cases where cardiovascular disease coexists with other health conditions. Finally, patients with angina pectoris still need to be highly concerned, and the micro-mechanism of EECP treatment of angina pectoris needs to be further explored.

CRediT authorship contribution statement

Weimei Yang: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation. **Lijuan Lu:** Writing – review & editing, Methodology, Data curation. **Jie Cheng:** Writing – review & editing, Methodology, Data curation. **Xifei He:** Writing – review & editing, Visualization, Methodology, Data curation.

Data availability statement

The novel findings introduced in this research are embedded within the article and/or supplementary materials. For any additional queries, please consult the corresponding author.

Ethics approval statement

Review and/or approval by an ethics committee was not needed for this study because it does not involve primary data collection from human participants.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. All authors disclosed no relevant relationships.

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