Review

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Knowledge mapping and research trends on perioperative neurocognitive disorder from 1990 to 2022: a bibliometric analysis

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Introduction: Perioperative neurocognitive disorder (PND) has attracted consistently increasing attention worldwide. However, there are few bibliometric studies that systematically evaluate this field. This study aimed to visualize the knowledge structure and research trends in PND through bibliometrics to help understand the future development of basic and clinical research.
Methods: Literature related to PND in Web of Science and PubMed from 1990 to 2022 were collected through keywords retrospectively. Additionally, the source information, citation information, etc. of these publications were extracted. Finally, bibliometric analysis was performed by visualization software and statistical software.
Results: There were 2837 articles and reviews in total. An exponential rise in PND-related publications was observed. China had the most publication, followed by the US and Germany. The institution with the most output and citations was Harvard University (149 papers, 8966 citations). The most prominent author was Marcantonio Edward R with 66 publications and 5721 citations. The journal with the highest productivity for PND research was *Frontiers in Aging Neuroscience* followed by *Anesthesia and Analgesia*. Keywords were identified as six topics, including postoperative delirium, postoperative neurocognitive disorder, cardiac surgery, anaesthesia, orthopedic surgery, and dementia. According to keyword analysis, the most recent popular keywords in PND research were prevention, older patients, emergence delirium, orthopedic surgery, and dexmedetomidine.
Conclusions: Publications on PND are increasing at an alarming rate from 1990 to 2022. Current research and future trends will concentrate on the prevention and treatment of PND, as well as PND associated with orthopedic surgery in older adults.

Keywords: bibliometrics, CiteSpace, hotspots, perioperative neurocognitive disorder, research trends, VOSviewer

Introduction

Perioperative neurocognitive disorder (PND) is a serious cognitive dysfunction and is recommended as a collective name for preoperative and postoperative cognitive impairment, including preoperative cognitive decline, postoperative delirium (POD), delayed neurocognitive recovery, and mild or major postoperative neurocognitive disorder (POCD)[1]. With the increased aging of the population and ongoing advancements in surgical and anaesthetic methods, progressively sicker and older patients are receiving functional and life-saving treatments. Unfortunately, many of these debilitated individuals, particularly those who have had orthopedic and cardiac surgery, will develop PND[2,3]. POD incidence ranged from 13.2 to 41.7%, and POCD incidence ranged from 8.9 to 46.1%[4], while the incidence could be higher in older patients[5]. In addition, PND is frequently linked to prolonged hospitalization, as well as increased treatment costs, readmission rates, dementia, and mortality[6]. However, the pathogenesis and pathophysiology of PND are not fully understood, and effective management options are still lacking.

A thorough, retrospective bibliometric study is necessary to comprehend the evolution of research subjects, characterize the

HIGHLIGHTS

- This study conducted a comprehensive bibliometric analysis of global publications on perioperative neurocognitive disorder (PND) from 1990 to 2022 and visualized the knowledge structure and research trends in PND.
- PND has attracted consistently increasing attention worldwide. The number of publications about PND was increasing exponentially. Publications were mainly concentrated in North America, Europe, and East Asia.
- The prevention and treatment of PND and orthopedic surgery-related PND in elderly patients are considered to be current hotspots and important research directions for the future.

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global knowledge network, and further investigate research trends on PND research because of the rise in PND-related publications from all over the world in recent years. In comparison to systematic reviews, bibliometric methods could provide a more objective and systematic assessment in a certain domain. It has found widespread application in psychiatry[7,8] and other medical specialties[9–11]. In a recent study, Grever *et al.*[8] conducted bibliometric research to evaluate the overall contours and publishing characteristics of the literature related to delirium from 2001 to 2020. Ji *et al.*[12] reviewed the research status, potential hotspots, and trends of predictive markers related to neurocognitive dysfunction after cardiac surgery through bibliometric analysis. Mi *et al.*[13] analyzed the characteristics of the top 100 publications about PND up to 2020. However, this study could not provide a comprehensive overview due to the limited number of articles. Yao *et al.*[14] conducted a comprehensive bibliometric analysis of PND and found that neuroinflammation has been a hot topic of research in recent studies. Yet, the data of this study only came from the Web of Science database, which may have the issue of data omission. Therefore, the goal of the current study was to thoroughly analyze the scientific papers on PND published between 1990 to 2022 in order to assess the state of the field, map out the existing body of knowledge, and forecast future directions.

Material and methods

Data collection and search strategy

All data were collected from the Web of Science (www.webofscience.com) and PubMed (https://pubmed.ncbi.nlm.nih.gov) databases[15,16]. The search process is displayed below: TI = ("cognitive dysfunction*" OR "cognitive Impairment*" OR "cognitive deficit*" OR "cognition disorder*" OR "cognitive Decline*" OR "neurocognitive disorder*" OR delirium*) and TI = (surger* OR surgical* OR *operati* OR an*esthe*). The articles' language was left unrestricted. The publication date of the papers was only valid from 1990 until 2022. The publication type was selected as original articles and reviews, and the duplicated literature was removed (Fig. 1). In the end, 2837 reviews and original papers were collected for bibliometric analysis.

Data analysis

To guarantee the correctness and dependability of the findings, two separate researchers extracted the data. Any differences of opinion were debated until an agreement was reached. The information collection process and the application of the software were referred to our previous literature[9,16]. In the bibliometric analysis, visualization tools including VOSviewer (Version 1.6.14), CiteSpace (Version 5.8.R3), and Scimago Graphica were employed. IBM SPSS 26.0 was used to perform the statistical analysis (IBM Corp.). Spearman's correlation coefficient was used to determine the degree of correlation between continuous variables. P less than 0.05 was considered statistically significant. In this study, the top 10 contributing countries, institutions, journals, and authors are highlighted, and they are sorted by the number of publications. The publication profiles of countries, institutions, journals, and authors were descriptive, while the identification of trends and themes and the collaboration network analysis were exploratory.

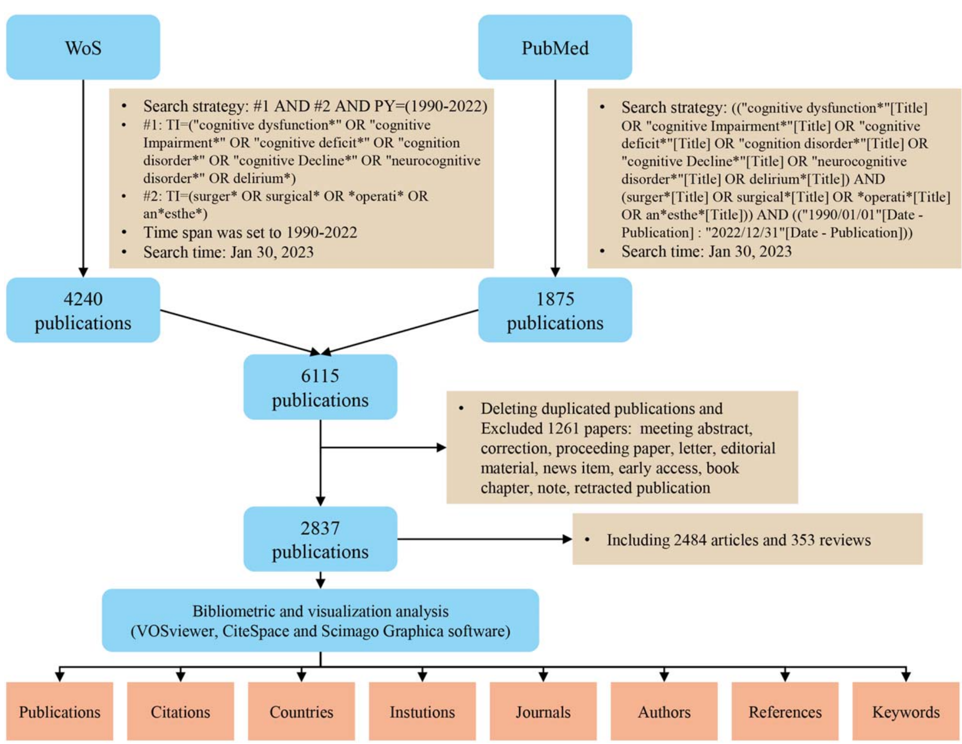

Figure 1. Flowchart of the present study.

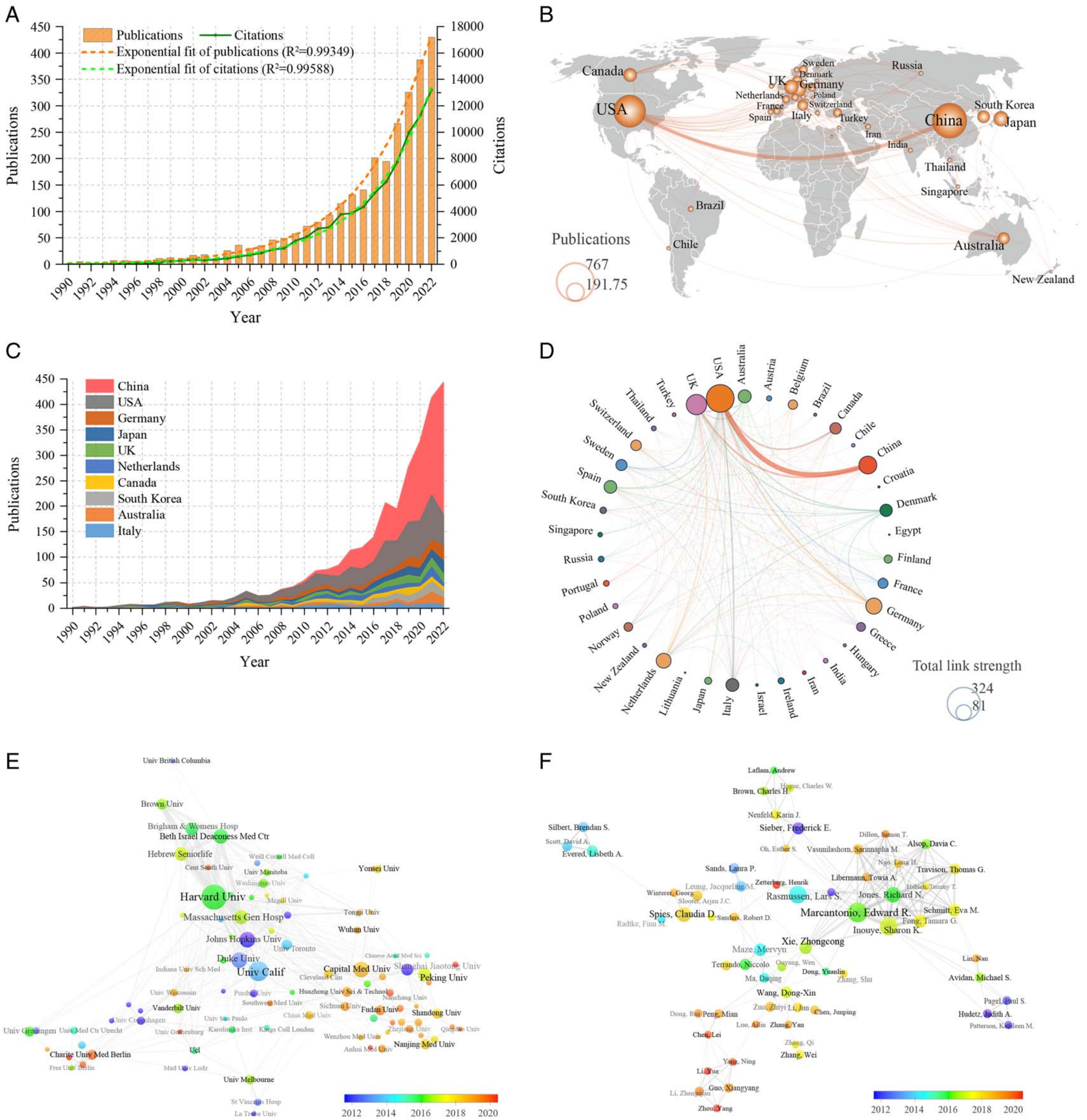

Figure 2. Visualization of publication characteristics and collaboration network. (A) Trends in annual citations and publications about perioperative neurocognitive disorder over the past 30 years. (B) World distribution of publications. The size of the node indicates the number of papers. (C) Trends in annual publications for the top ten countries. (D–F) Map of the collaboration network among countries, institutions, and authors. The size of the circle represents the total number of collaborations, while the width of the lines connecting two nations, organizations, or writers denotes the degree of collaboration. Nodes are presented by different colours according to the average appearing year.

Results

Trends in publications and citations

Ultimately, 2837 papers were examined, comprising 2484 (87.6%) original articles and 353 (12.4%) reviews. Almost all were English publications (2776, 97.8%), followed by German (28, 1.0%). Figure 2A displayed the precise distribution of PND research articles each year. It is evident that there has been an exponential increase in the number of yearly publications and citations. From 2010 onwards, all annual publications exceeded 50 articles, with a total of 2498 articles (88.1%). In terms of citations, the total number of citations (TC) for all papers was

Table 1

Top 10 countries and institutions with the most publications

Rank	Country/institution	TP	TC	AC	HI
	Country				
1	China	1028	14 288	13.90	52
2	USA	718	36 199	50.42	95
3	Germany	185	6965	37.65	36
4	Japan	168	3599	21,42	34
5	UK	159	10 674	67.13	49
6	Netherlands	133	8148	61.26	44
7	Canada	121	5771	47.69	43
8	South Korea	108	1475	13.66	20
9	Australia	101	3343	33.10	33
10	Italy	76	2584	34.00	28
	Institution				
1	Harvard University	149	8966	60.17	47
2	University of California System	98	6682	68.18	38
3	Beth Israel Deaconess Medical Center	88	5624	63.91	38
4	Capital Medical University	76	841	11.07	16
5	Johns Hopkins University	65	2927	45.03	31
6	Duke University	64	3310	51.72	30
7	Massachusetts General Hospital	65	2184	33.60	24
8	Free University of Berlin	58	1827	31.50	18
9	Brigham & Women's Hospital	57	4740	83.16	31
10	Charité Universitätsmedizin Berlin	57	1824	32.00	18

AC, average number of citations; HI, Hirsch index; TC, total number of citations; TP, total number of publications.

83503 (54851 after self-citations were removed). In addition, the average number of citations (AC) for every article was 29.43. The Hirsch index (HI) for PND studies was 124.

Knowledge networks worldwide

Countries/regions

A total of 60 countries have participated in the PND research. The bulk of the publications was made by scholars from North America, Europe Oceania, and East Asia, as can be seen from the global map (Fig. 2B). Particularly, China (1028 papers) and the USA (718 papers), which together account for 61.5% of the total number of publications (TP), are the two countries with the highest publications in this area (Table 1). Moreover, a strong positive link between the TP and Gross Domestic Product (GDP) was also discovered by this study ($r = 0.948$, $p = 0.001$). The USA dominated the number of articles on the subject until 2015, as seen in Fig. 2C, whereas China grew quickly starting in 2011 and eventually overtook the USA following that year. The collaboration among the various nations was depicted in Fig. 2D. The USA had the most international collaboration (330), followed by the United Kingdom (179) and China (135). Aside from that, China and the USA collaborated the most.

Table 2

The top 10 journals

Rank	Journal	TP	TC	AC	IF	JQ
1	Frontiers in Aging Neuroscience	75	462	6.16	5.702	Q2
2	Anesthesia and Analgesia	68	4392	64.59	6.627	Q1
3	British Journal of Anaesthesia	59	3507	59.44	11.719	Q1
4	BMC Anesthesiology	52	757	14.56	2.376	Q3
5	Anesthesiology	51	6405	125.59	8.986	Q1
6	Journal of the American Geriatrics Society	51	3296	64.63	7.538	Q1
7	Plos One	49	1441	29.41	3.752	Q2
8	Medicine	45	283	6.29	1.817	Q3
9	Journal of Clinical Anesthesia	41	695	16.95	9.375	Q1
10	Journal of Cardiothoracic and Vascular Anesthesia	40	1049	26.23	2.894	Q3

AC, average number of citations; IF, impact factor; JQ, journal quartiles; TC, total number of citations; TP, total number of publications.

Institutions

The top 10 producing institutions were listed in Table 1. Seven institutions in this list are from the USA, one from China, and two from Germany. Specifically, Harvard University ranked first with 149 articles and HI with 47, followed by the University of California System. In addition, Brigham & Women's Hospital had the highest average citation of 83.16. Ninety-six institutions published no less than 10 articles. The intricate and intimate collaboration among many institutions was illustrated in Fig. 2E. Harvard University-centred collaborations occurred most frequently, demonstrating the institution's significant influence. Additionally, a number of the organizations highlighted in red, including Charité Universitätsmedizin Berlin, Gothenburg University, Central South University, Qingdao University, Anhui Medical University, and Fudan University, were fresh additions to PND research in recent years.

Journals

In total, 531 (18.7%) articles were published in the top 10 list in Table 2. The most of articles were published in *Frontiers in Aging Neuroscience* (75), followed by *Anesthesia and Analgesia* (68), *the British Journal of Anaesthesia* (59), *BMC Anesthesiology* (52), and *Anesthesiology* (51). Half of the top ten scholarly journals were classified as Q1. *Anesthesiology* has the highest total citations (6405) and the average citations (125.59).

Overview of landmark articles and authors

Authors

The top ten productive authors were shown in Table 3, Marcantonio Edward R. from Beth Israel Deaconess Medical Center ranked first, followed by Inouye Sharon K. and Spies Claudia D. Inouye Sharon K., Fong Tamara G., and Schmitt Eva M. were from the same institution, Hebrew SeniorLife. It's interesting to observe that eight of these authors came from American institutions, while the remaining authors came from Danish and German organizations. The visual graph of the author's co-authorship (Fig. 2F) showed that most cooperation centred on Marcantonio Edward R., indicating his high influence. A few authors labelled in red, namely Zetterberg Henrik, Chen Lei, Yang Ning, Li Yue, and Zhou Yang, were new contributors to the PND study.

Top cited articles

The top ten articles on PND that received the most citations were shown in Table 4. These original articles received over 400 citations. Three of these articles were published in Anesthesiology. The top-ranked article had 1769 citations and was published in the Lancet (IF = 202.731)[17]. High co-cited references were visualized in a knowledge map in Fig. 3A. Out of all of these papers (Fig. 3B), Inouye and colleagues' work had the highest

Table 3

Top 10 most prolific authors on the research of perioperative neurocognitive disorders

Rank	Author	Affiliation of the author	TP	TC	AC	HI
1	Marcantonio, Edward R.	Beth Israel Deaconess Medical Center, USA	66	5721	86.68	33
2	Inouye, Sharon K.	Hebrew SeniorLife, USA	56	3889	69.45	28
3	Spies, Claudia D.	Charité Universitätsmedizin Berlin, Germany	43	1506	35.02	15
4	Jones, Richard Norman	Warren Alpert Medical School of Brown University, USA	37	2856	77.19	23
5	Rasmussen, Lars S.	Copenhagen University Hospital, Denmark	33	4577	138.7	23
6	Sieber, Frederick E.	Johns Hopkins Bayview Medical Center, USA	29	1531	52.79	18
7	Maze, Mervyn	University of California-San Francisco, USA	27	3095	114.63	18
8	Fong, Tamara G.	Hebrew SeniorLife, USA	26	1427	54.88	16
9	Schmitt, Eva M.	Hebrew SeniorLife, USA	25	1064	42.56	16
10	Xie, Zhongcong	Massachusetts General Hospital, USA	24	1049	43.71	15

AC, average number of citations; HI, Hirsch index; TC, total number of citations; TP, total number of publications.

citation burst[20]. The article by Aldecoa *et al.*[21] was in second place with a strength of 45.07.

Research hotspots and frontiers

Clusters of co-cited references

We obtained a total of 10 different clusters by the log-likelihood ratio algorithm[16,22], including neuroinflammation, dexmedetomidine, delirium, trauma, neuroleptics, predictive variables, postoperative cognitive dysfunction, complications hypoxaemia, postoperative recovery, vascular surgery. The cluster of neuroinflammation (#0) was ranked first, followed by dextromethorphan (#1) and delirium (#2), as shown in Fig. 3C. Additionally, such a timeline view can be used to analyze each cluster's evolution features. As seen, the cluster of dexmedetomidine (#1) has been and continues to be a prominent focus in PND research.

Analysis of keywords

We obtained the top twenty keywords through CiteSpace software[23], as presented in Fig. 4A. Among these keywords, the ones whose burst period continued to the present were prevention, older patient, emergence delirium, orthopedic surgery, and dexmedetomidine. Altogether, 452 keywords co-occurred over 8 times in the PND research field. These 452 keywords were classified into 6 clusters by the VOSviwer software (Fig. 4B). The clusters could be summed up as #1 POD, #2 POCD, #3 cardiac surgery, #4 anaesthesia, #5 orthopedic surgery, and #6 dementia based on the keywords in the groupings.

Discussion

The present work conducted a thorough and detailed bibliometric study of publications on PND research to capture the citation and publication characteristics, themes, and frontiers of PND research. We found that the TP and TC of PND were surprising and increasing over the last three decades (Fig. 2A). In other words, a growing interest in PND has been captured by scholars around the world. This tendency could be linked to the increasing incidence and prevalence of PND over the world, which is most likely owing to insufficient care and the shifting age composition of surgery patients[5,24].

Although 60 countries contributed to PND research, the TP from China and the USA exceeded 60%, which indicated that both China and the USA play a vital role in PND research. Notably, although being first in the TP, the TC, AC, and HI of Chinese publications were far lower than those of American publications (Table 1). Moreover, in terms of the TP, seven of the top ten productive institutions were from the United States, two from Germany, and one from China. Overall, high-income nations like the USA, Germany, the UK, Japan, the Netherlands, and Canada created the majority of the papers. According to our findings, there was a strong positive link between GDP and country outputs, demonstrating the importance of economic power in influencing scientific research. High-income nations

Table 4

Top 10 high-cited articles on the research of perioperative neurocognitive disorders

Rank	Authors	Year	Article title	Journal	TC
1	Moller *et al.*	1998[17]	Long-term postoperative cognitive dysfunction in the elderly: ISPOCD1 study	Lancet	1769
2	Monk *et al.*	2008[18]	Predictors of cognitive dysfunction after major noncardiac surgery	Anesthesiology	933
3	Steinmetz *et al.*	2009[19]	Long-term consequences of postoperative cognitive dysfunction	Anesthesiology	730
4	Saczynski *et al.*	2012	Cognitive trajectories after postoperative delirium	New England Journal of Medicine	696
5	Marcantonio *et al.*	1994	A clinical-prediction rule for delirium after elective noncardiac surgery	JAMA-Journal of the American Medical Association	656
6	Cibelli *et al.*	2010	Role of interleukin-1 beta in postoperative cognitive dysfunction	Annals of Neurology	581
7	Aldecoa *et al.*	2017[21]	European Society of Anaesthesiology evidence-based and consensus-based guideline on postoperative delirium	European Journal of Anaesthesiology	528
8	Terrando *et al.*	2010	Tumor necrosis factor-alpha triggers a cytokine cascade yielding postoperative cognitive decline	P Natl Acad Sci USA	526
9	Sikich *et al.*	2004	Development and psychometric evaluation of the pediatric anesthesia emergence delirium scale	Anesthesiology	496
10	Schagen *et al.*	1999	Cognitive deficits after postoperative adjuvant chemotherapy for breast carcinoma	Cancer	445

TC, total citations; P Natl Acad Sci USA, Proceedings of the National Academy of Sciences of the United States of America.

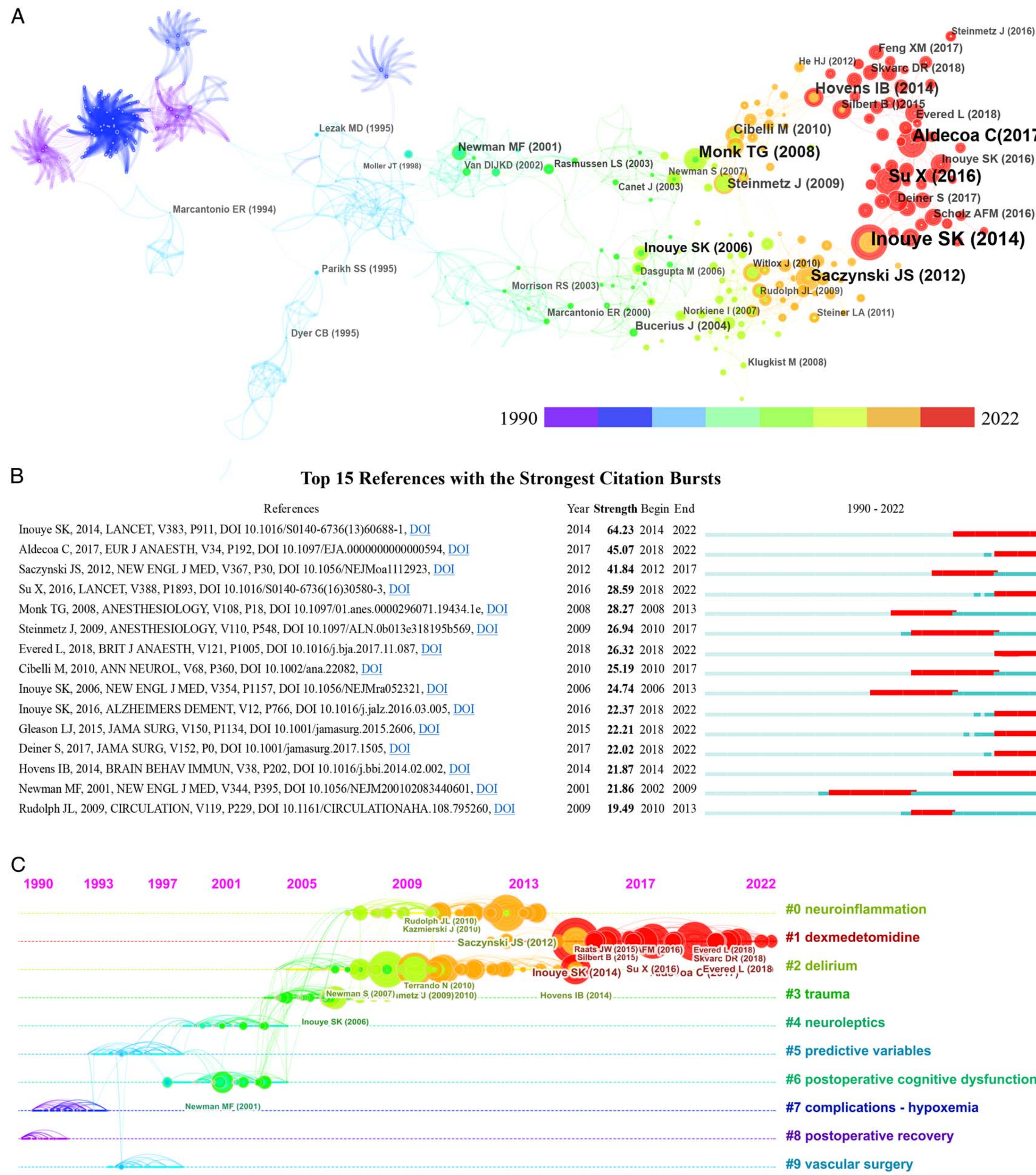

Figure 3. Visualization of the co-cited references analysis. (A) The co-cited reference knowledge map. The node size represents the number of co-citations. (B) The top 15 references with the strongest citation bursts. The red band in the graph indicates the burst time of the reference. (C) Timeline diagram of the clusters of co-cited references.

may allocate significant funding for scientific research[8,15,25]. In addition, there is a need to increase research output in developing countries, which is important because the prevalence and outcomes of PND vary in different settings.

Regarding publications and citations, the results from Marcantonio Edward R. (Beth Israel Deaconess Medical Center, USA) were very appealing (Table 3) with 66 papers and 5721 citations. Further evidence of Marcantonio Edward R.'s significant academic impact is provided by the sheer quantity of

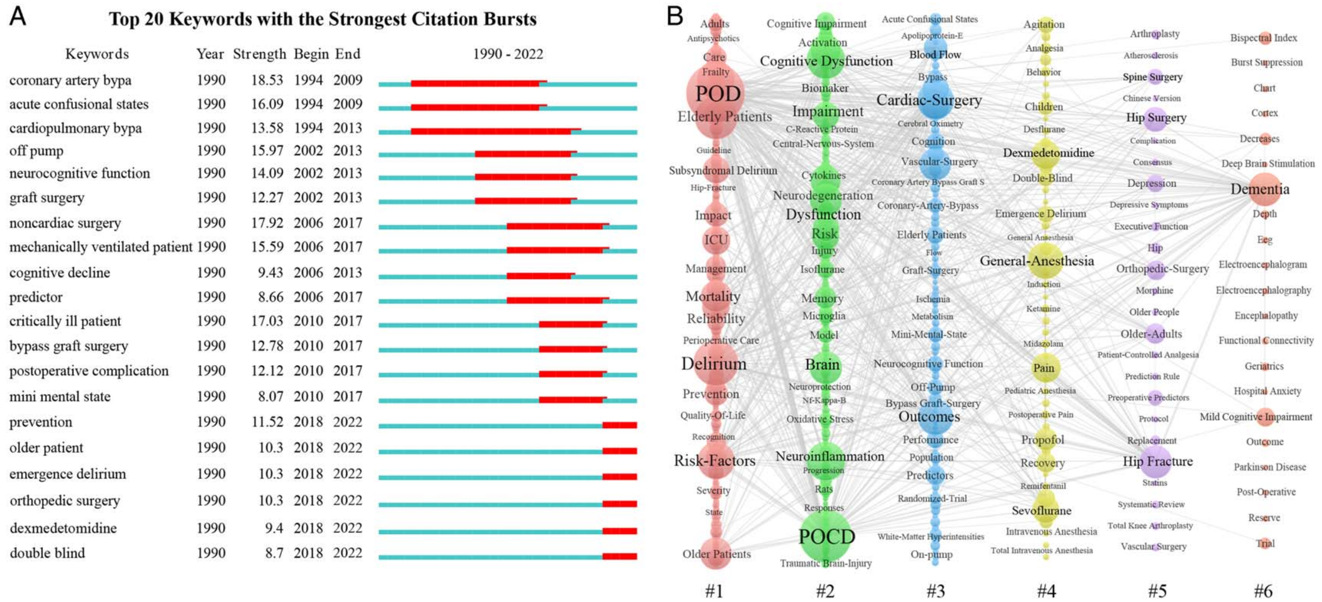

Figure 4. Visualization of the keywords analysis. (A) The top 20 keywords with the strongest citation bursts. (B) The clusters of keywords. The size of the nodes is positively proportional to the number of keyword occurrences; the width of the lines is positively proportional to the number of keyword co-occurrences. POCD, postoperative neurocognitive disorder; POD, postoperative delirium.

cooperation that was focused on him (Fig. 2F). Prior to performing a study, new investigators should read articles that have received a lot of citations because these publications are often regarded as the most significant and influential studies in the area (Table 4 and Fig. 3A&B). For example, Moller and colleagues presented an international multicenter prospective study that was the most often cited article in PND research and has enormous historical relevance. This study reported the incidence and predictors of POCD after major non-cardiac surgery[17]. Similar studies were subsequently published and it was noted that POCD can increase mortality[18,19]. Inouye *et al.*[20] comprehensively summarized the epidemiology, aetiology, pathophysiology, diagnosis, evaluation, prevention, and treatment strategies of delirium in older adults. The evidence-based and consensus-based guidelines for POD developed by the European Society of Anaesthesia also quickly gained scholarly acceptance and widespread use[21]. These two articles have strong citation bursts of 64.23 and 45.07, and their bursts have lasted until now (Fig. 3B). In addition, Evered *et al.*[1] recommended the term "PND" to refer to pre-/postoperative cognitive dysfunction in order to promote the development and communication of PND research and clinical practice. All of the above literature are milestones in PND research.

In this study, 452 keywords were categorized into 6 clusters by VOSviwer software that reflected the 6 themes of PND research (Fig. 4B). The most frequent keywords in cluster #1 included POD, delirium, subsyndromal delirium, older patients, risk factors, mortality, etc., indicating that this cluster was primarily concerned with researching the aetiology and prognosis of POD[26,27]. The keywords POCD, cognitive dysfunction, impairment, brain, neuroinflammation, neurodegeneration, etc. were frequently found in cluster #2, which indicated that this group was primarily focused on the investigation of pathogenic mechanisms of POCD[28,29]. The reason for the above classification (#1 and #2) may be that POD and POCD have not been unified as PND before 2018[1]. The common keywords in cluster #3 were cardiac surgery, blood flow, graft surgery, off-pump, vascular surgery, coronary-artery bypass, etc., which indicated that this cluster was mainly concentrated on the investigation of the correlation between cardiovascular surgery and PND. In cardiovascular surgery, low heart expulsion and secondary cellular metabolic stress and neuroinflammatory response may cause cerebral insufficiency[30,31]. Furthermore, the exploration of PND predictive models has proven crucial for the management of PND following cardiovascular surgery[32]. The common keywords in cluster #4 were dexmedetomidine, general anaesthesia, pain, propofol, sevoflurane, etc., suggesting that this cluster was focused on studies of the correlation between anaesthetic modality and anaesthetic agents and PND. A recent meta-analysis including 19 RCTs indicated that the anaesthesia method had no effect on PND, whereas the anaesthetic agent did[33]. Sevoflurane may increase the incidence of PND[34]. The effects of dexmedetomidine and propofol on PND, however, remain a matter of debate[30,35]. In cluster #5, notable keywords were hip fracture, hip surgery, spine surgery, orthopedic surgery, etc., demonstrating that this cluster is mostly devoted to research on orthopedic surgery and PND[36,37]. Age, gender, comorbidity, and psychiatric disorders were shown to be risk factors for PND. Conversely, PND also can lead to poor outcomes in orthopedic surgery[38,39]. Finally, the keyword dementia was most noticeable in cluster #6. Evidence suggested that PND and the subsequent onset of Alzheimer's disease were associated, possibly because they shared biomarkers of neuronal damage, such as tau and amyloid[40].

Clustering analysis of co-cited references presented as a timeline graph can clearly demonstrate the evolving process of the research themes[41]. In this study, a total of ten reference clusters were obtained. Figures 3C and 4A visualized the transformation process of the research themes of PND. It can be seen that the association between cardiac surgery and PND continued to receive attention from 1994 to 2013[42–44]. Since 2006, the relationship between non-cardiac surgery and PND has gradually attracted a lot of research[45]. With increasing research, tremendous progress has been made in understanding the predictors and pathogenesis of PND. The onset of PND may be related to anaesthesia, tissue injury, neuroinflammation, surgery, and mental disorders, among which the most represented is the neuroinflammatory theory[46,47]. Proinflammatory cytokines including TNF-α, Interleukin-1β, and Interleukin-6, can block hippocampus neurons from integrating and proliferating, thus preventing the morphological plasticity necessary for learning and memory and eventually leading to PND[48–50]. In recent years, PND related to orthopedic surgery in older patients and how to prevent and treat PND have become hot topics and research trends. Many drugs have been tested for PND prevention, with dexmedetomidine being the most competitive. A randomized, double-blind, controlled study first showed that prophylactic infusion of low-dose dexmedetomidine, an α_2 adrenergic receptor agonist sedative, can significantly reduce the incidence of POD without increasing adverse events[51]. Subsequently, many studies also supported this view[52–54]. However, whether the favourable effects provided by this new dexmedetomidine application will improve long-term outcomes is unclear and further studies are expected in the coming years.

Conclusion

This bibliometric evaluation showed an exponential increase in PND-related publications from 1990 to 2022. China, Harvard University, and Marcantonio Edward R. were the top contributing countries, institutions, and authors, respectively, in the area of PND research. Current research hotspots mainly focus on orthopedic surgery-related PND in older patients as well as on the management of PND, both of which will be cutting-edge topics in the coming years.

Ethical approval

Ethics approval was not required for this review.

Consent

Informed consent was not required for this review.

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Author contribution

P.W. and P.L. wrote the original draft and analyzed the data. P.W., L.L. and P.X. designed the study. M.Y., J.H., and Y.L. contributed to the data collection process and prepared all tables. P.W. carried out software operation and figure drawing. All authors contributed to the review of the manuscript. All authors have read and approved the final manuscript.

Conflicts of interest disclosure

The authors report no conflicts of interest in this work.

Research registration unique identifying number (UIN)

1. Name of the registry: Not Applicable.
2. Unique Identifying number or registration ID: Not Applicable.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): Not Applicable.

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Data availability statement

The data in this study are publicly available.

Provenance and peer review

Not commissioned, externally peer-reviewed.

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