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Emerging Trends and Hot Topics in Cardiopulmonary Resuscitation Research: A Bibliometric Analysis from 2010 to 2019

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Background: Cardiopulmonary resuscitation (CPR) is a topic of great scientific and clinical interest that has received much attention in the past decade. Our study aimed to predict the trends in CPR research activities and evaluate hot topics via bibliometric means, quantitatively and qualitatively.

Material/Methods: All data were collected from a search of the Web of Science Core Collection on May 12, 2020. Retrieved information was investigated with bibliometric analysis by CiteSpace and VOSviewer software and the Online Analysis Platform of Literature Metrology to analyze and predict the trends and hotspots in this field.

Results: Our search returned a total of 9563 articles and reviews on CPR published from 2010 through 2019. The number of original research studies on CPR has been increasing annually. The journal Resuscitation published the greatest number of manuscripts involved CPR, and the leading country and institution with regard to contributions on CPR were the United States and the University of Pennsylvania. Keyword co-occurrence/co-citation-cluster analysis showed that the most popular terms associated with CPR occurred in the manner of cluster labels, such as therapeutic hypothermia and treatment recommendation, among others. In addition, palliative care, sepsis, extracorporeal membrane oxygenation, and brain injury were identified as new foci through burst detection analysis.

Conclusions: Our study showed that the scientific research focus on CPR is switching from traditional therapeutic treatments to a public health practice, with in-depth understanding and development of CPR-related techniques expanding over the past decade. These results demonstrate trends in the CPR research and detected the possible neo-foci for ensuing research.

MeSH Keywords: **Bibliometrics • Cardiopulmonary Resuscitation • Emergency Service, Hospital**

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Background

Cardiac arrest (CA) has continuously manifested as a public health burden, with the vast majority of patients having poor outcomes, regardless of being in or out of a hospital. In the United States alone, approximately 290 000 experience in-hospital cardiac arrest (IHCA) and 350 000 people experience out-of-hospital cardiac arrest (OHCA) annually, with less than 25% and 10% surviving, respectively. Around the globe, the incidence and mortality rates of CA are increasing [1–3]. Modern cardiopulmonary resuscitation (CPR), which represents additional development and advances in earlier forms of CPR, encompasses rapid first-aid and life-supporting technology for sudden cardiac and respiratory arrest. It involves emergency airway management; artificial-assisted ventilation; chest compression; electric defibrillation; correction of ventricular fibrillation (VF) or pulseless ventricular tachycardia or electrical activity; and other basic or advanced cardiac life support [3–5]. Modern CPR is capable of saving patients by promoting the return of spontaneous circulation and decreasing CA-related mortality. Furthermore, robust CPR guidelines, especially those published by the American Heart Association (AHA) in 2015 and the latest updates on 2019, underline not only the importance of high-quality CPR, but also provide detailed information about first-aid life-chain in adult CPR, such as dispatcher-assisted CPR, cardiac arrest centers, prehospital treatment of presyncope, and so forth [6,7]. Nevertheless, the success rate for CPR remains low and significant controversies need to be resolved. For example, some recommendations lack persuasive evidence because large randomized controlled trials have not been conducted; further, the clinical practice of CPR varies greatly in quality and compliance with some recommended targets is poor [8]. Consequently, urgent priorities include exploring research hotspots in combination with clinical practice and continuously advancing CPR technology to improve CA/CPR-related disease prognosis.

Recently, the use of bibliometric analysis has become a popular means of identifying trends and hotspots within specific areas of research. Such analysis enables quantitative measurement of contributions of a specific field of research, including different countries/regions, institutions, journals, authors, co-cited networks, and other details that highlight research trends or hotspots in a field [9]. However, literature-metrology study on CPR is scarce, let alone any focus on analysis and prediction of research hot topics or trends [10]. In this article, we aimed to identify potential hotspots and trends in CPR research from various aspects, including technological development, pathogens, pathophysiology, complications, prognosis, and clinical guidelines. Our goal was to contribute to the improvement of CPR performance via a comprehensive analysis of information from manuscripts published worldwide from 2010 to 2019.

Material and Methods

We restricted our literature search to original articles and reviews from 2010 to 2019, using the Web of Science Core Collection (WoSCC) database, which contains the Science Citation Index-Expanded (SCIE) and the Social Science Citation Index (SSCI). The retrieval strategy was “TS=(cardiopulmonary resuscitation) AND Language=English,” with the document types refined as “article OR review.” Document retrieval and recording were entirely completed on May 12, 2020, to avoid variation in citations caused by frequent database updates. Moreover, 2 reviewers (T. Jia and C. Luo) were independently in charge of the primary search; their agreement showed a considerable accordance. They identified 9563 studies, which cited 57 688 references that were eventually obtained and bibliometrically analyzed through the Online Analysis Platform of Bibliometry (<http://bibliometric.com/>), CiteSpace V5.6.R4, and VOSviewer 1.6.15. This analysis eventually indicated top authors, journals, institutions/countries, clustered networks of co-cited references/authors, and keywords with the strongest citation bursts.

Results

Distribution characteristics of articles

Altogether, 9563 research publications (8492 articles and 1071 reviews) from 2010 to 2019 were filtered out by customized retrieval strategies and inclusion criteria. An increasing trend was clearly apparent for the amount of original research literature on CPR annually as a whole (from 631 in 2010 to 1192 in 2019), although there was a plateau between 2011 and 2012 and slowdown from 2016 till the end of 2019 (Figure 1A). Growth trends and the number of publications by separate country or region were both demonstrated by publication years (only top 10 of countries/regions are listed in Figure 1B).

Among all 120 countries/regions from which literature on CPR originated, the United States contributed the largest number of publications on CPR research (3653), followed by Canada (706), Japan (657), China (640), and South Korea (615). In addition, the degree of centrality index showed by CiteSpace, particularly with regard to Freeman’s betweenness centrality in social networks, was another vital indicator used to evaluate the significance of nodes in a definite network, independent of the article counts [11]. By this measure, we found that Australia (centrality=0.13), which was ranked eighth in the number of articles, had an extraordinary centrality. This finding indicated that it was the most influential, overtaking research from the United States, England (0.12), and Italy (0.10) (Table 1). However, the centrality values of the top 10 institutions was below 0.15, which implies that these institutions had

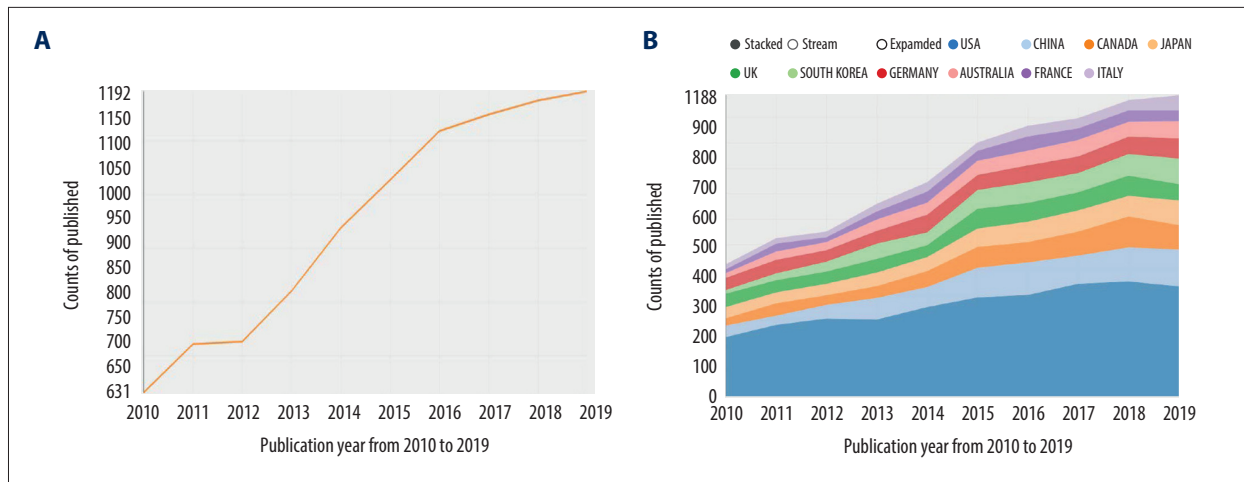


Figure 1. The number and linear growth trends of academic publications (A) and the top 10 countries/regions (B) for cardiopulmonary resuscitation research from 2010 to 2019.

Table 1. The top 10 countries/regions and institutions contributing to publications in cardiopulmonary resuscitation research.

Rank	Country/region	Article counts	Centrality	Institutions	Article counts	Centrality	Total number of citations	Average number of citations	Total number of first authors	Total number of first author citations	Average number of first author citations
1	USA	3653	0.12	Univ Penn	606	0.11	9204	15.19	134	1612	12.03
2	Canada	706	0.05	Univ Washington	509	0.14	7642	15.01	118	1131	9.58
3	Japan	657	0.01	Univ Toronto	461	0.02	4970	10.78	59	468	7.93
4	China	640	0.01	Univ Pittsburgh	424	0.12	5030	11.86	102	899	8.81
5	South Korea	615	0.07	Univ Michigan	303	0.03	4875	16.07	50	534	10.68
6	Germany	614	0.02	Children's Hosp Philadelphia	286	0.08	3297	11.53	67	646	9.64
7	England	579	0.12	Johns Hopkins Univ	282	0.06	2390	8.48	61	562	9.21
8	Australia	487	0.13	Seoul Natl Univ	271	0.07	1543	5.69	79	457	5.78
9	France	375	0.05	Mayo Clin	260	0.02	2261	8.70	65	335	5.15
10	Italy	345	0.10	Monash Univ	239	0.01	1954	8.18	56	443	7.91

less influence than we expected. The top 10 research institutions included the University of Pennsylvania (606), University of Washington (509), University of Toronto (461), University of Pittsburgh (424), and University of Michigan (303) (Table 1). However, the map of the CPR research network presented us with a low-density level (density=0.0267) (Figure 2A), which indicates that the teams devoted to CPR research are dispersed in various institutions throughout the world and deeper cooperation is needed. In addition, we used network analysis to confirm the relationship of collaboration between countries, and we found that the most frequent cooperation occurred

between the United States and Canada, followed by the United States and China (Figure 2B).

Until 2019, 1150 journals have included articles on CPR research. The top 10 most active journals published 3292 articles, which accounted for 34.42% of the 9563 articles on CPR in our research. Table 2 lists the top 10 journals, sorted by article counts. Of the top 3 journals, *Resuscitation* alone accounted for almost 17.69% of the articles, which far exceeded the other 2 journals. However, in terms of impact factor (IF), *Circulation* was in first place (23.054), followed by *Critical Care*

Table 2. The top 10 most active journals publishing articles in cardiopulmonary resuscitation research (sorted by count).

Rank	Journal title	Article counts	Percentage (N/9563)	IF (2018)	Quartile in category (2018)	H-index	Total number of citations	Average number of citations
1	Resuscitation	1691	17.69%	4.572	Q1	66	20077	11.87
2	American Journal of Emergency Medicine	369	3.86%	1.651	Q2	38	1275	3.46
3	Critical Care Medicine	227	2.37%	6.971	Q1	87	3395	14.96
4	Circulation	192	2.01%	23.054	Q2	165	9100	47.95
5	Critical Care	156	1.63%	6.959	Q1	81	1329	8.52
6	Scandinavian Journal of Trauma Resuscitation & Emergency Medicine	144	1.51%	2.556	Q1	32	652	4.53
7	PLoS One	141	1.47%	2.776	Q2	176	334	2.37
8	Pediatric Critical Care Medicine	135	1.41%	2.798	Q2	41	693	5.13
9	Prehospital Emergency Care	124	1.29%	2.557	Q1	30	603	5.15
10	Emergency Medicine Journal	113	1.18%	2.307	Q2	38	573	5.07

Medicine (6.971), *Critical Care* (6.959), *Resuscitation* (4.572), and *Pediatric Critical Care Medicine* (2.798). Meanwhile, the Journal Citation Reports assessment system, which is also an important evaluating tool and method for SCI journals, divided journals into 176 different subject categories and classifies them into quartiles, according to the level of a journal's impact factor. Our study results showed that all top 10 journals were classified as either Q1 or Q2, which means that these journals likely have a strong influence on research about CPR.

The top 10 most productive authors of all the 32 810 authors identified in the current study are shown in Table 3; the top 3 were Robert A. Berg, who ranked first with 160 articles; Vinay M. Nadkarni, 144 articles; and Clifton W. Callaway, 100 articles. The top 2 authors have different affiliations, but are in the same region: separately, Center for Resuscitation Science at the University of Pennsylvania and the Children's Hospital of Philadelphia.

Next, the networks of citation information for authors (Figure 3A) and co-cited authors (Figure 3B) were visualized with CiteSpace software. Our research output showed that Jerry P. Nolan with 1343 co-citation counts was in first place among the top 10 co-cited authors, followed by Robert W. Neumar (1078), Gavin D. Perkins (1012), Graham Nichol (909), and Mary Ann Peberdy (985) (Table 3). Of all the values of centrality among the top 10 productive authors, only 2 scholars, Jerry P. Nolan's (0.18) and Vinay M. Nadkarni's (0.11) were more than 0.1, which implies that both of them have made outstanding achievements in the fields of CPR research and have provided crucial foundation for follow-up scientific studies.

The top 10 co-cited articles with cited frequency, half-life, article, and research types are listed in Table 4. Among these articles, most were published in *Resuscitation* and *Circulation*, which have always been the most influential and authoritative journals in the fields of critical and cardiovascular medicine. In addition, these top 10 articles are considered as clinical instruction in CPR research.

The visualization of keywords co-occurrence network-based methods was applied successfully in the 9563 scholarly articles to screen out 256 keywords from a total of 17 093 samples. The selection criteria included a keyword having a minimum of 60 occurrences, and the keywords were then classified into 6 clusters via VOSviewer (Figure 4).

Co-citation and cluster analysis of CPR research

To identify CPR-related research hotspots, we created a co-citation and clustered network from 1356 references (not excluding duplicates) cited in the 9563 learning-manuscripts and mapped via CiteSpace in a hierarchical order (Figure 5A). In addition, in this special network, the size of each cluster was composed of different node types representing the number and centrality of co-cited references. The representative citations displayed the major research topics and thematic concentrations of each cluster. As shown in Figure 5A, the co-cited references clustered into 9 major cluster labels, including therapeutic hypothermia, treatment recommendation, OHCA, chest compression, AHA guideline, and so forth. In addition, Figure 5B shows the clear co-citation network in a timeline

Table 3. The top 10 most productive authors and co-cited authors contributed to publications in cardiopulmonary resuscitation research (sorted by count).

Authors	Years	Journal	Cited frequency	Half-life	Title	Article type	Research type
Nichol G	2008	JAMA – J Am Med Assoc	535	5	Regional variation in out-of-hospital cardiac arrest incidence and outcome	Article	Prospective observational study
Peberdy MA	2010	Circulation	444	5	Part 9: Post-Cardiac Arrest Care 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care	Article	Guideline
Neumar RW	2010	Circulation	370	5	Part 8: Adult Advanced Cardiovascular Life Support 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care	Article	Guideline
Neumar RW	2008	Circulation	341	5	Post-Cardiac Arrest Syndrome Epidemiology, Pathophysiology, Treatment, and Prognostication A Consensus Statement From the International Liaison Committee on Resuscitation	Editorial Material	Guideline
Berg RA	2010	Circulation	309	5	Part 5: Adult Basic Life Support 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care	Article	Guideline
Nolan JP	2010	Resuscitation	279	5	European Resuscitation Council Guidelines for Resuscitation 2010 Section 1 Executive summary	Article	Guideline
Perkins GD	2015	Resuscitation	240	3	European Resuscitation Council Guidelines for Resuscitation 2015 Section 2. Adult basic life support and automated external defibrillation	Article	Guideline
Abella BS	2005	JAMA – J Am Med Assoc	188	6	Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest	Article	Prospective observational study
Jacobs IG	2011	Resuscitation	160	4	Effect of adrenaline on survival in out-of-hospital cardiac arrest: A randomised double-blind placebo-controlled trial	Article	Randomized Controlled Trial

view, and the top 6 have higher degrees of citation bursts. Meanwhile, it is obvious that the central points in CPR research have shifted from a concentration on brief treatment principles to pursuing technical means for life support and standardization of the CPR process.

A burst detection algorithm is designed to identify the emerging concepts in professional terminology. We used the keywords from the 9563 articles identified in the WoSCC database search and listed the top 25 of 98 keywords with the strongest citation bursts (Figure 6). The timeline with a sky-blue background

color is divided by year, and once a subject has been found to “burst,” it is marked in red on the blue timeline to signify the beginning and ending years and the duration of the burst.

Although the number of keywords with the most robust citation bursts approached 100, not all of them had real significance in clinical practice. Figure 6 shows those that specifically pertain to research trends for CPR. Throughout 2010 to 2019, VF had the highest burst strength (26.6972), followed by targeted temperature management (TTM, 24.9031), cardiopulmonary resuscitation (22.4629), mild hypothermia (20.5559),

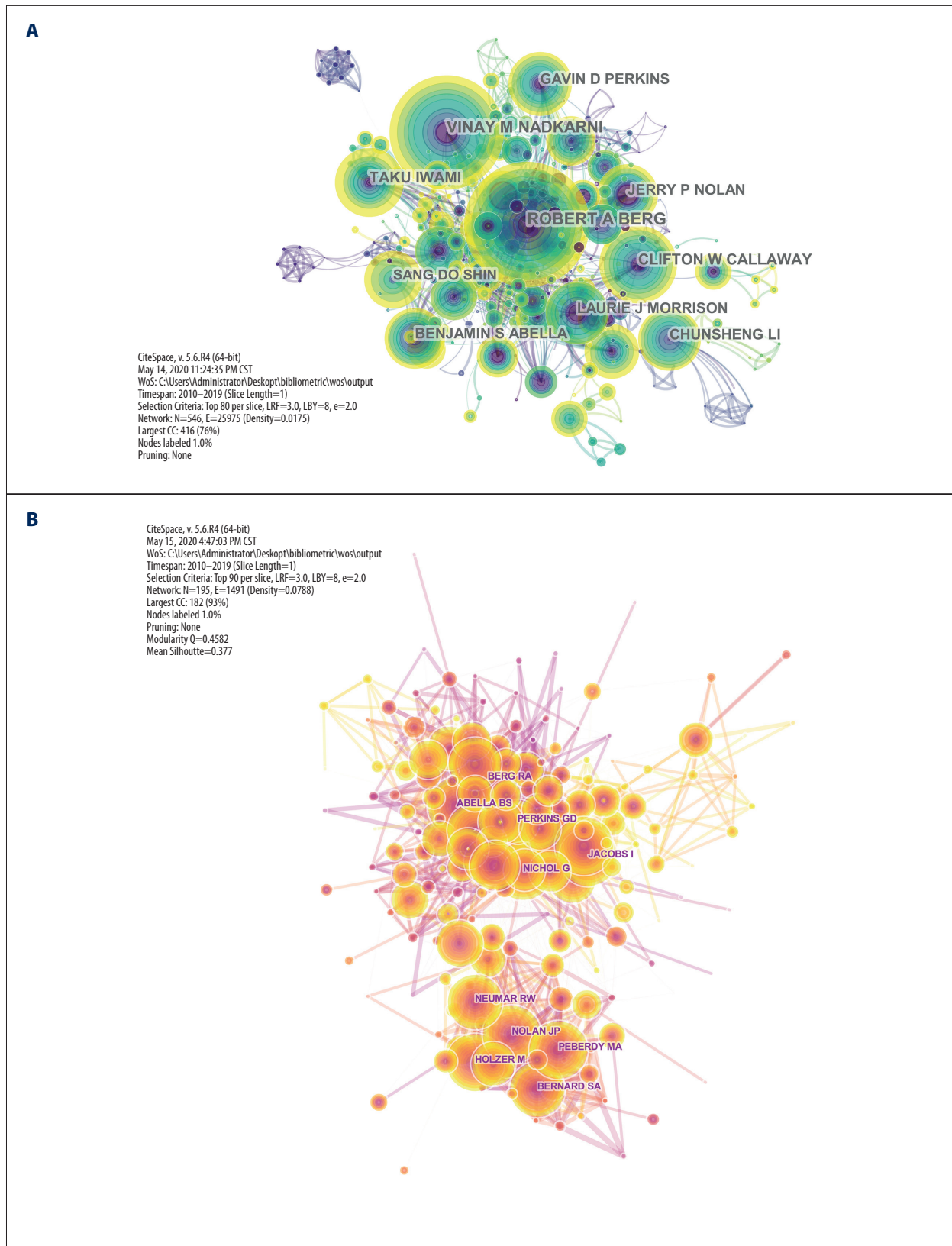


Figure 3. The network map of the most productive authors (A) and the most frequently cited authors (B) who participated in cardiopulmonary resuscitation research.

Table 4. The top 10 co-cited authors and their co-cited articles (sorted by cited frequency).

Rank	Author	Article counts	Centrality	Total number of citations	Average number of citations	First author counts	First author citation counts	Average first author citation counts	Corresponding author	Corresponding author citation counts	Co-cited author	Citation counts	Centrality
1	Berg RA	160	0.08	5495	34.34	5	424	84.8	9	120	Nolan JP	1343	0.04
2	Nadkarni VM	144	0.11	3778	26.24	1	12	12	1	3	Neumar RW	1078	0.01
3	Callaway CW	100	0.09	4585	45.85	5	456	91.2	6	118	Perkins GD	1012	0.14
4	Morrison LJ	92	0.03	3963	43.08	9	275	30.56	10	75	Nichol G	990	0.20
5	Iwami T	91	0.04	1885	20.71	2	88	44	33	1029	Peberdy MA	985	0.02
6	Perkins GD	90	0.05	2191	24.34	11	682	62	25	382	Jacobs I	895	0.03
7	Li CS	89	0	378	4.25	0	0	0	86	372	Bernard SA	843	0.08
8	Shin SD	84	0.06	690	8.21	0	0	0	24	358	Abella BS	788	0.07
9	Nolan JP	83	0.18	3200	38.55	18	804	44.67	19	669	Holzer M	787	0.04
10	Abella BS	79	0.02	1789	22.65	3	19	6.33	17	212	Berg RA	786	0.05

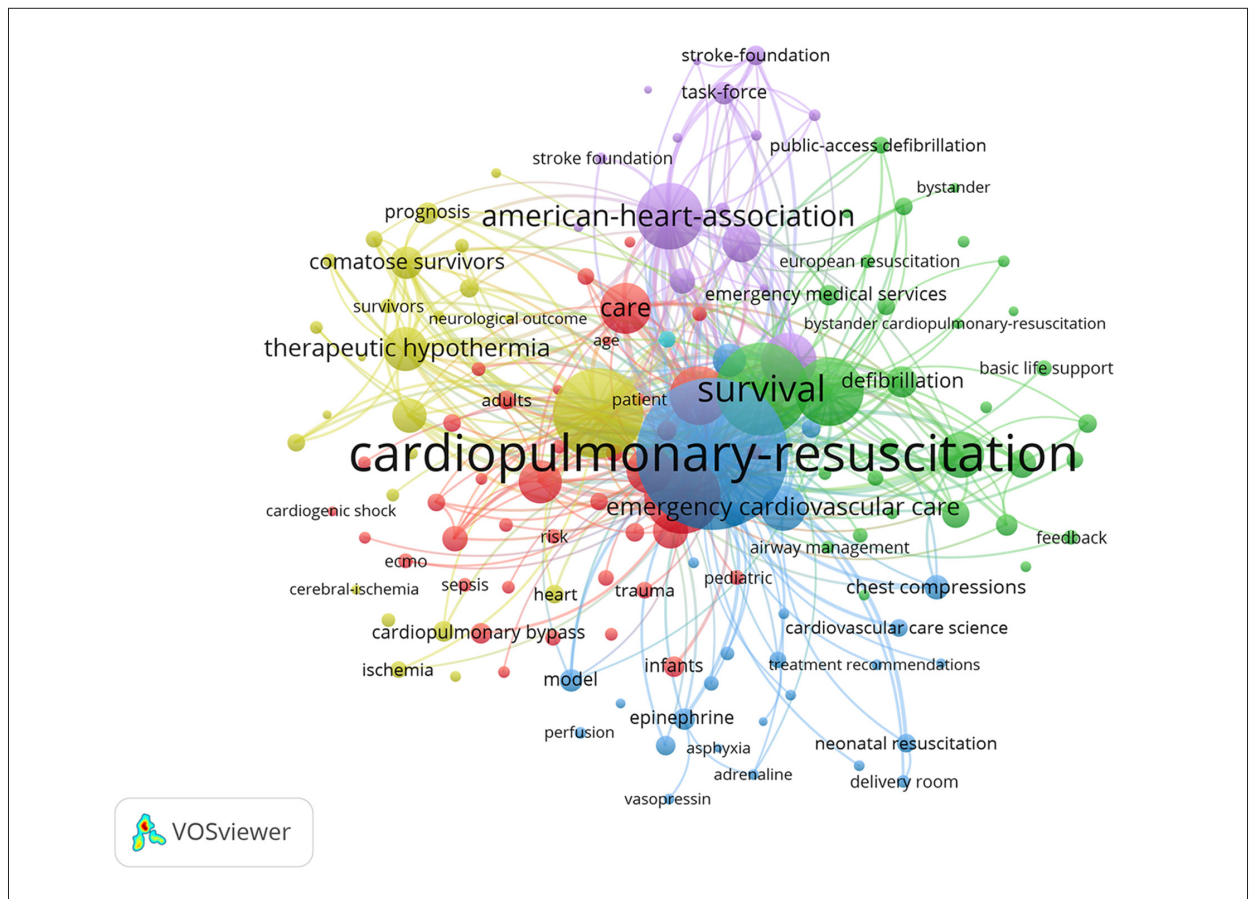


Figure 4. The network map of keyword clustering showed 256 keywords from a total of 17 093 samples with a minimum of 60 occurrences and classified into 6 clusters.

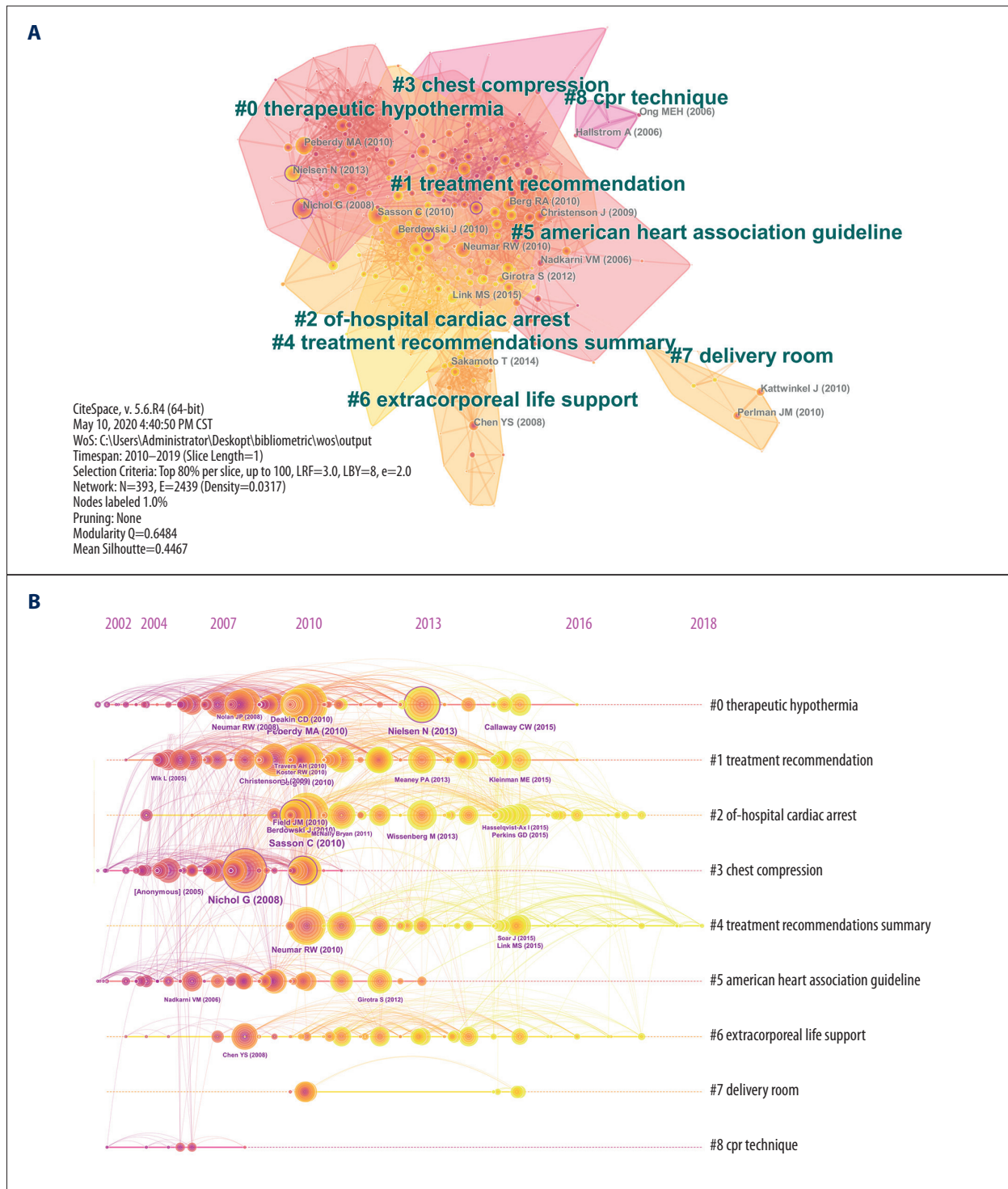


Figure 5. The clustered network map of co-cited references on cardiopulmonary resuscitation research (A) and the timeline view of co-citation clusters with their cluster labels on the right (B).

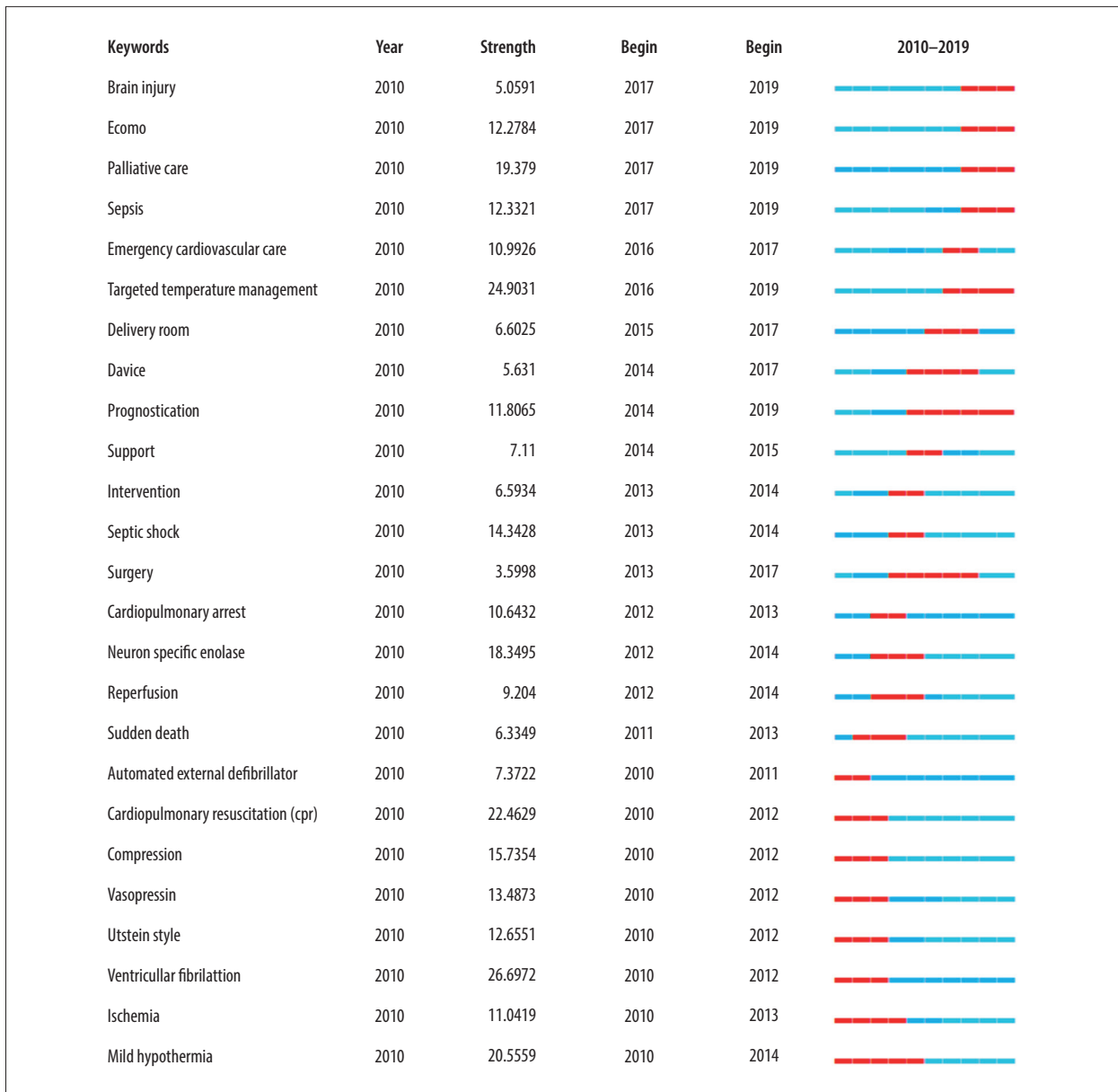


Figure 6. Keywords with the strongest citation bursts in original articles on cardiopulmonary resuscitation research activities published from 2010 to 2019.

and palliative care (19.379). In terms of the beginning year, of the last 8 keywords at the bottom of Figure 6, aside from the 3 with the strongest burst strength, the rest included compression, vasopressin, Utstein style, ischemia, and automated external defibrillator were the focus of CPR research. In the ensuing years, some keywords had only a short-term burst, such as sudden death, reperfusion, neuron specific enolase, and septic shock, among others. Regardless of the beginning year of bursts, however, plenty of bursts have continued until 2019, including prognostication, TTM, and some that emerged in 2017 (i.e., sepsis, palliative care, extracorporeal membrane oxygenation [ECMO], and brain injury).

Discussion

The visualization functions of CiteSpace, VOSviewer, and the Online Analysis Platform of Literature Metrology enabled conducting a bibliometric analysis of original articles involving in CPR research over the past decade. The analysis clearly showed a growing trend in the number of scientific articles published on the topic from 2010 through 2019. From this, we find that CPR has gradually become an important subject in fields of related research. Furthermore, we also find that the burst of studies during the most recent 10 years has mainly varied with the quinquennial updates of authoritative clinical guidelines,

particularly those developed by the AHA-led International Liaison Committee on Resuscitation since 2000. Obviously, the development of CPR-related technology is a driving force for this research, but more importantly, thousands of scholars and researchers have gained a deeper understanding of the epidemiology, pathophysiology, treatment, and prognostication about CPR-related illnesses and complications as well as strengthened the role of evidence-based medicine.

An analogous conclusion can also be drawn from the rank of the journals with the largest number of articles published on CPR. As shown in Tables 2 and 4, the journals with enormous influence in emergency/critical care and cardiovascular medicine were predictably the most prominent in our analysis: the overwhelming majority of the articles appeared in *Resuscitation* and *Circulation*, which are the publications in which significant guidelines are reported. In addition, since 1974, clinical guidelines for CPR have been constantly updated through intense discussions of new advances in the field of CPR research and problems discovered from the implementation of older guidelines. This process promotes global professional training and the popularization of CPR. Therefore, most of the top 10 co-cited articles were instructive expert consensuses on the dynamic changes of representative hot topics, such as the necessity of improving the quality of CPR during IHCA or OHCA; consensus statements on the impact of post-CA syndrome (PCAS); and discussion of the ongoing improvement in treatment strategies and technology of basic or advanced cardiac life support and their impact on CPR prognosis [12–17].

By combining the keyword co-occurrence and co-citation cluster analysis (Figures 3, 4A, 4B), it is not difficult to find that treatment recommendation (e.g., therapeutic hypothermia, an important part of care bundle), authoritative and instructive guidelines (AHA and emergency cardiovascular care), CPR technical means (extracorporeal life support and chest compressions), and prognostication (survival and prognosis) have always been central topics of investigations on CPR. Furthermore, as previously mentioned, VF and TTM have attracted considerable research attention in the past decade, but since 2017, sepsis, palliative care, ECMO, and brain injury have become the novel foci (Figures 5, 6). This shift could be explained by issues related to patient-specific pathophysiology having been solved through new techniques, so scholars have started to pay more attention to risks that threaten long-term survival of patients. Keyword bursts with the most strength and prominence can reveal recent trends and hotspots in CPR research.

VF has been considered to be a leading pathogenesis of sudden cardiac arrest, in or out of the hospital, but definitely more emergent and dangerous in OHCA [18]. Thus, a great amount of research and constantly updated guidelines during the past decade have focused on VF-related pathophysiology

and explored how to correct the progress of VF and reduce the associated damage via a feasible first-aid strategy [4,7,19]. Recently, awareness and utilization of AEDs have unambiguously increased, but even so, the overall survival from CA remains low. Ample animal experiments and clinical trials support previous findings that showed improved survival to hospital discharge when CPR was provided for a prescribed time period before defibrillation rather than an immediate shock approach in patients with OHCA due to VF [13,20,21]. Moreover, as mentioned in a section of recent guidelines of the European Resuscitation Council, patients failing to receive early defibrillation can still benefit from effective chest compression provided by bystanders than those without CPR, although averaging 3% to 4% decline in survival per minute delay to defibrillation [16]. Meanwhile, assessment of the success of defibrillation is also indispensable to the process of CPR of sudden cardiac arrest resulting from VF. Most recently, a study has proposed that VF waveform measures combined with prior shock outcome may make possible prediction of defibrillation success during CPR [22].

TTM, also known as therapeutic hypothermia, was a new treatment concept first proposed by Holzer in 2010 [23]. Throughout the ensuing decade, TTM has been identified as a therapeutic intervention to limit neurologic injury after a patient's resuscitation from CA, and it gradually became a central point of PCAS care research owing to concerns arising from equal outcomes from 2 clinical studies that used profoundly distinct target temperature levels [24]. In addition, a notable divergence has been identified via meta-analyses. Specifically, more recent meta-analyses showed that TTM may not improve mortality or neurological outcomes in postarrest survivors, while the great majority of previous studies indicated consistency with current best medical practice as recommended by international resuscitation guidelines [25–28]. Nevertheless, most current guidelines persist in recommending that all adult comatose survivors of OHCA with an initial shockable cardiac rhythm should receive TTM with a selected and constant temperature between 32°C and 36°C [3,29,30]. Hence, employing therapeutic hypothermia as a standard of care strategy of postarrest care in survivors may need to be reevaluated by more persuasive research evidence in the years to come.

The subtle relationship between palliative care and CPR, as an extremely controversial ethical issue, began to be explored more deeply and to provoke ongoing debate early in the 21st century. Despite palliative care and CPR appearing to be incompatible and mutually exclusive, the related national council and association of palliative medicine guidelines have stated that CPR is relevant in palliative care if the quality of a patient's life could be promoted [31]. A review published in 2013 concluded that CPR is futile for in-hospital cancer patients with widespread incurable disease and poor performance status,

and there is a trend for survival to decline with increasing extent of the cancer disease [32]. In addition, as the “do not attempt cardiopulmonary resuscitation” decisions have become embedded into clinical practice in the United Kingdom, recent studies concentrate more on the decisive role of patients’ autonomy on decision making, which is especially prominent in this policy [33–35]. Consequently, ongoing research is laying further stress on the feasibility of CPR in light of different populations in palliative care clinical practice.

Venoarterial ECMO, which evolved as a salvage therapeutic tool in CPR situations refractory to medical treatment including ECMO and cardiopulmonary bypass and is referred to as extracorporeal cardiac life support (ECLS) or extracorporeal cardiopulmonary resuscitation (ECPR), has been applied to striving for additional time to treat reversible underlying causes of CA over the past years, especially in patients with OHCA [5,36–38]. Moreover, Matsuoka et al. [39] recently conducted a population-based cohort study and clearly showed that hospitals’ ECPR capabilities are associated with favorable neurologic outcomes in OHCA patients who had refractory VF or pulseless ventricular tachycardia. This positive result has been demonstrated in many other meta-analyses [40–42] and a current case report [43]. However, in a nationally representative cross-sectional study, researchers found that patients hospitalized with CA who received ECMO had significantly higher mortality than those who did not [44]. This was no doubt different from the outcomes reported in studies on OHCA and IHCA. Thus, in the near future, conducting more high-quality evidence RCTs to identify the actual prognosis and survival of patients for whom ECMO is used, regardless of OHCA or IHCA, might be the new research focus of CPR treatments driven by emerging extracorporeal technologies.

In addition to the keywords mentioned above, sepsis/septic shock-associated CA and brain injury, which are always likely to have a worse prognosis than CA without sepsis, are also drawing increased attention. As early as 2011, sepsis was considered to be a potential prearrest predictor of mortality after IHCA in a meta-analysis, even though many broad-scale studies have not demonstrated prearrest sepsis as a predisposing factor for IHCA, and epidemiological data on sepsis-associated CA are limited [45,46]. Hereafter, aiming to describe the prearrest period in severe sepsis and septic shock more clearly and in greater detail, a more representative experimental swine model of human CA and CPR has been successfully made [47]. In addition, an increasing number of research studies have begun to focus on the long-term survival rate after a prearrest sepsis and multiorgan dysfunction inducing IHCA, and conclusions are in accordance with short-term outcomes [48–50]. Nevertheless, owing to the complexity of a combined effect generated by the pathophysiology of ongoing septic shock and PCAS and the higher rates of mortality with

sepsis-associated IHCA, high-quality CPR and other traditional interventions or care are insufficient. More research should target sepsis-related pathophysiology before, during, and after CA in order to improve patient outcomes [46].

Interestingly, either severe sepsis or PCAS can lead to systemic inflammation or ischemia-reperfusion injury and finally cause some extent of brain injury, even developing into irreversible damage or brain death [46,51]. Meanwhile, a bibliometric analysis spanning 25 years has shown that *Critical Care Medicine* and *Resuscitation*, both universally acknowledged as international and domestic journals publishing the most articles on CPR, were also listed among the top 5 journals focusing on brain death [52]. Although there a great quantity of studies have covered a variety of potential factors that affect, assess, or predicate prognostication after CA (e.g., the length of CPR, electroencephalography, serum biomarker), the AHA writing group still determined that the overall quality of existing neurological prognostication studies and the degree of confidence in the predictors remain low [53–56]. Therefore, how to improve the quality of neurological prognostication in patients who survive CA has become the crux of the ensuing studies on CPR-related brain injury.

Conclusions

In this article, the graphs and charts formed by CiteSpace, VOSviewer, and the Online Analysis Platform of Literature Metrology showed that our understanding of CPR has markedly advanced during the past decade. Our intention was to assess past research on CPR and to predict new trends and hot topics in specific subjects and subfields. We conclude that scientific research on CPR not only focuses on therapeutic means, but is also adopting a public health practice perspective. Ultimately, the results may also foster future studies.

Strengths and limitations

Our study is the first bibliometric analysis specifically on CPR research activities. In contrast with traditional analyses, our analysis, which was based on professional bibliometric software, displays a better status of CPR research hotspots and trends, despite some limitations. First, only original articles and reviews were included. Second, some words were counted more than once because of their multiple expressions. Finally, as a result of the highly cited guidelines in the field of CPR, the accuracy of top co-cited authors and their articles was inevitably reduced.

Conflict of interests

None.

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