Original Article

Global trends in anesthetic research over the past decade: a bibliometric analysis

Manhai Gao[#], Weirong Liu[#], Zhiqiang Chen[#], Wei Wei, Yanlong Bao, Qiang Cai

Department of Anesthesia Surgery, The First Affiliated Hospital of Baotou Medical College, Inner Mongolia University of Science and Technology, Baotou, China

Contributions: (I) Conception and design: M Gao, W Liu; (II) Administrative support: Z Chen; (III) Provision of study materials: W Wei; (IV) Collection and assembly of data: Y Bao; (V) Data analysis and interpretation: Q Cai; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Qiang Cai. Department of Anesthesia Surgery, The First Affiliated Hospital of Baotou Medical College, Inner Mongolia University of Science and Technology, Baotou 014010, China. Email: xunuo03@163.com.

Background: Anesthesia is the reversible inhibition of function of the central and/or peripheral nervous system using drugs or other means to ensure a successful operation. This inhibition is mainly manifested as a loss of sensation, especially pain.

Methods: Bibliometric analysis was used to identify the characteristics, hotspots, and frontiers of global anesthesiology scientific output during the past 10 years. Literatures between 2011 and 2020 in the Web of Science Core Collection (WoSCC) were reviewed and analyzed. VOSviewer was used to visualize trends and hotspots in anesthesia research.

Results: A total of 16,213 publications were retrieved and results showed that there was no significant correlation between the number of articles published each year and the year of publication. England had the most published papers, the greatest number of citations (NC), and the highest h-index. The University of London and the British Journal of Anesthesia were the richest affiliate and journal, respectively. The publication written by Heidenreich *et al.* had the highest global citation score (GCS).

Conclusions: Our research found that global publications on anesthesia have raised. Recently, "surgery", "management", "propofol", and "analgesia" appeared most frequently, which were active areas of research. In the future research, pain management, pediatric anesthesia, safety, dexmedetomidine, *et al.* will be the hotspot and mainstream trend of research.

Keywords: Bibliometrics; anesthesia; hotspots; trends; VOSviewer

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Introduction

Anesthesia is a reversible functional inhibition of the central and/or peripheral nervous system induced by drugs or other methods. This inhibition is mainly characterized by the loss of sensation, especially pain. Anesthesia is a great achievement in the history of medicine. The emergence of anesthesia enabled many complex diagnoses and surgical operations to be conducted relatively smoothly and safely (1). Clinically, anesthesia is accompanied by surgery, and the two are inseparable. The pain and stress reaction caused by surgery can be remarkably weakened or even eliminated by anesthesia, which can effectively improve the prognosis of patients and reduce the adverse consequences of medical treatment. More than 300 million people worldwide receive anesthesia and surgery every year. With the continuous development of medical treatments, as well as social and economic advancements, the population receiving anesthesia

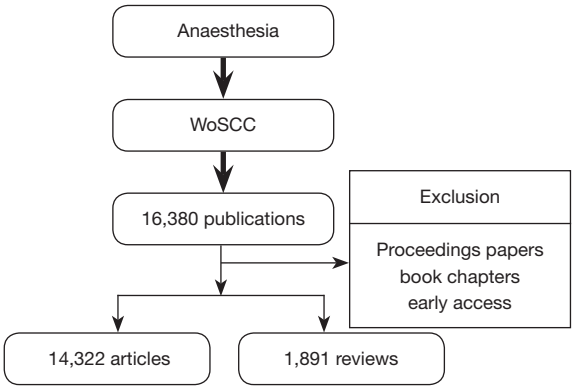

Figure 1 Flowchart of the screening process. WoSCC, Web of Science Core Collection.

is also increasing (2). Moreover, the equipment used in the anesthetic process, the type and route of administration of anesthetics, and the monitoring standards have been greatly improved (3). However, modern medical research shows that anesthesia can damage nerves (4). The probability of obvious pain after anesthesia is more than 20% (5). A retrospective study showed that children who underwent multiple anesthesia and surgery before the age of 4 were at greater risk of reduced ability to calculate and read in the long-term (6). The elderly may experience early delirium after anesthesia, and even persistent cognitive impairment in severe cases (7). In addition, the introduction of novel technologies and the emergence of new concepts in the field of anesthesia represent great challenges for researchers and medical staff. Therefore, it is crucial to quantitatively analyze the research status, key fields, and future prospects of anesthesia.

Bibliometrics is the analysis of published information (including books, journal articles, data sets, and blogs) and their associated (such as abstracts, keywords, and citations) using statistics to describe or show relationships between published works (8). As a method of quantifying research objects, it is often used to determine the laws of literature (9). Unlike traditional narrative criticism, which relies on the researcher's experience and knowledge, bibliometrics treats science as a knowledge generation system (10). It can provide characters and trend of a research area (11,12) and summarize the research status of open publications (13,14).

In recent years, double cluster analysis has been widely used in bibliometrics. For example, Zhu *et al.* used BI (bibliometric) cluster analysis to predict research trends in the application of stenting in pancreatic diseases (15). The anesthetic research was a very big topic. With the expansion of the scope and field of anesthesia, anesthesiology has been divided into many sub disciplines. With the application of new technology, new theory and new knowledge, it has promoted the modernization of anesthesiology. At present, the research of anesthesiology is very complex. Therefore, it is necessary to conduct bibliometric analysis on the whole discipline of anesthesiology. This current study systematically analyzed anesthesiology research so as to assess the current status and hotspots in the field.

Methods

Data sources and search strategies

A literature search was conducted using the Web of Science Core Collection (WoSCC) developed by Thomson Scientific. Considering the rapid updating of the database, the literature search was conducted over a single day (16 November 2021) to avoid deviations. The study included published literature from 2011 to 2020. As part of the search, we used "anaesthetization" or "narcosis" or "narcotism" or "anesthesia" as search terms. Finally, "anesthesia" was used as the search term as it resulted in the greatest number of relevant search results. Only articles and reviews were included. A total of 16,213 publications were analyzed in this bibliometric research. The detailed filtering procedure is shown in *Figure 1*.

Data collection

Raw data was downloaded with WoSCC. The following information was collated: year of publication, number of papers and citations, h-index, country/region, affiliates, authors, journals, references, and keywords. The data was analyzed using VOSviewer V.1. 6.10.0 (Research Centre for Science and Technology, Leiden University, The Netherlands).

Bibliometric analysis

For bibliometric analyses, visualization technology was used to obtain the research results. As an interdisciplinary research method, bibliometrics based on mathematical statistics reveals the law of scientific literature and the development trend of the discipline. In addition, rules that reflect the above structural characteristics of scientific knowledge in digital form will be visually displayed in graphical form through visualization (16). Therefore, VOSviewer was specifically used in this study.

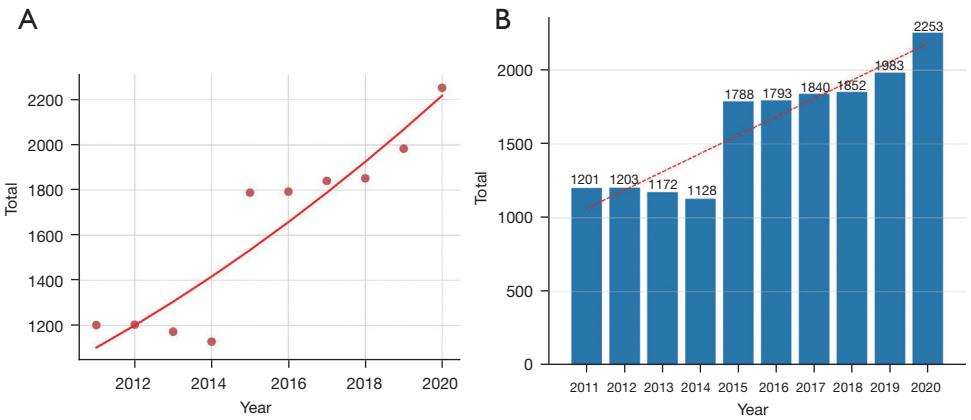

Figure 2 Annual publications. (A) Curve fitting of the total annual growth trend of publications; (B) the number of publications by year over the past 10 years.

The VOSviewer software was developed by Van Eck and Waltman at Leiden University in the Netherlands (17). Coupling analysis takes a static form and is according to same number of references between two papers. The two approaches complement each other (18). The number of publications (NP), the number of citations without self-citation (NC), the h-index (19), and the impact factor (IF) (20) were analyzed. The change of keywords can reflect the change trend of research hotspots. In a visual network diagram, nodes represent the objects being analyzed, and the higher the frequency, the larger the nodes. The change from cold to warm tones reflects the time change from early to recent. The edges between nodes and their thickness represent the co-occurrence or co-citation relationship and strength, respectively (21).

Results

A summary of publications on Anesthesia

According to the retrieval strategy, 16,213 articles and reviews published from 2011 to 2020 were retrieved in all. This demonstrated that there are a large number of papers on anesthesia, which is the focus of current scientific research.

The annual trend of paper publication

Figure 2A shows a polynomial fitting curve for the annual trend in the number of print publications. There was no significant correlation between annual NP and publication year. According to *Figure 2A*, the correlation coefficient R^2 only reached 0.8549. These findings indicated that anesthesia research has become a research focus. *Figure 2B* shows annual NP associated with anesthesia. Overall, despite fluctuations between 2011 and 2014, the number of annual papers increased from 1,201 in 2011, to 2,253 in 2020, with NP peaking in 2020. Since 2011, the annual NP from the United States of America (USA), the United Kingdom (UK), Germany, and Australia has remained stable, while publications from India have increased rapidly. *Figure 3* showed the annual number of documents issued by the top five countries. The geographical distribution of the number of documents issued is shown in *Figure 4*.

Contributions of countries/regions

The top 10 countries/regions based on the NP is listed in *Table 1*. England published most papers (2,463/15.19%), followed by India (1,956/12.06%), and the USA (1,439/8.88%). Papers from England were cited by 40,981 times, followed by the USA [31,624], and Germany [20,948]. In addition, England achieved highest h-index [86], more than twice figure for China [42], India [28], and Turkey [25]. Compared with India, the NP in the USA, Germany, Australia, France, China, Italy, and Switzerland were moderately lower, but these countries had a remarkably higher h-index and NC. The network of co-occurrence of countries/regions was shown in *Figure 5*.

Performance of affiliations

The top 10 most productive affiliations are displayed in *Table 2*. The University of London had the highest NP [575], followed by the University College London [349],

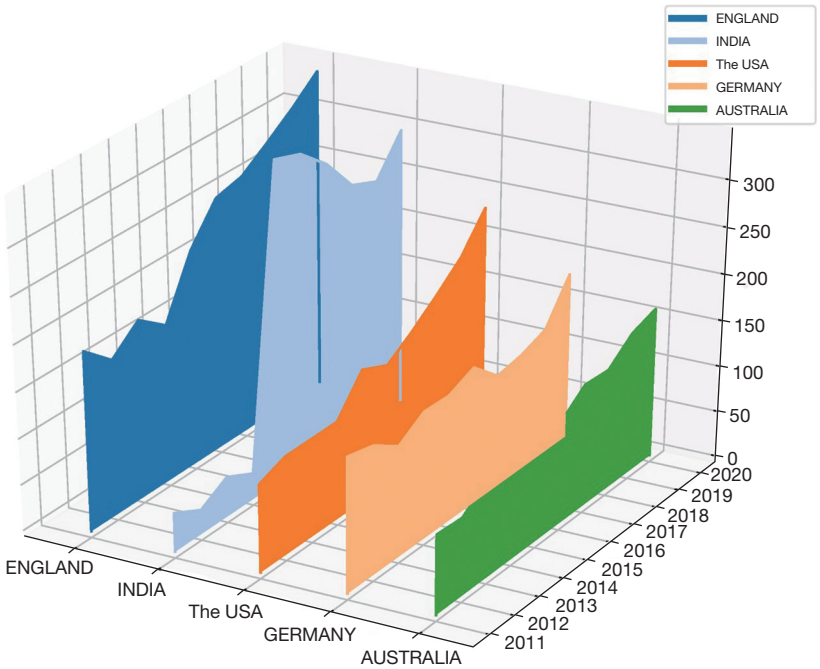

Figure 3 The number of documents issued by the top five countries each year.

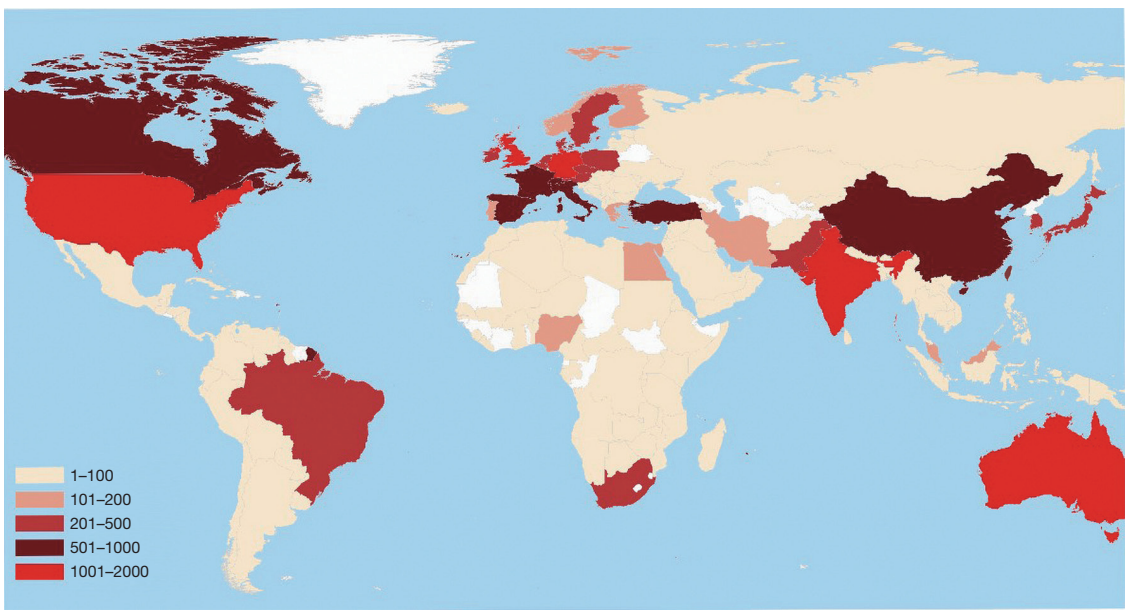

Figure 4 Geographical distribution of anaesthesia-related research articles.

and the Assistance Publique Hopitaux Pris APHP [318]. The University of London ranked first in terms of the NC [11,956], as well as the highest h-index. Although the NP of Hopitaux Pris APHP and Sante et de la Recherche Medicale Inserm in France was moderately high, their h-index was lower than University of Toronto and the Imperial College London. Among the top 10 institutions, 3 are from England, 2 are from France, 2 are from Australia, and 1 is from the United States, Canada and Denmark. The network of co-occurrence of affiliations

Table 1 Publications in the 10 most productive countries/regions

Rank	Country/region	NP	% of 16,213	NC	H-index	Average per item
1	England	2,463	15.19151	40,981	86	17.37
2	India	1,956	12.06439	5,859	28	3.14
3	The USA	1,439	8.875594	31,624	81	22.49
4	Germany	1,395	8.604207	20,948	60	15.45
5	Australia	1,153	7.111577	15,130	53	13.52
6	France	966	5.958182	14,201	52	15.11
7	China	860	5.304385	9,304	42	11.04
8	Turkey	736	4.539567	4,122	25	5.7
9	Italy	681	4.200333	12,370	47	18.41
10	Switzerland	622	3.836428	10,746	47	17.68

NP, number of publications; NC, number of citations.

was shown in *Figure 6*.

Performance of authors

The top 10 productive authors are shown in *Table 3*. Together, they published 356 papers, accounting for 2.6% of the total NP. Cook TM from Royal United Hospital NHS Foundation Trust ranked first in the field of investigating anesthesia, followed by Sessler DI from Cleveland Clinic in the USA and Lee JH from Chungbuk National University Hospital in South Korea. As shown in *Table 3*, Cook TM had a remarkably high NC. Among the top 10 scholars, 3 are from Germany, 2 are from India and South Korea, 1 is from Switzerland, the United States, and England. The network of co-occurrence of authors was shown in *Figure* 7.

Performance of journals

As shown in *Table 4*, *British Journal of Anaesthesia* (918 publications, IF: 9.166) published the most papers concerning anesthesia. The *Journal of Evolution of Medical and Dental Sciences Jemds* (573 publications, removed) and *Anaesthesia* (546 publications, IF: 6.995) ranked second and third. In the top 10 journals, more than 25% of the papers were published (4,364/26.8%). Among the top 10 journals, *British Journal of Anaesthesia* (IF: 9.166), *Anaesthesia* (IF: 6.995), and *European Journal of Anaesthesiology* (IF: 4.33) were journals with high IF (>4.000). *British Journal of Anaesthesia* had the highest number of citations and h-index. However, the *Journal of Evolution of Medical and Dental Sciences Jemds*, the *Indian Journal of Anaesthesia*, *Anaesthesia and Intrinsic Care Medicine*, and the *Journal of Clinical and Diagnostic Research* have all been removed from SCI.

Analysis of literature global citation scores (GCSs)

Figure 8 shows the number of GCSs each year of top 10 papers. The paper written by Heidenreich *et al.* ranked first, with a GCS of 1,121. In this article, the author points out that the knowledge in the field of cancer of the prostate (PCa) is changing rapidly. It also puts forward guidelines on PCa, summarizes the latest findings, and applies them to clinical practice (22). In addition, the works of Cook *et al.* suggested that the during general anesthesia incidence of brain injury and death from airway management was low, and statistical analysis indicated that only 25% of related events may be reported. It provided a lower limit indication. Review of airway management showed that in most cases there was "room for improvement" (23). In addition, at least a quarter of major airway events in a hospital may occur in the intensive care unit (ICU) or emergency department (ED). The outcomes of these events were particularly adverse. Analysis of cases revealed repeated gaps in care, including poor identification of high-risk patients, poor or incomplete planning, insufficient technical staff and equipment to successfully manage these events, delays in event identification, and rescue failures due to lack or failure to interpret capnography. The results of the study showed that deaths because of airway complications in ICU and ED patients are preventable (24). Vahrmeijer *et al.* introduced

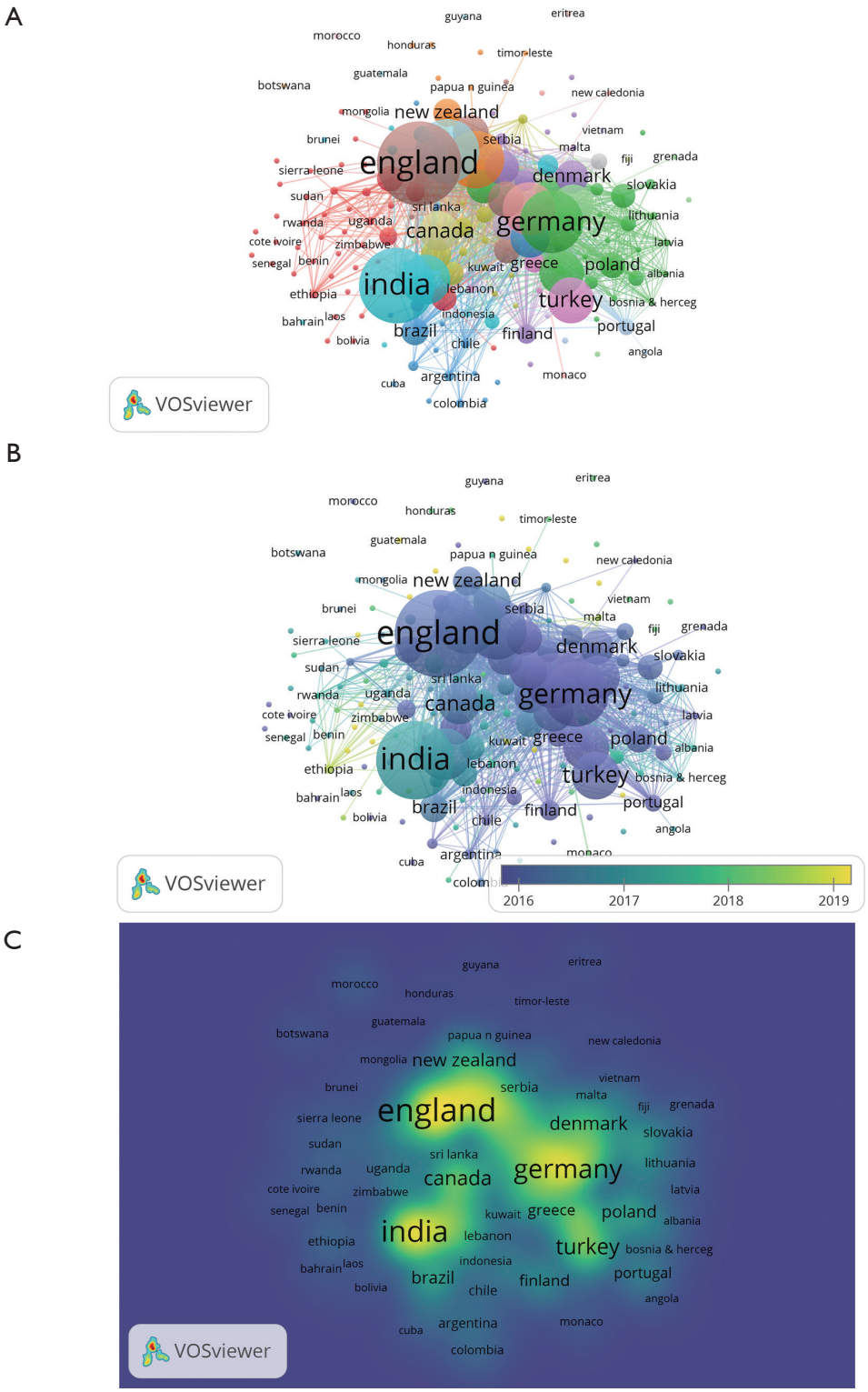

Figure 5 Mapping on countries of studies related to anaesthesia. (A) Network map of countries; (B) visualization of countries according to the APY; (C) density visualization for countries. APY, average publication year.

Table 2 The top 10 productive affiliations

Rank	Affiliations	Country	NP	% of 16,213	NC	H-index	Average per item
1	University of London	England	575	3.5465367	11,956	53	21.23
2	University College London	England	349	2.1525936	8,137	46	23.77
3	Assistance Publique Hopitaux Paris APHP	France	318	1.961389	5,082	32	16.24
4	University of Copenhagen	Denmark	271	1.6714982	6,329	43	23.94
5	Institut National de la Sante et de la Recherche Medicale Inserm	France	245	1.511133	3,529	28	14.56
6	University of Toronto	Canada	194	1.1965707	6,211	39	32.21
7	Imperial College London	England	186	1.1472275	4,636	37	25.47
8	University of Melbourne	Australia	186	1.1472275	4,016	31	21.92
9	Harvard University	The USA	181	1.1163881	6,802	38	38.16
10	University of Sydney	Australia	177	1.0917165	1,721	20	9.88

NP, number of publications; NC, number of citations.

the concept of near-infrared fluorescence imaging in surgery, provided a review of the clinical trial literature to date, an overview of key issues related to imaging systems and contrast agent optimization, a discussion of limitations and leverage, (25). Davidson *et al.* suggested that there was strong evidence showing that exposure to sevoflurane for less than 1 hour in infancy did not increase the risk of neurodevelopmental outcomes (26). Smith *et al.* provided an overview of existing knowledge on perioperative fasting and an assessment of the quality of evidence (27). Shorvon *et al.* reviewed the treatment approaches of super-refractory status epilepticus (28). In the study by Rasmussen *et al.*, four treatments for varicose great saphenous veins were compared and the results showed that all treatments were effective. The technique had the highest failure rate after foam sclerotherapy (29). Thielmann *et al.* investigated the safety and efficacy of tele-ischemic preconditioning, and demonstrated that tele-ischemic preconditioning provides perioperative myocardial protection and improves outcomes in patients undergoing elective CABG surgery (30).

Analysis of co-citations

A line between two nodes indicates that the two nodes are cited by one publication, and a shorter line indicates that the two papers are closer to each other. The size of the node shows total link strength and the total amount of common references to the document. In addition, the paper is divided into different clusters using nodes of different colors.

Analysis of research hotspots

In addition to the retrieval method, keywords of 16,213 papers were also analyzed with VOSviewer (*Figure 9*). As shown in *Figure 9A*, cluster 1 (red) keywords are mainly clinical research related to the role of anesthesia in the surgical treatment of diseases. Cluster 2 (green) mainly includes basic research regarding the efficacy and side effects of anesthetics. Cluster 3 (blue) focuses on the sequelae of anesthesia and the main protective measures. Cluster 4 (yellow) mainly relates to airway management. The keywords with the highest frequency are "anesthesia", "surgery", "management", "propofol", and "analgesia", suggesting that the research related to anesthesia mainly focuses on clinical studies. As shown in *Figure 9B*, the colors of all nodes were divided based on average publication year (APY). The most recent keywords are "desflurane" (APY: 2016, 18.88), "airway management" (APY: 2016, 34), and "intubation" (APY: 2016, 47). Density visualization for keywords was shown in *Figure 9C*.

Journals

The minimum number of citations of a journal was set as 514. Among the 40,443 journals cited by the retrieved publications, 120 were selected for further analysis (*Figure 10*). These were divided into 7 clusters. Cluster 1–7 had 49, 30, 25, 6, 4, 4, and 2 journals, respectively. The top 10 most cited journals are *Anesthesiology* (23,658

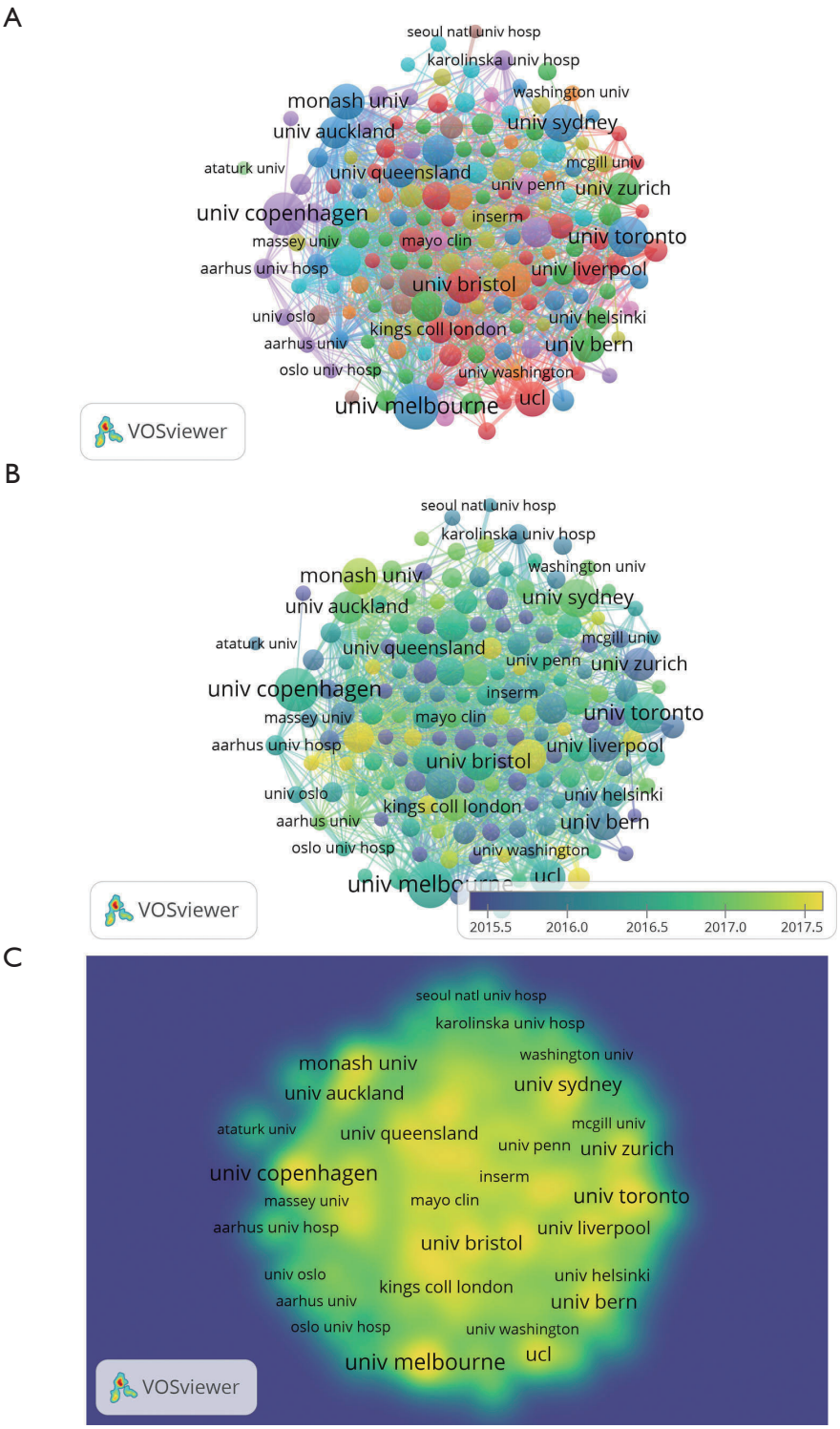

Figure 6 Mapping on affiliations of studies related to anaesthesia. (A) Network map of affiliations; (B) visualization of affiliations according to the APY; (C) density visualization for affiliations. APY, average publication year.

Table 3 The top 10 authors with the most publications

Rank	Author	Country	Affiliations	NP	% of 16,213	NC	H-index	Average per item
1	Cook TM	England	Royal United Hosp NHS Fdn Trust	50	0.3083945	3,838	30	80
2	Sessler DI	The USA	Cleveland Clin	39	0.2405477	568	13	15.57
3	Lee JH	South Korea	Chungbuk Natl Univ Hosp	37	0.2282119	329	8	9.57
4	Rossaint R	Germany	Univ Hosp Aachen	36	0.222044	158	6	4.68
5	Kim SH	South Korea	Univ Ulsan	35	0.2158761	259	11	8.53
6	Kumar A	India	Cent Sci Instruments Org	34	0.2097083	158	6	4.68
7	Bettschart-wolfensbergr R	Switzerland	Univ Zurich	32	0.1973725	259	11	8.53
8	Hollmann MW	Germany	Acad Med Ctr	31	0.1912046	1,342	15	43.65
9	Kranke P	Germany	Univ Klinikum Wurzburg	31	0.1912046	1,369	15	44.45
10	Kumar S	India	MGM Med Coll & Hosp	31	0.1912046	108	6	3.48

NP, number of publications; NC, number of citations.

citations), Anesthesia & Analgesia (22,509 citations), *British Journal of Anaesthesia* (20,373 citations), *Anaesthesia* (11,749 citations), *Acta Anaesthesiologica Scandinavica* (6,381 citations), *Lancet* (4,411 citations), *European Journal of Anaesthesiology* (4,265 citations), *The New England Journal of Medicine* (4,184 citations), *Veterinary Anaesthesia and Analgesia* (4,019 citations), and the *Canadian Journal of Anesthesia* (3,883 citations).

Authors

The minimum number of citations of each author was set as 111. Of the 195,558 authors cited by the retrieved papers, 120 were selected for further analysis (*Figure 11*). These were divided into 8 clusters, and cluster 1–8 had 29, 22, 17, 16, 14, 11, 6, and 5 authors, respectively. The top 10 most cited authors are Cook TM (695 citations), Myles PS (554 citations), Kehlet H (450 citations), Higgins JPT (434 citations), Pandit JJ (409 citations), Apfel CC (397 citations), Gan TJ (395 citations), World Health Organization (383 citations), Kain ZN (376 citations), and Mertes PM (306 citations).

References

Considering the large number of references cited, the minimum number of references was set at 42. Of the 319,699 references cited in the retrieved papers, 123 were selected for further analysis (*Figure 12*). Group 1 (red) includes 26 references, which mainly focused on surgical clinical research. Group 2 (green) includes safety studies related to anesthesia, clinical and neurophysiological features of general anesthesia, and their relationship to sleep and coma. Group 3 (blue) focuses on anesthesia related complications and their impact on disease treatment. Group 4 (yellow) focuses on major complications of airway management and management guidelines for unanticipated difficult intubations. Cluster 5 (purple) consists of studies examining the clinical analgesic effect of anesthesia. Cluster 6 (in wathet) is mostly related to the PRISMA Statement and was far away from the other clusters. Cluster 7 (orange) relate to adverse reactions caused by anesthesia and the effects on physical development. The theme of cluster 8 (brown) is prevention and treatment of postoperative nausea and vomiting. Cluster 9 (pink) is comparative studies on anesthetic effects without anesthesia.

Analysis of bibliographic coupling

Bibliographic coupling refers to two papers citing one same document. Usually, the number of citation coupling can be used to quantitatively measure the static relationship between the two documents. The more citation coupling, the stronger the correlation between the two documents. The strength of coupling depends on the number of common references (cited documents). Document coupling can be divided into paper coupling, discipline coupling, author coupling, and journal coupling. In addition, there is also country coupling and document coupling. Document coupling is applied to discipline fields such as information science, bibliometrics, science, and futurology.

As shown in *Figure 13*, a total of 121 journals

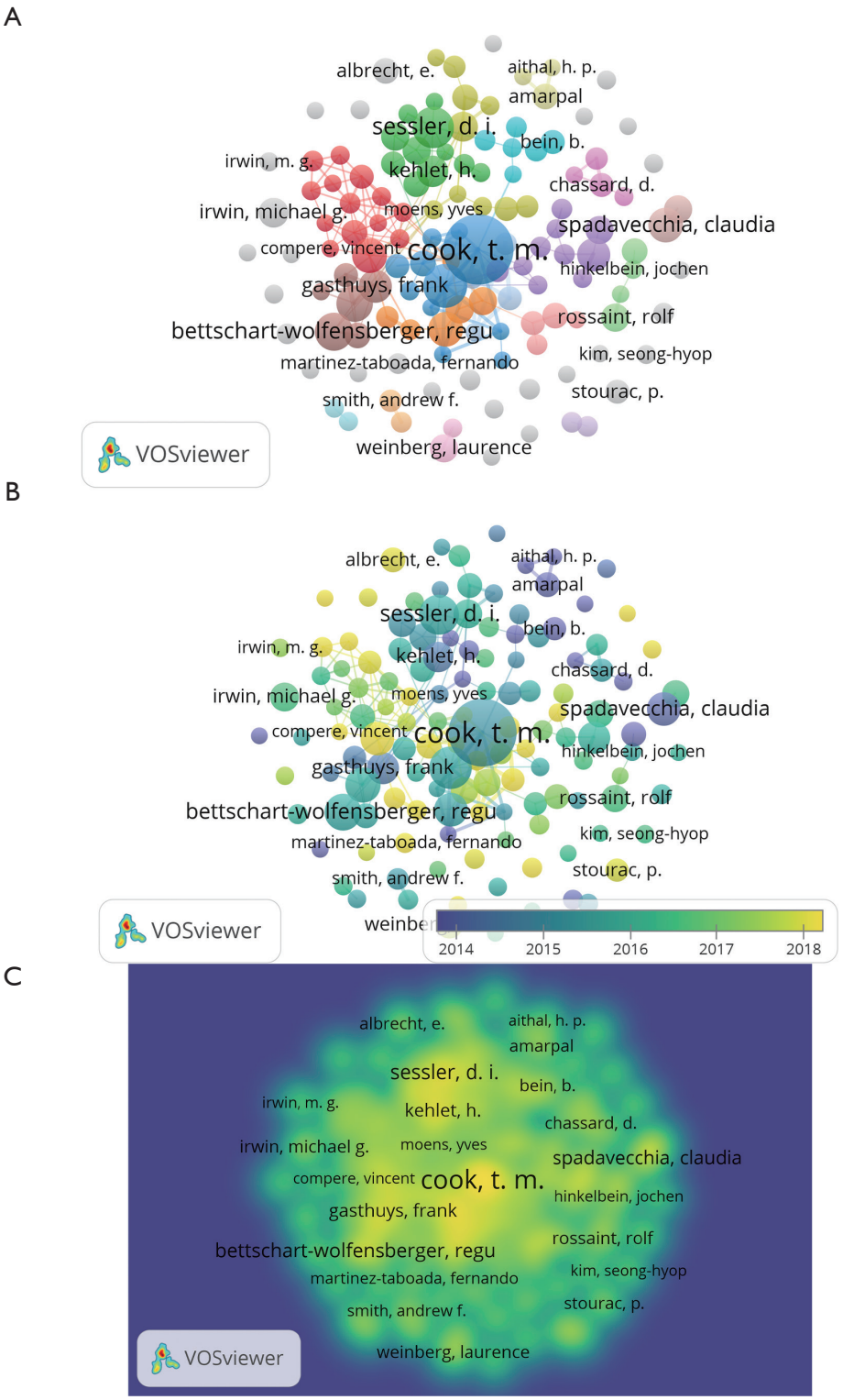

Figure 7 Mapping on authors of studies related to anaesthesia. (A) Network map of authors; (B) visualization of authors according to the APY; (C) density visualization for authors. APY, average publication year.

Table 4 The top 10 most active journals

Rank	Journal	IF (2020)	NP	% of 16,213	NC	H-index	Average per item
1	*British Journal of Anaesthesia*	9.166	918	5.662123	29,813	79	33.46
2	*Journal of Evolution of Medical and Dental Sciences Jemds*	Removed	573	3.534201	141	3	0.27
3	*Anaesthesia*	6.995	546	3.367668	12,291	53	23.49
4	*European Journal of Anaesthesiology*	4.33	421	2.596682	6,574	38	15.86
5	*Indian Journal of Anaesthesia*	Removed	390	2.405477	1,905	19	5.16
6	*Veterinary Anaesthesia and Analgesia*	1.648	345	2.127922	3,140	26	10.32
7	*Anaesthesia and Intensive Care*	1.669	324	1.998396	2,132	19	6.77
8	*Acta Anaesthesiologica Scandinavica*	2.105	296	1.825695	4,089	31	14.05
9	*Anaesthesia and Intensive Care Medicine*	Removed	289	1.78252	179	4	0.63
10	*Journal of Clinical and Diagnostic Research*	Removed	244	1.504965	552	10	2.28

NP, number of publications; NC, number of citations; IF, impact factor.

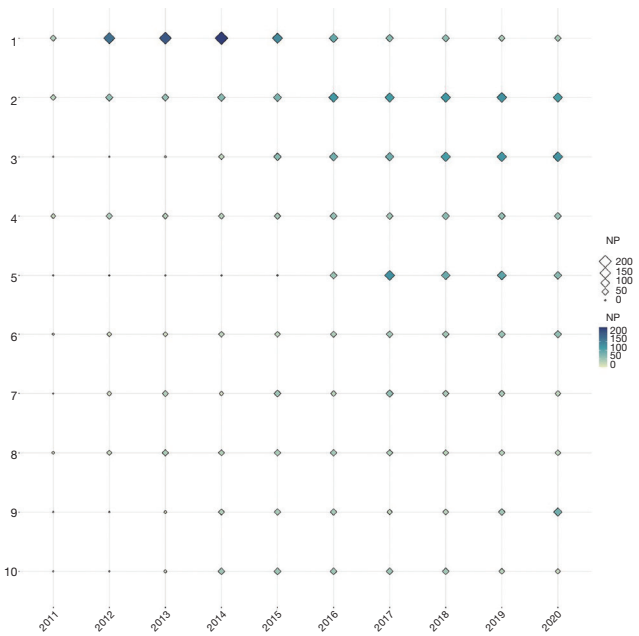

Figure 8 The yearly number of local citations of papers with high GCS. The size and colors of the circle represent the GCS of papers. 1. EAU Guidelines on Prostate Cancer. Part 1: Screening, Diagnosis, and Treatment of Clinically Localized Disease. 2. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1. 3. Image-guided cancer surgery using near-infrared fluorescence. 4. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2. 5. Neurodevelopmental outcome at 2 years of age after GAS: an international multicenter, randomized controlled trial. 6. Perioperative fasting in adults and children: guidelines from the European Society of Anaesthesiology. 7. The treatment of super-refractory status epilepticus: a critical review of available therapies and a clinical treatment protocol. 8. Randomized clinical trial comparing endovenous laser ablation, radiofrequency ablation, foam sclerotherapy and surgical stripping for great saphenous varicose veins. 9. Midwife-led continuity models versus other models of care for childbearing women. 10. Cardioprotective and prognostic effects of remote ischemic preconditioning in patients undergoing coronary artery bypass surgery: a single-center randomized, double-blind. NP, number of publications; GCS, global citations; EAU, European Association of Urology; UK, United Kingdom; GAS, general anaesthesia and awake-regional anaesthesia in infancy.

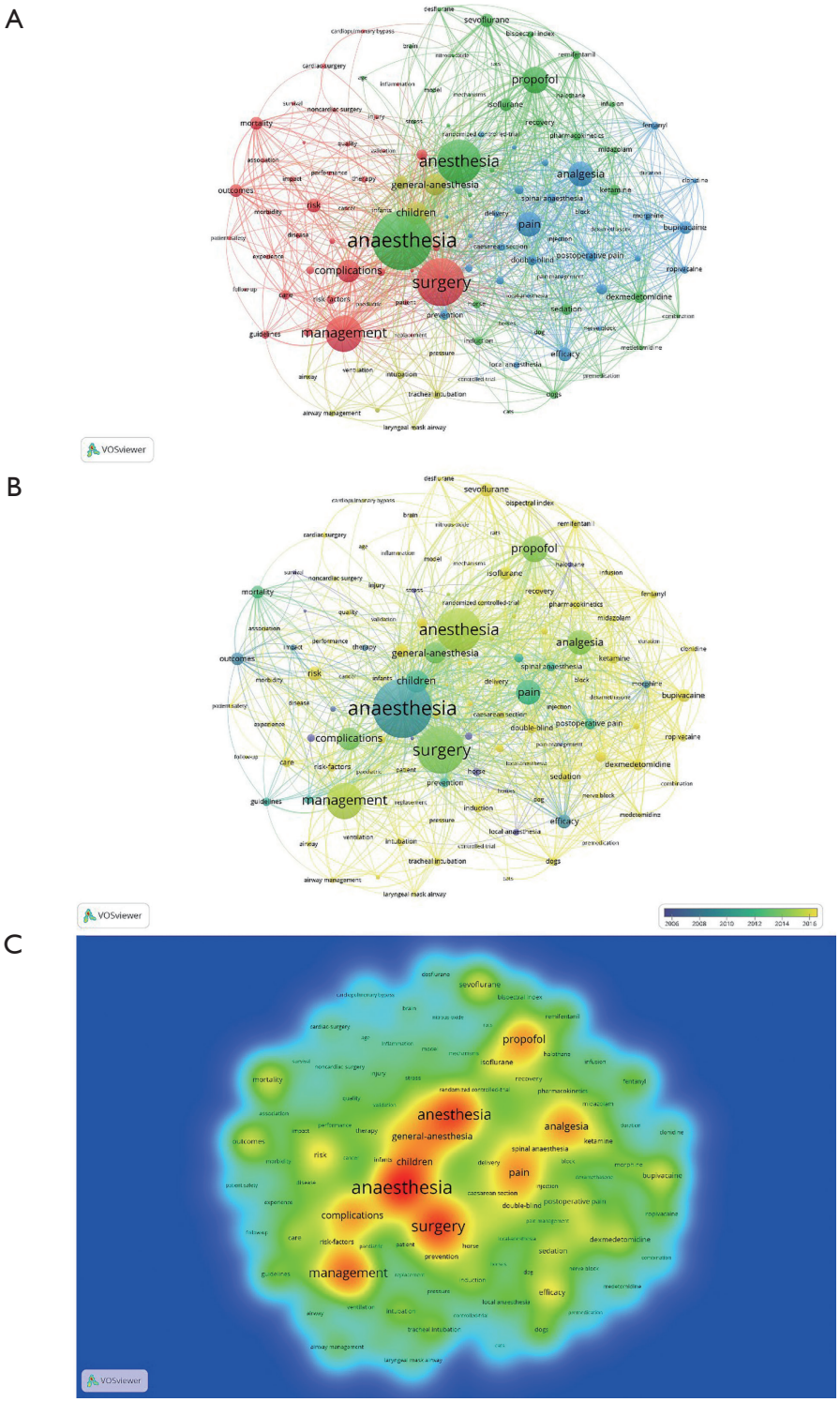

Figure 9 Mapping on keywords of studies related to anaesthesia. (A) Network map of keywords; (B) visualization of keywords according to the APY; (C) density visualization for keywords. APY, average publication year.

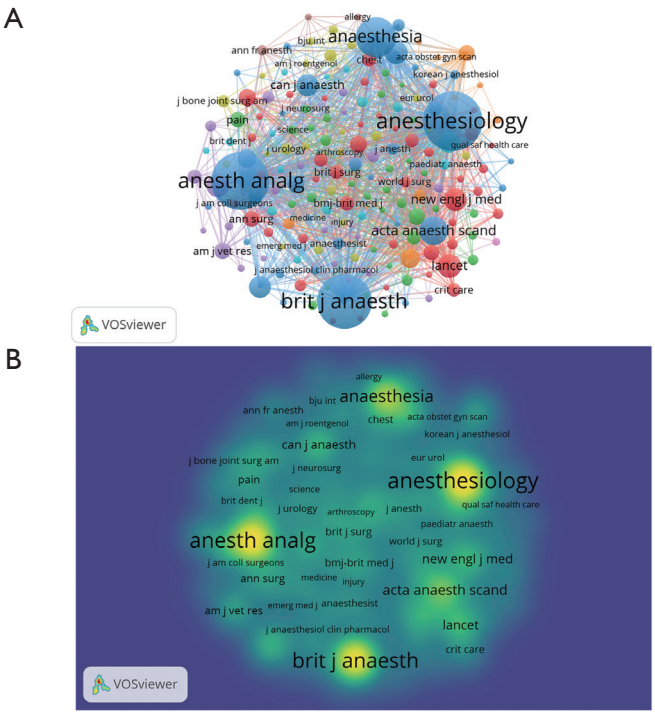

Figure 10 Mapping on co-cited journals related to anaesthesia. (A) Network map of co-cited journals; (B) density visualization for co-cited journals. APY, average publication year.

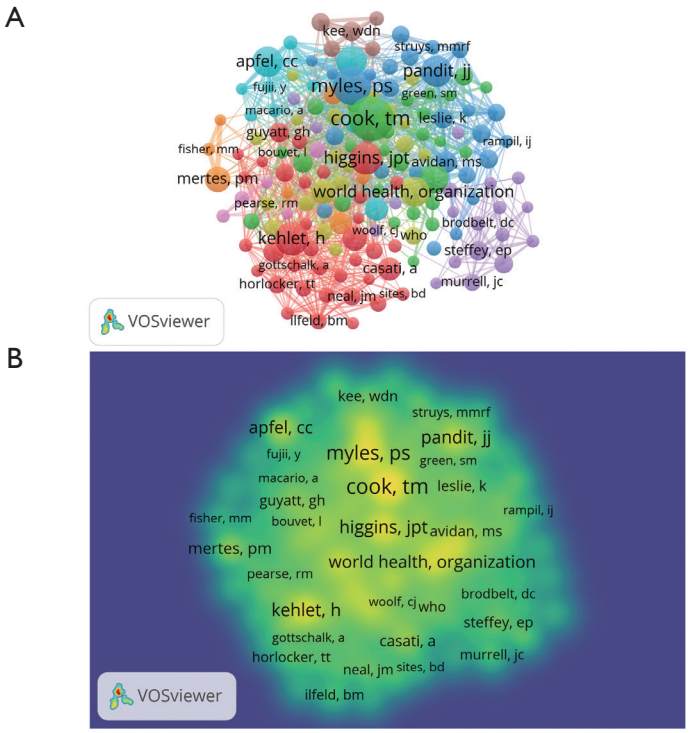

Figure 11 Mapping on co-cited authors related to anaesthesia. (A) Network map of co-cited authors; (B) visualization of co-cited authors according to the APY. APY, average publication year.

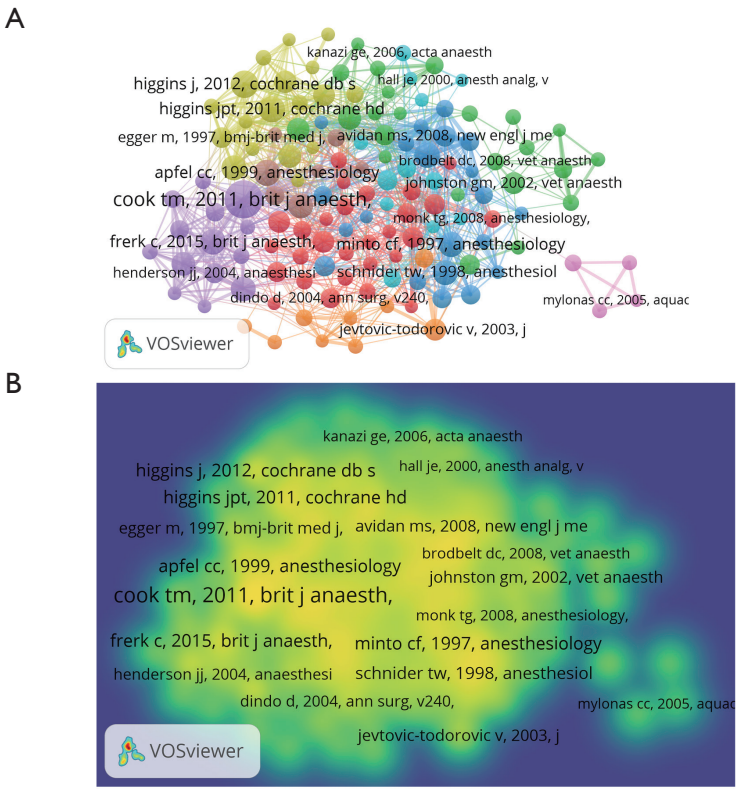

Figure 12 Mapping on co-cited references related to anaesthesia. (A) Network map of co-cited references; (B) visualization of co-cited references according to the APY. APY, average publication year.

were identified. The top 10 journals with the largest citations are as follows: *British Journal of Anaesthesia* (30,714 citations), *Anaesthesia* (12,827 citations), *European Journal of Anaesthesiology* (6,679 citations), *Cochrane Database of Systematic Reviews* (6,283 citations), *Acta Anaesthesiologica Scandinavica* (4,159 citations), *Veterinary Anaesthesia and Analgesia* (3,559 citations), *PLoS One* (2,596 citations), *Anaesthesia and Intensive Care* (2,195 citations), *Indian Journal of Anaesthesia* (2,011 citations), and *British Journal of Surgery* (1,704 citations).

A total of 121 affiliations were analyzed with VOSviewer (*Figure 14*). The top 10 affiliations with the greatest citations are as follows: University of Toronto (3,769 citations), University of Melbourne (3,736 citations), University of Copenhagen (3,482 citations), Royal United Hospital (3,332 citations), University College London (3,128 citations), Cleveland Clinic (2,862 citations), Karolinska Institute (2,497 citations), Harvard University (2,406 citations), University of Bristol (2,223 citations), and University of Western Australia (2,090 citations).

There were 164 countries/regions included and publications were analyzed with VOSviewer (*Figure 15*). The top 10 countries/regions with the largest citations are as follows: England (42,478 citations), the USA (32,217 citations), Germany (21,518 citations), Australia (15,552 citations), France (14,551 citations), Canada (13,573 citations), Italy (12,491 citations), Netherlands (10,959 citations), Switzerland (10,951 citations), and China (9,481 citations).

A total of 121 documents were analyzed with VOSviewer (*Figure 16*). The top 10 documents with the largest number of citations are as follows: Heidenreich A (2011; 1,121 citations), Cook TM (2011; 989 citations), Vahrmeijer AL (2013; 743 citations), Cook TM (2011a; 516 citations), Davidson AJ (2016; 481 citations), Sandall (2013; 401 citations), Smith I (2011; 388 citations), Cook TM (2020; 377 citations), Shorvon S (2011; 363 citations), and Rasmussen LS (2011; 358 citations).

A total of 132 authors were analyzed with VOSviewer (*Figure 17*). The top 10 authors with the largest number of citations are as follows: Cook TM (3743 citations), Pandit JJ (1,282 citations), Patel A (1,252 citations), Kranke

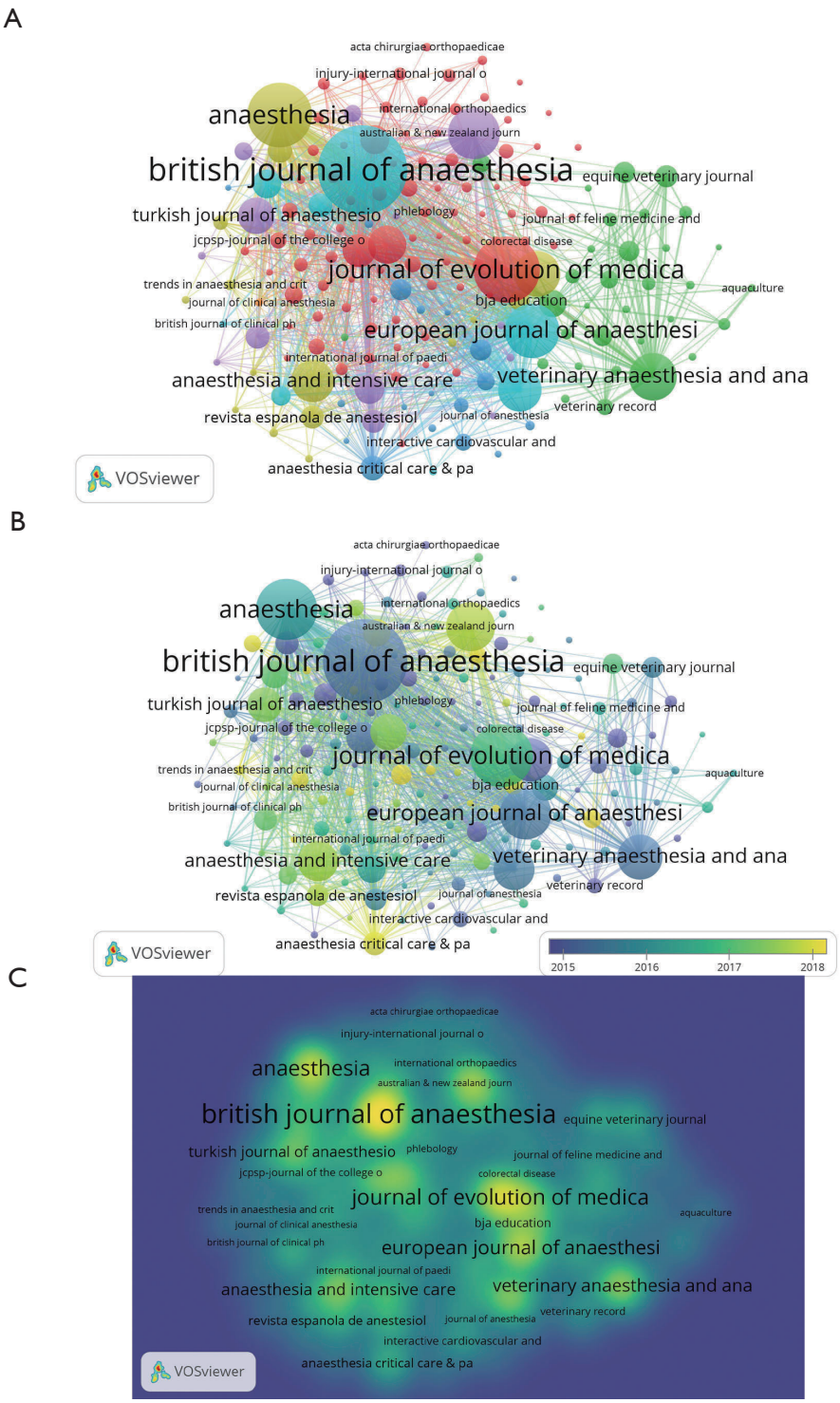

Figure 13 Mapping on bibliographic coupling journals related to anaesthesia. (A) Network map of bibliographic coupling journals; (B) visualization of bibliographic coupling journals according to the APY; (C) density visualization for bibliographic coupling journals. APY, average publication year.

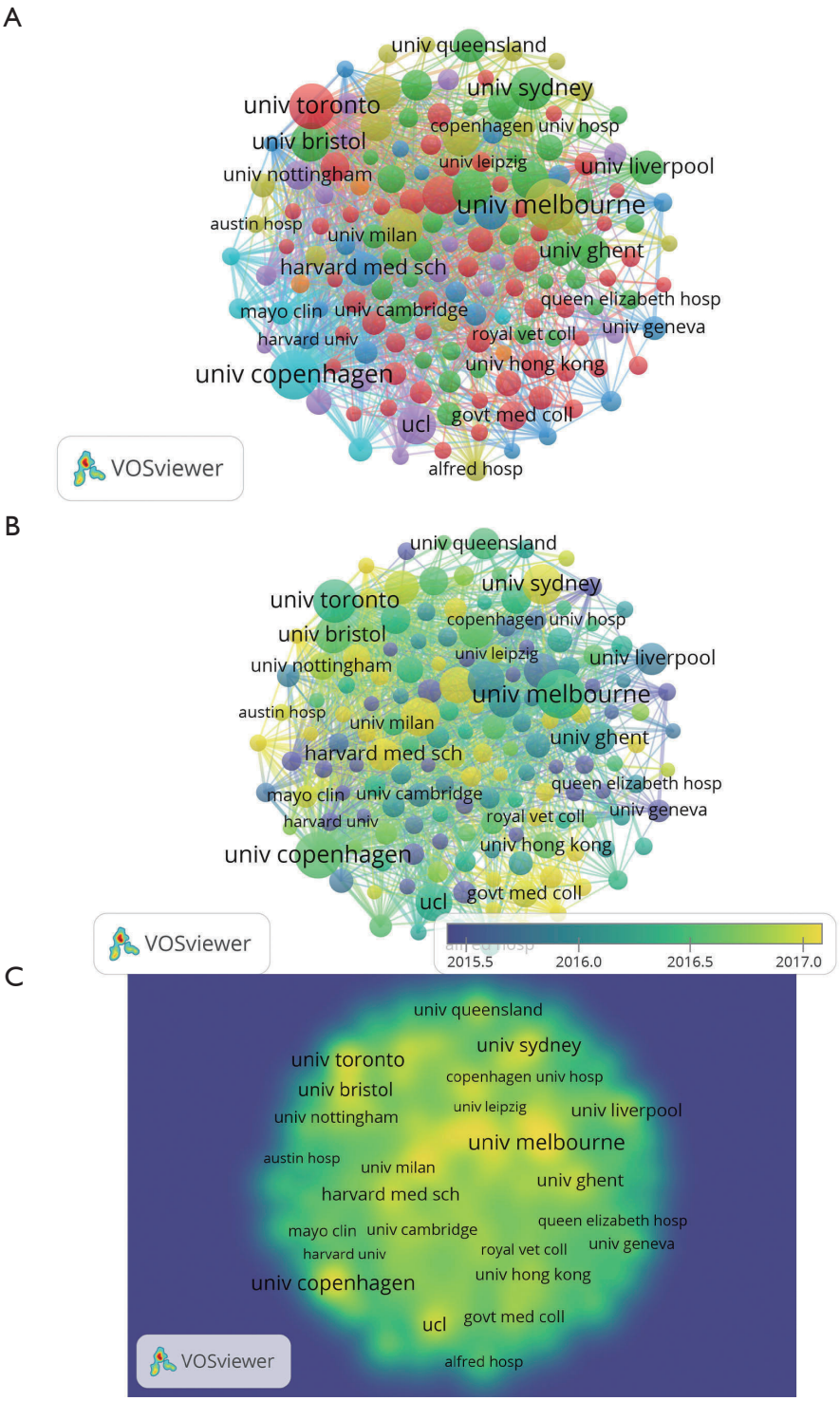

Figure 14 Mapping on bibliographic coupling affiliations related to anaesthesia. (A) Network map of bibliographic coupling affiliations; (B) visualization of bibliographic coupling affiliations according to the APY; (C) density visualization for bibliographic coupling affiliations. APY, average publication year.

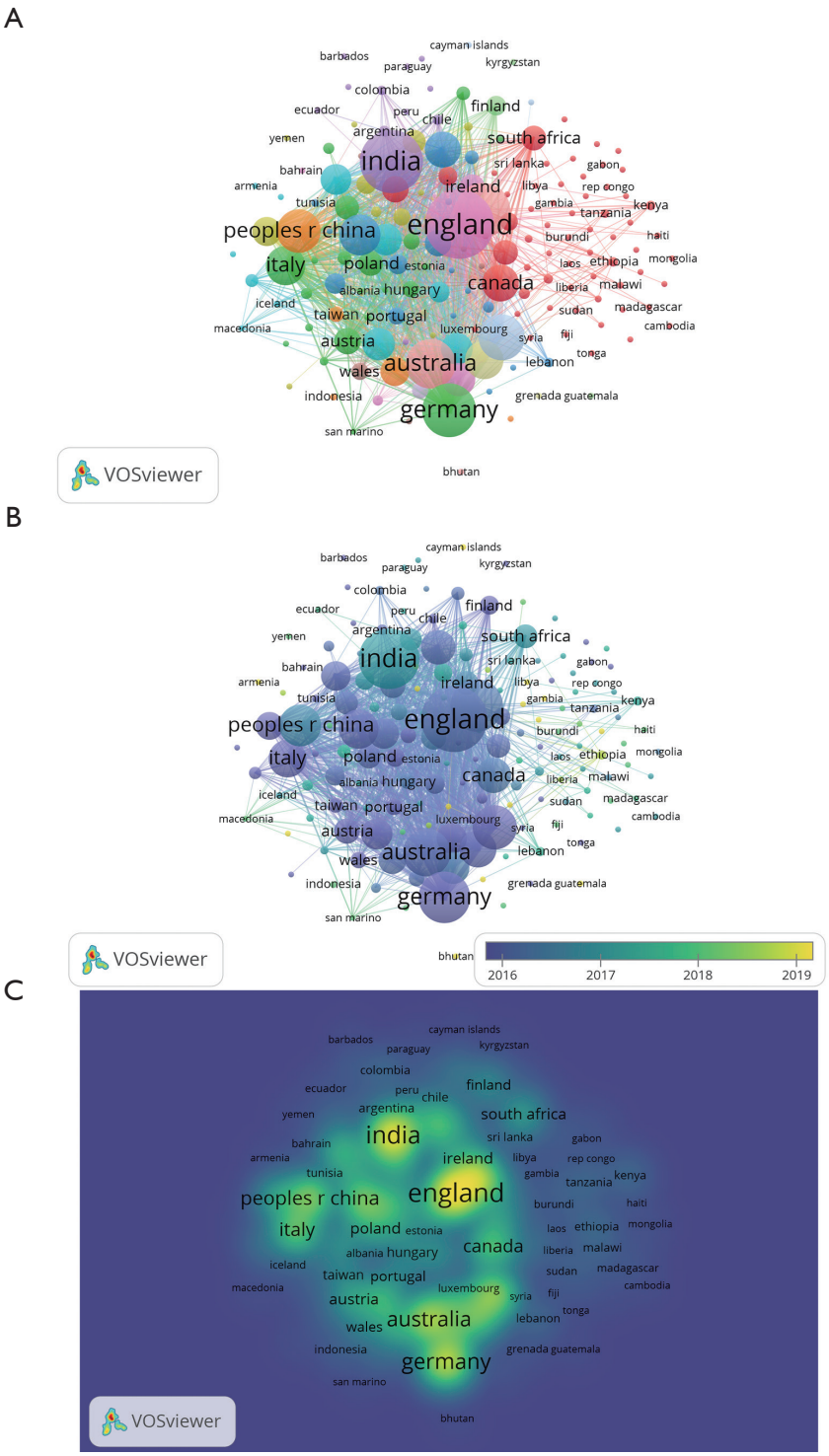

Figure 15 Mapping on bibliographic coupling countries related to anaesthesia. (A) Network map of bibliographic coupling countries; (B) visualization of bibliographic coupling countries according to the APY; (C) density visualization for bibliographic coupling countries. APY, average publication year.

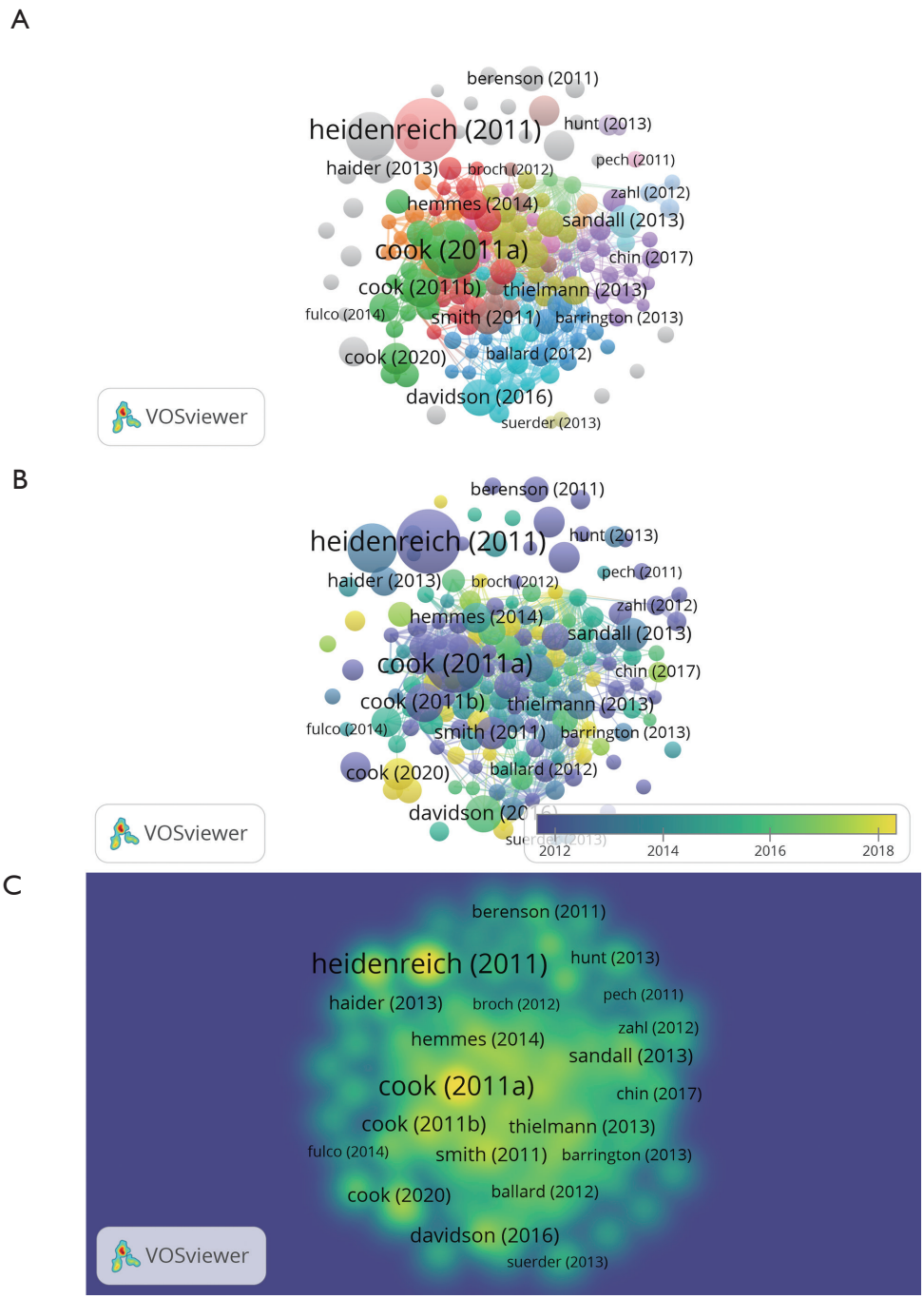

Figure 16 Mapping on bibliographic coupling documents related to anaesthesia. (A) Network map of bibliographic coupling documents; (B) visualization of bibliographic coupling documents according to the APY; (C) density visualization for bibliographic coupling documents. APY, average publication year.

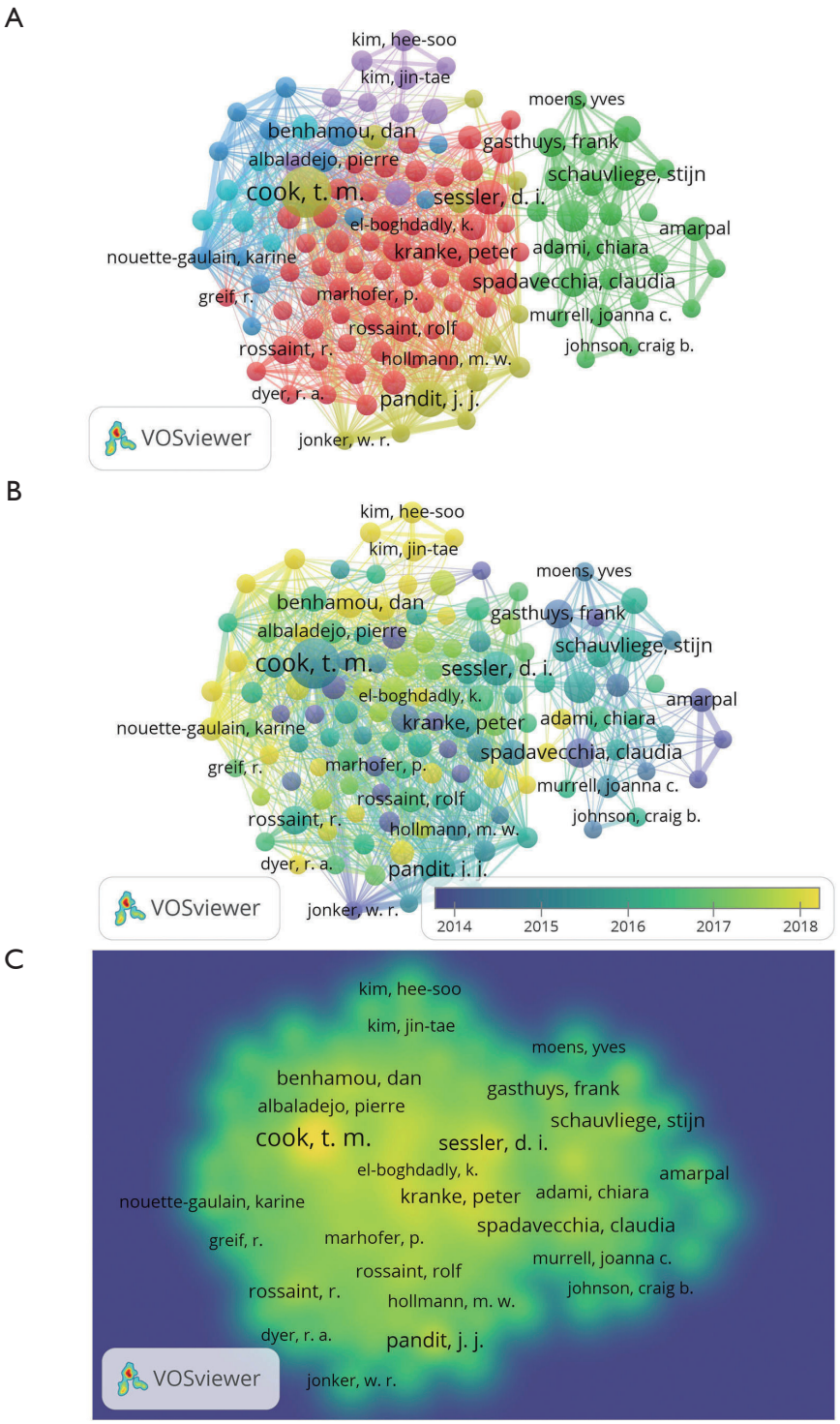

Figure 17 Mapping on bibliographic coupling authors related to anaesthesia. (A) Network map of bibliographic coupling authors; (B) visualization of bibliographic coupling authors according to the APY; (C) density visualization for bibliographic coupling authors. APY, average publication year.

P (900 citations), Kehlet H (894 citations), Sessler DI (822 citations), Smith AF (760 citations), El-Boghdadly K (690 citations), Sessler DI (681 citations), and Rasmussen LS (631 citations).

Discussion

In this study, the VOSviewer software was used to perform bibliometric analysis on the trends and hotspots of anesthesia research using the WoSCC database. A total of 16,213 articles and reviews were retrieved. The amount of annual publications indicated an upward trend after 2014. Among these countries/regions, the UK ranked first as for NP, indicating that the UK is a high yield country for anesthesia research. In anesthesia research, three UK affiliates and one UK author were among the top 10. However, despite its high NP, India's NC and h-index lagged far behind other countries, indicating that the quality of the papers published in this field is not high and further improvement is needed. Indian scholars are advised to focus on quality rather than quantity. It is worth noting that only 2 of the top 10 journals with the highest output have high IF, and 4 journals have been deleted by SCI. Research into anesthesia should be more in-depth and innovative. Scholars in this field should reflect on this.

Quantitative analysis and visualization of literature has provided some insights into the development trends and hotspots in this field. In addition, using GCS as the indicator, this research helps to better understand the important nodes in this field. However, there were some limitations to this study. First, only SCI articles and reviews were included. Second, VOSviewer may have missed some information because it cannot analyze the full text of a publication. Finally, some newly published high quality papers may have low NC, and these papers were thus excluded. Therefore, there may be a degree of lag time related to this study.

Keyword analysis showed that there was a large number of research related to propofol, painless anesthesia, management, and surgery. Propofol is a short acting intravenous anesthetic used for the induction and maintenance of general anesthesia (31). Propofol has the clinical characteristics of rapid onset, short action time, rapid recovery, and less adverse reactions. It is widely used in severe patients in various medical departments (32). In 1977, Kay and Roy first demonstrated the anesthetic effect of propofol in a clinical setting (33). Propofol can not only induce and maintain anesthesia, but also protect ischemic and hypoxic cardiomyocytes. Its main mechanism of action is to alleviate oxidative stress and increase the release of endogenous cannabinoid (34). Propofol has a long-term brain protective effect and can block and reduce the neuronal death of hippocampal cells after 7 days of ischemia (35). However, in recent years, a study has suggested that propofol can act on multiple signaling pathways, resulting in the death of embryonic brain cells in rats, abnormal synaptic development, and reduced numbers of neurons in brain cells, leading to adverse effects on learning and memory ability (36). These studies showed that propofol is like a double-edged sword. Clinical anesthesiologists should make full preoperative preparations, standardize the use of propofol, formulate a relatively safe anesthesia scheme, and minimize the mechanical damage caused by propofol anesthesia to patients. After anesthesia, the patient's state was very fragile and his consciousness was not awake. During the escort, paying attention is necessary to observe that the patient had no abnormal symptoms. If the postoperative patient does not go through the observation stage when waking up, it is likely to have respiratory depression symptoms during movement. In this process, the doctor needs to go with him, be in the position of the patient's head, observe the patient's breathing at any time, and make the patient absorb oxygen if necessary. Analgesic drugs with anesthetic effects such as morphine and fentanyl can help patients block pain in most cases, but they cannot be used for anesthesia in all cases, especially when patients are awake. For conscious patients, it is necessary to block the nerve essentially before surgical treatment, so as to ensure that the patients have no pain during the operation. Anesthetics have protective effects on ischemia of many organs. The protective effect of anesthetics on organs has gradually become the focus of researchers. By regulating autophagy level, antioxidant, anti-inflammatory, anti-apoptosis and other mechanisms, anesthetics can reduce motor neuron injury after spinal cord ischemia-reperfusion, distal limb ischemia and lung ischemia.

Neuropathic pain is a very difficult problem threatening health, which has a serious impact on the quality of life of patients and a certain challenge in clinical treatment. Therefore, neuroprotection has a better synergistic therapeutic effect on pain relief. In the future research, pain management, pediatric anesthesia, safety, risk , et al will be the hotspot of research.

Conclusions

This bibliometric analysis demonstrated that anesthesia research has developed rapidly since 2014. England is a major producer and has made many outstanding breakthroughs in this field. The *British Journal of Anesthesiology* and *Anesthesiology* published the latest research and new advances in this field. In addition, research on anesthesia has mainly focused on clinical practice.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-1599/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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