Journal of Pain Research

Dovepress
open access to scientific and medical research

Open Access Full Text Article

REVIEW

The Topics and Publication Trends in Emergence Deliri-Um: A Bibliometric Analysis from 2002 to 2022

Ting Liu, Fang Luo

Department of Anesthesiology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, People's Republic of China

Correspondence: Fang Luo, Department of Anesthesiology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, No. 1095, Jiefang Avenue, Wuhan, People's Republic of China, Tel +8618872246972, Email luofang0909@hotmail.com

Background: Emergence delirium is an early postoperative behavior change in pediatric patients, posing risks to patient safety and leading to prolonged hospital stays and increased medical costs. As a result, the research on emergence delirium has grown substantially. This study aims to identify the most influential literature, trends, and topics in emergence delirium research, as well as to quantify the fundamental data of academic publications on this topic.

Methods: We searched for articles on emergence delirium in the Science Citation Index Expanded databases, covering the period from 2002 to 2022. Bibliographic information, including countries, institutions, journals, authorships, references, and keywords, was collected for further analysis.

Results: A total of 739 articles on emergence delirium published between 2002 and 2022 were collected. China emerged as the most prolific publisher in this field, accounting for over 30% of all articles (226 publications), followed by the United States (n = 143) and South Korea (n = 92). The top three productive journals were *Pediatric anesthesia* (n=78, IF=2.129), *Anesthesia and Analgesia* (n=28, IF=6.627), and *BMC Anesthesiology* (n=28, IF=2.583). Yonsei University was the most active institution, with 22 publications related to emergence delirium. Among authors, Kin, Hee-Soo (n = 9) published the most articles in this field, followed by Yao, Yusheng (n = 7), Lee, Ji-Hyun (n = 7). The prominent topics in emergence delirium research during the past two decades were "children", "emergence delirium" and "propofol".

Conclusion: Through bibliometric analysis, this study provides a comprehensive overview of the trends and developments in the field of emergence delirium over the past two decades. The results demonstrate a significant growth in emergence delirium research worldwide, with China leading in the number of publications. Despite the wealth of literature on strategies for preventing and managing emergence delirium in clinical settings, further basic research is needed to elucidate the underlying mechanisms of emergence delirium.

Keywords: bibliometric analysis, emergence delirium, anesthesia, pediatric anesthesia

Introduction

Emergence delirium (ED) is an early postoperative behavior change during the recovery period, characterized by symptoms such as crying, thrashing, and disorientation.[1,2] The prevalence of ED varies depending on the grading method and anesthetic technique used, ranging from 1.3% to 80%, with a higher incidence observed in preschool children.[3–7] It has been demonstrated that ED is associated with adverse effects, such as incorrect removal of intravenous catheters or drains, damage to incision sites, and harm to the patient or healthcare personnel, all of which also lead to increased nursing requirements, parental anxiety, and dissatisfaction with perioperative care.[8] Extensive research has focused on identifying predisposing factors for ED, including volatile anesthetics, preschool children, pain, ophthalmology, otorhinolaryngology procedures, and preoperative anxiety.[1,9–11] Propofol, ketamine, fentanyl, dexmedetomidine, and preoperative analgesia have been proven to have a prophylactic impact in avoiding ED.[12,13] The pharmacologic remedy of ED involves the administration of intravenous drugs such as midazolam, propofol, opioids, and dexmedetomidine.[13,14] However, the underlying pathogenesis of ED remains unclear, necessitating further research for more effective therapeutic strategies. In this study, we conducted a comprehensive analysis of publications and topics in the field of ED.

Received: 2 May 2023
Accepted: 22 July 2023
Published: 7 August 2023

Bibliometric analysis has gained popularity in recent years as it enables the examination of large amounts of scientific data and the graphical representation of high-impact research.[15] Researchers employ bibliometric analysis for a wide range of purposes, including identifying developing trends in article and journal performance, analyzing collaboration patterns, exploring research elements, as well as delving into the underlying intellectual structure of a field's extant literature.[16,17] Previous bibliometric studies on ED have focused only on the last decade and did not manually filter irrelevant articles.[18] To address this limitation, we examined over two decades of research on ED and performed a second screening based on the titles and abstracts. Our research aimed to investigate the cutting-edge developments and growth patterns of ED over the last 20 years using co-occurrence network maps of nations, academic institutions, active journals, authors, academic publications, and keywords.

Materials and Methods

Search Strategy

An online literature search was conducted on Feb 2, 2023, utilizing the Science Citation Index Expanded databases in the WoS Core Collection. The search strategy included the terms "emergence agitation", "emergence delirium", "emergence agitated", and "postanesthetic agitation", covering the period from January 1, 2002, to December 31, 2022. We downloaded all data within 24 hours on February 3, 2023, with no language restrictions. A total of 1232 studies were obtained. Figure 1 shows the detail of the search flow. Excluded publications were meeting abstracts (n = 35), editorial material (n = 27), letters (n = 46), proceedings paper (n = 19), early access (n = 11), book chapters (n = 1), retracted publication (n = 1), and correction (n = 5). We evaluated the titles and abstracts of the remaining literature, resulting in 739 articles relevant to our study. We used CiteSpace to preprocess the data,

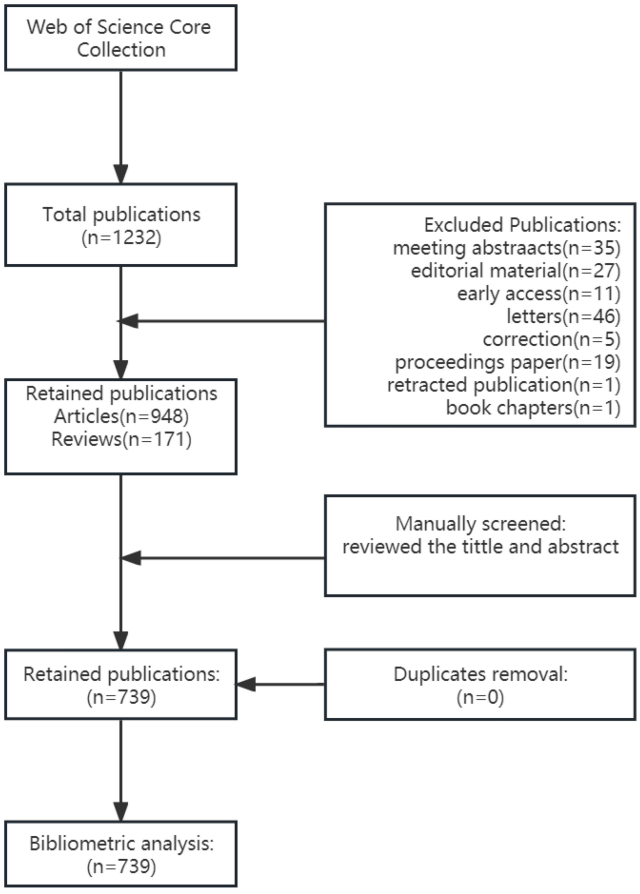

Figure 1 Flowchart for the publication chosen included in this study.

remove duplicates and rejections, and visualize and analyze the 739 records, consisting of 647 articles and 92 reviews.

Data Analysis

The analysis of WOS data was primarily conducted using Microsoft Office Excel 2020 (Microsoft, Redmond, WA, USA). In our study, we drew charts using Excel 2020 to visually display trends between the publications and years. Using the R (Version 4.0.3) package bibliometric, the collaboration across countries/regions was carried out. Investigating collaborative networks between nations/journals/authors, and keywords were done using VOSviewer (1.6.18). VOSviewer offers three primary visual maps: the network visualization map, the overlap visualization map, and the density visualization map.[19] The size of the nodes representing nations, institutions, journals, and authors in VOSviewer was based on how often they were mentioned in the titles and abstracts of the papers included in the analysis.[20] CiteSpace (6.1.6.0) is another well-liked visualization tool that can be used to visualize emerging trends and sudden shifts.[21] This research was utilized primarily to generate a visualization map for co-citation analysis of co-cited journals/references and to isolate the keywords/references with the highest citation bursts. For our CiteSpace analysis, we considered a time range from 2002 to 2022, with a year per slice, selecting node types one at a time, using a selection criteria of g-index (k = 25), and a minimum duration (MD = 1).

Results

Annual Growth Trend of Publications

Upon conducting a thorough search of the WOS database, we identified 739 articles related to ED from 2002 to 2022, which included 647 articles (87.55%) and 92 reviews (12.45%). As can be seen in Figure 2, there was a lot of variation in the pace at which the yearly number of publications in ED occurred between the years 2002 and 2010. The distribution of publications exhibited variation over the years, with significant increases observed from 2012 to 2015 and a rapid rise in the number of relevant publications after 2016. The overall trend of published literature was steadily increasing, except for slight fluctuations in 2012 and 2016, and reached a peak in 2022 (n = 90, 12.18%). It has been shown that there was an association between the number of publications and the year in which they were published, and this correlation has a coefficient of $R^2 = 0.96$. Based on the fitting graph (Figure 2), it is predicted that the yearly number of publications on ED will surpass 94 by 2023.

Analysis of Productive Countries/Regions and Institutions

Participating in this investigation exploring ED research were a total of 52 countries. The geographical contribution map of ED is visually depicted in Figure 3, revealing that the majority of ED studies were conducted in Asia and North America. The top 10 most active countries contributing to the development of ED globally are listed in Table 1. Among these countries, China emerged as the most prolific publisher in the field, making up more than 30% of all articles

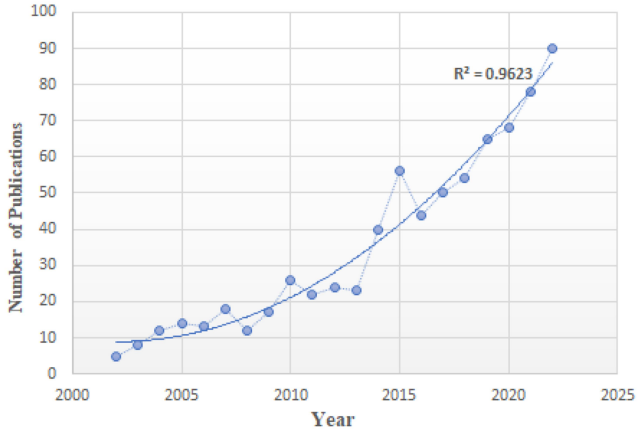

Figure 2 A polynomial curve that fits the rise of publications in emergence delirium.

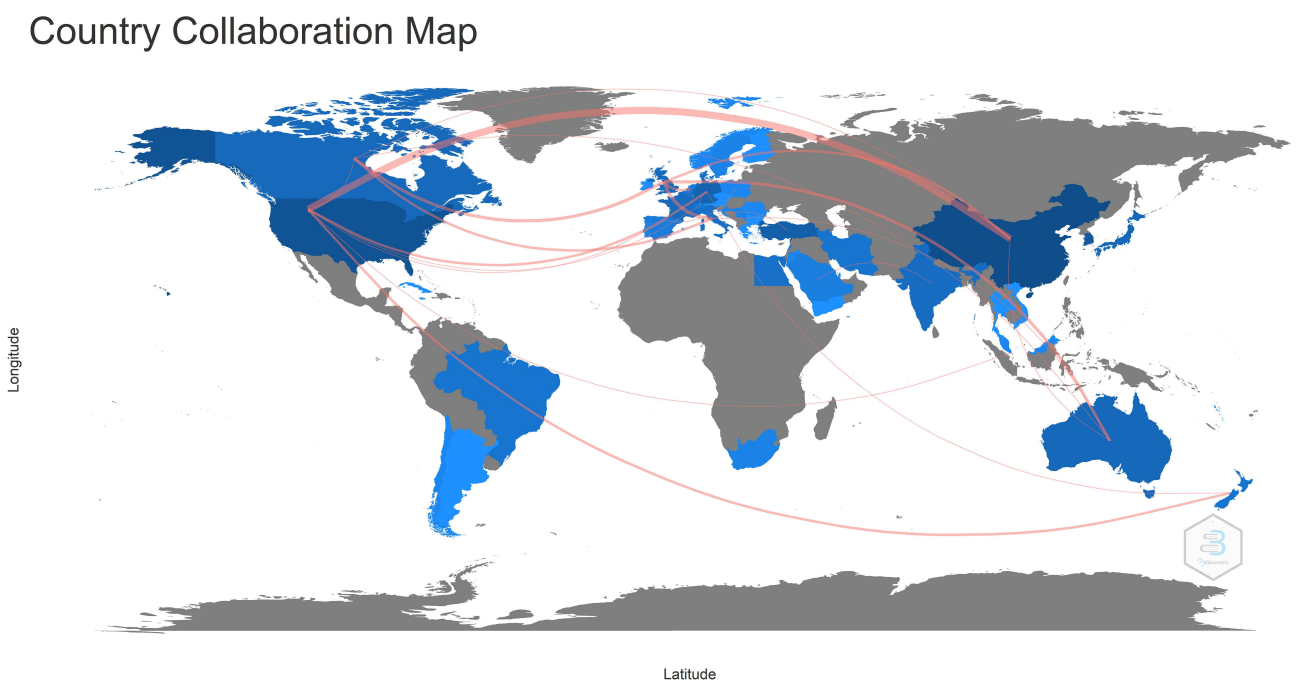

Figure 3 Geographic contribution map based on the total publications of different countries.

included with 226 publications. With two-thirds of all publications in China, the United States was the second most creative country (143/739, 19.35%). Notably, the United States had 5376 citations, significantly more than any other country. Furthermore, despite its relatively smaller number of publications, Canada demonstrated the highest citation ratio (44.35) among the top ten countries, indicative of the production of high-quality papers.

As shown in Figure 4, we used VOSviewer to visualize the contributions of each country or region in the field of ED. The map of country/region contribution included 22 nodes and 61 links, highlighting the collaborative research networks established by 22 countries or regions in the domain of ED. In VOSviewer, the size of each circle represents the number of papers published in that country. Additionally, the thickness of the lines indicates the strength of the relationships between two countries or regions. The results obtained from the co-authorship analysis reveal that the United States serves as the central hub of the network, engaging in frequent collaborations with China. This finding underscores the significance of international cooperation in advancing research on ED.

Table 1 The Top 10 Active Countries/Regions Related to Emergence Delirium

Country	Publications (N = 739), n (%)	Rank Based on Total Publications	Citations	Rank Based on Citations	Citation Per Publication
China	226 (30.58)	1	1880	2	8.32
United States	143 (19.35)	2	5376	1	37.59
South Korea	92 (12.45)	3	1356	4	14.74
Turkey	54 (7.31)	4	1183	3	21.91
Germany	34 (4.60)	5	587	7	17.26
Japan	26 (3.52)	6	531	9	20.42
Australia	24 (3.25)	7	556	8	23.17
Canada	23 (3.11)	8	1020	5	44.35
France	18 (2.44)	9	765	6	42.5
India	17 (2.30)	10	195	10	11.47

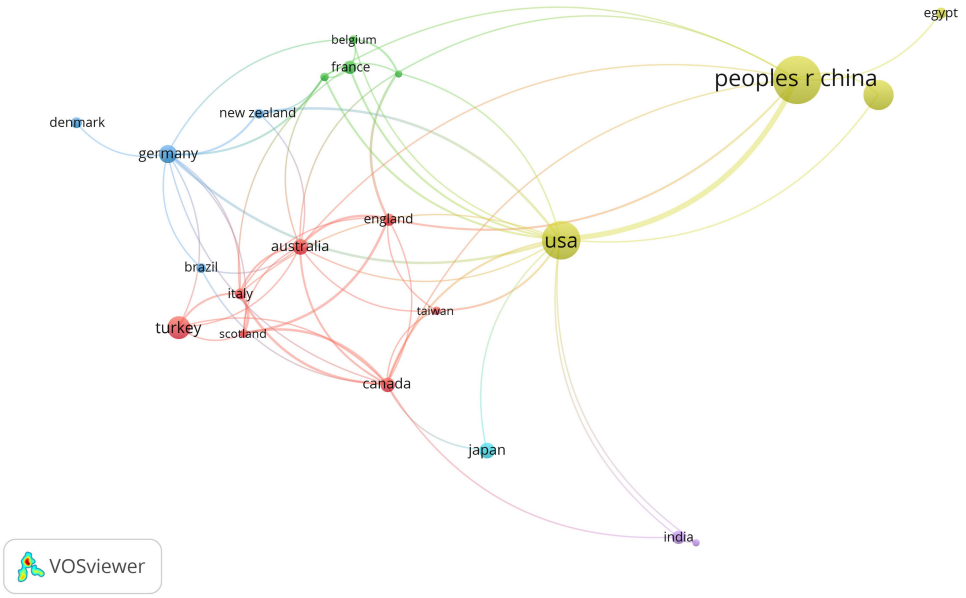

Figure 4 Bibliometric map created using network visualization mode and co-authorship analysis between countries.

Through our co-authorship analysis using VOSviewer, we identified a total of 45 institutions that have made notable contributions to the investigation of ED, as depicted in Figure 5. The analysis generated 572 links, representing the collaborative relationships among these institutions. The top 10 institutions were Yonsei University (n = 22), Seoul National University (n = 16), Shanghai Jiao Tong University (n = 13), Korea University (n = 12), Sichuan University (n = 11), Zhejiang University (n = 11), Xuzhou Medical University (n = 10), Wenzhou Medical University (n = 10), Capital Medical University (n = 10), and Yale University (n = 8), as presented in Table 2. Of these institutions, 6 were located in China, highlighting the significant role of China in this research field. It is worth highlighting that despite having only published 8 relevant articles, Yale University has amassed an impressive citation count of 1101. This suggests that these papers are of exceptional quality and possess substantial reference value.

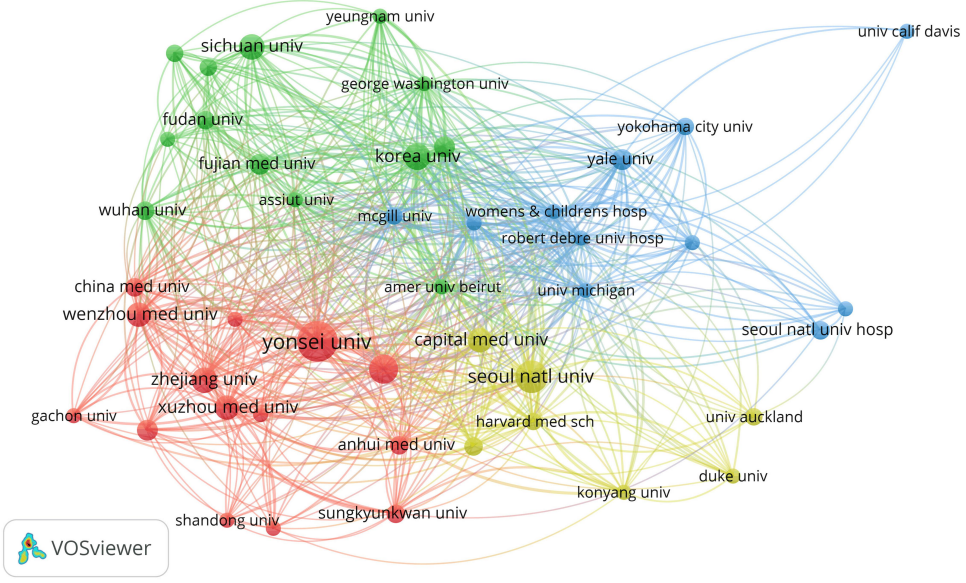

Figure 5 Bibliometric map created using network visualization mode and co-authorship analysis between institutions.

Table 2 The Top 10 Active Institutions Related to Emergence Delirium

Rank	Institution	Document	Citations	Citation Per Document
1	Yonsei University, Seoul, South Korea	22	431	19.59
2	Seoul National University, Seoul, South Korea	16	226	14.13
3	Shanghai Jiao Tong University, Shanghai, China	13	80	6.15
4	Korea University, Seoul, South Korea	12	172	14.33
5	Sichuan University, Sichuan, China	11	86	7.82
6	Zhejiang University, Zhejiang, China	11	85	7.73
7	Xuzhou Medical University, Xuzhou, China	10	102	10.20
8	Wenzhou Medical University, Wenzhou, China	10	81	8.10
9	Capital Medical University, Beijing, China	10	42	4.20
10	Yale University, New Haven, United States	8	1101	137.63

Analysis of Active Journals and Co-Cited Journals

We utilized VOSviewer (1.6.18) and CiteSpace (6.1.6.0) to perform a comprehensive analysis of the journals and co-cited journals in the field of ED, to identify the most prolific and highly cited publications. The top 10 active journals and co-cited journals were tabulated in Table 3 and the density map highlighted the most frequently published journals (Figure 6). Among them, *Pediatric Anesthesia* (n = 78, IF = 2.129), *Anesthesia and Analgesia* (n = 28, IF = 6.627), and *BMC Anesthesiology* (n

Table 3 The Top 10 Active Journals and Co-Cited Journals Related to Emergence Delirium

Rank	Journals	Country	Publications	IF (2021)	Citations	Citation Per Publication	Co-Cited Journals	IF (2021)	Citations
1	Pediatric Anesthesia	United Kingdom	78	2.129	2549	32.68	Anesthesia and Analgesia	6.627	3390
2	Anesthesia and Analgesia	United States	28	6.627	2036	72.71	Pediatric Anesthesia	2.129	2833
3	BMC Anesthesiology	United Kingdom	28	2.376	251	8.96	Anesthesiology	8.986	2131
4	European Journal of Anesthesiology	United Kingdom	26	4.183	357	13.73	British Journal of Anesthesia	11.719	1422
5	Acta Anesthesiologic Scandinavica	Denmark	25	2.274	705	28.20	Acta Anesthesiologic Scandinavica	2.274	718
6	Journal of Perianesthesia nursing	United States	21	1.295	121	5.76	European Journal of Anesthesiology	4.183	405
7	British Journal of Anesthesia	United Kingdom	20	11.719	1245	62.25	Journal of Clinical Anesthesia	9.375	400
8	Medicine	United States	18	1.817	149	8.28	Journal of Anesthesia	2.931	300
9	Journal of Clinical Anesthesia	United States	17	9.375	231	13.59	Canadian Journal of Anesthesia	6.713	258
10	Current Opinion in Anesthesia	United States	16	2.733	389	24.31	Anesthesia Intensive Care	1.512	186

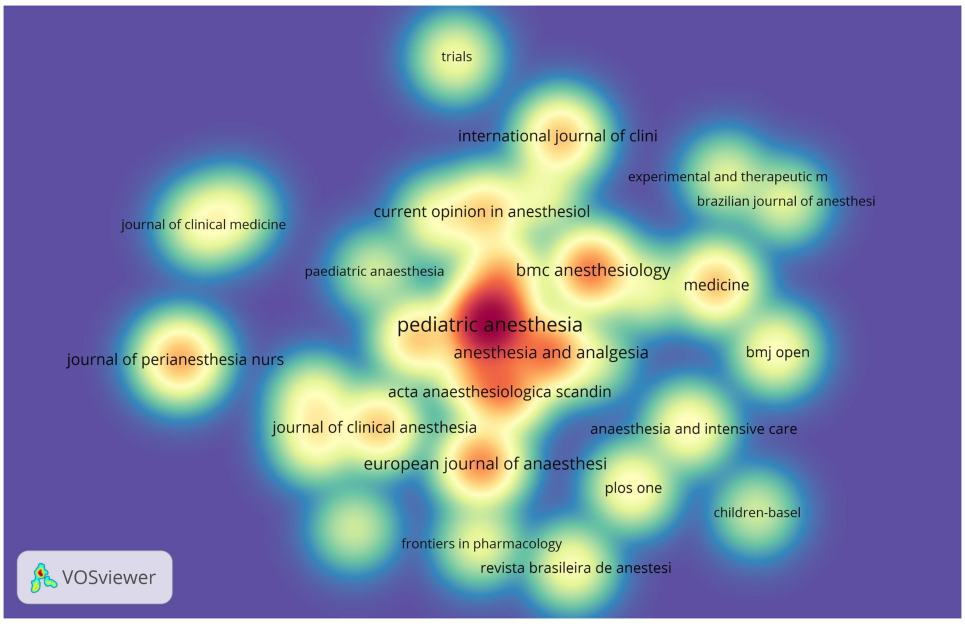

Figure 6 The density map of journals associated with emergence delirium, where the number of publications ≥5.

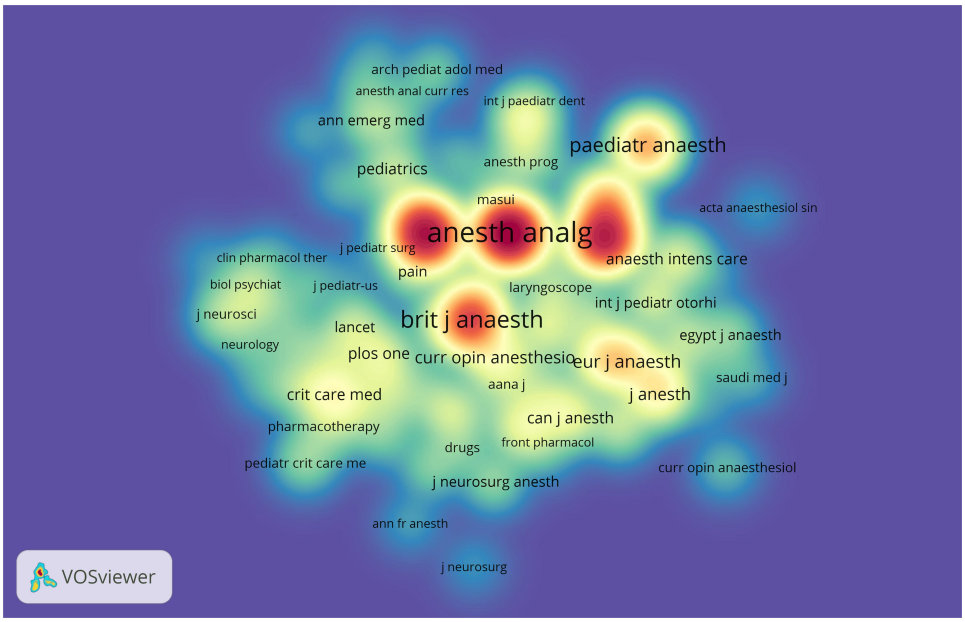

Figure 7 The density map of co-cited journals associated with emergence delirium, where the number of publications ≥20.

= 28, IF = 2.376) emerged as the top 3 productive journals. The *British Journal of Anesthesia* boasted the highest impact factor (IF = 11.719) and citation per publication (62.25), suggesting a positive correlation between paper quality and impact factor. Moreover, *Anesthesia and Analgesia* received the most citations (n = 3390), followed closely by *Pediatric Anesthesia* (n = 2833). Figure 7 illustrates that there were positive citation relationships between several journals.

Figure 8 presents a dual-map overlay of journals, illustrating the distribution of journals by subject. On the map, the citing journals were on the left, while the cited journals were on the right. The fields that the journals covered were indicated by the labels. The colorful lines showed the citation pathways from left to right. According to all of the possible

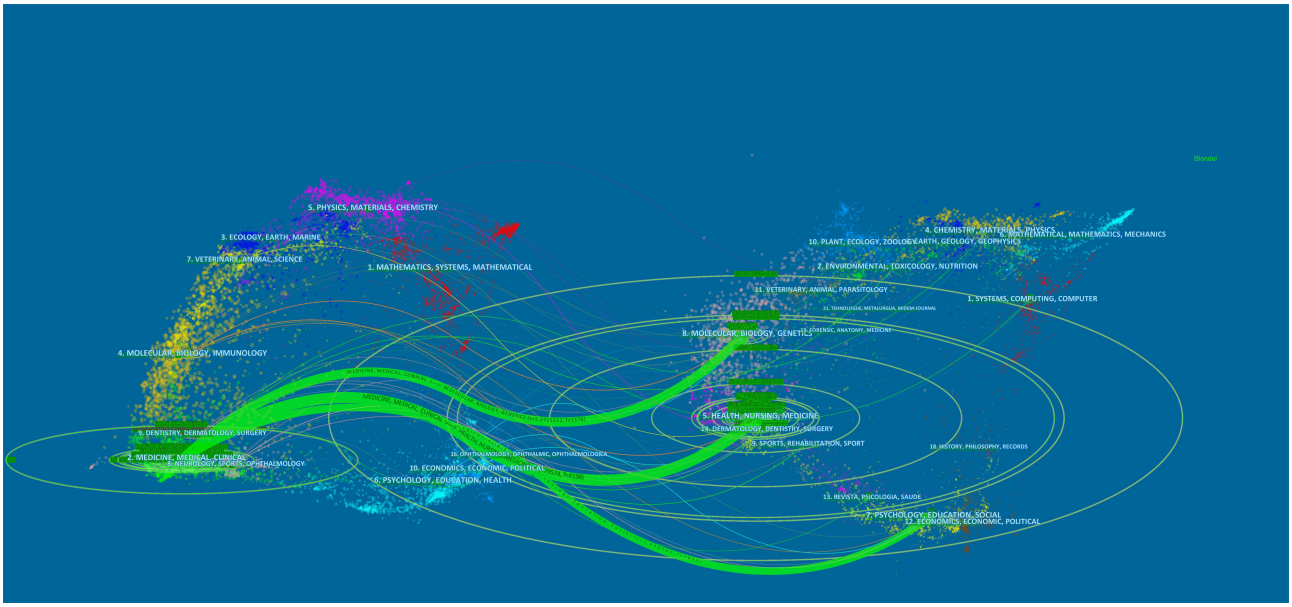

Figure 8 The dual-map overlay of journals related to emergence delirium.

branches, the studies published in Molecular/Biology/Genetics and Health/Nursing/Medicine journals are usually cited by Medicine/Medical/Clinical journals.

Analysis of Active Authors and Co-Cited Authors

The top 10 most prolific authors and co-cited authors among all scholars who participated in ED are presented in Table 4. It can be observed intuitively that Kin, Hee-Soo (n = 9) has published the most articles in this area, followed by Yao, Yusheng (n = 7), and Lee, Ji-Hyun (n = 7). However, it is important to highlight the exceptional impact of Aouad, Marie T, who has published only 4 relevant articles but has garnered an impressive citation count of 235. This indicates that the publications by Aouad are of exceptionally high quality and possess significant reference value. Figure 9 displays the authors who have contributed to a minimum of 3 different publications. The authors who fell into the green cluster are considered to be pioneers in the field of ED, whereas the authors who fell into the blue and yellow groupings has only started publishing articles relatively recently. In addition, Kain, Zeev N, Sikich, N, and Cohen, I.t emerged as the top 3 co-cited authors related to ED, demonstrating their supremacy in this field. Figure 10 displays the authors who are co-cited and have a minimum of

Table 4 The Top 10 Active Authors and Co-Cited Authors Related to Emergence Delirium

Rank	Author	Publications	Citations	Citation Per Publication	Co-Cited Authors	Citations
1	Kin, Hee-Soo	9	94	10.44	Kain, Zeev N	592
2	Yao, Yusheng	7	87	12.43	Sikich, N	273
3	Lee, Ji-Hyun	7	64	9.14	Cohen, It	226
4	Goto, Takahisa	6	43	7.17	Dahmani, Souhayl	209
5	Mihara, Takahiro	6	43	7.17	Aouad, Marie T	204
6	Kim, Jin-Tae	6	57	9.5	Voepel-Lewis, T	188
7	Ka, Koui	5	43	8.6	Aono, J	172
8	Sung, Tae-Yun	5	48	9.6	Vlajkovic, Gp	152
9	Li, Wenxian	5	72	14.4	Cravero, J	123
10	Aouad, Marie T	4	235	58.75	Cravero, Jp	119

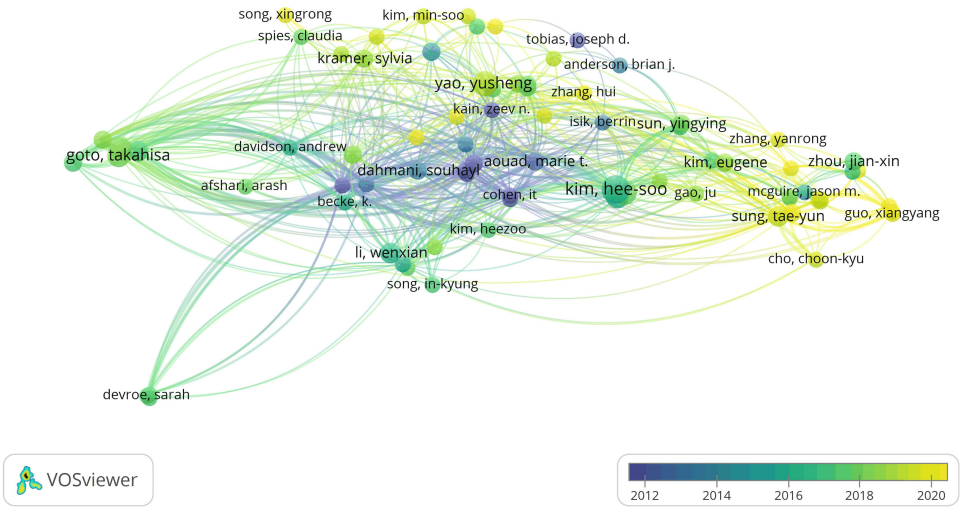

Figure 9 The overlay visualization of authors associated with emergence delirium, where the number of publications ≥3.

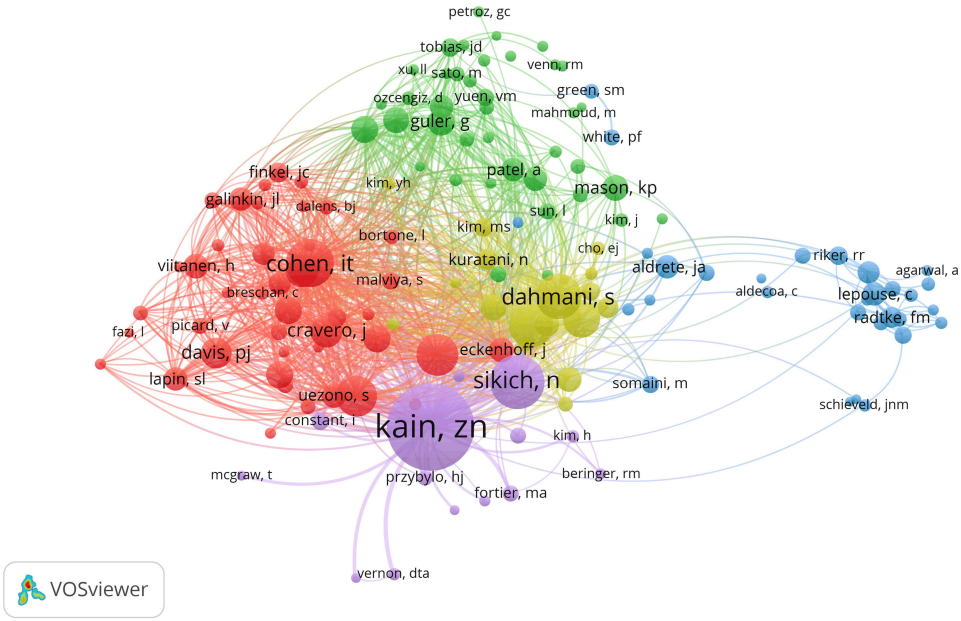

Figure 10 The network visualization of co-cited authors associated with emergence delirium, where the number of publications ≥20.

20 publications each to their credit. Each circle symbolizes a different author, and the size of the circle indicates the number of articles published. The lines connecting the circles represent the co-occurrence associations among the authors.

Analysis of References and Co-Cited References

In this research, a reference analysis was conducted to gain insights into the evolution of ED. The most highly cited references were examined, and the timeline of co-cited references was visualized using Citespace. Table 5 and 6 demonstrate the top 10 references in terms of both citations and co-citations. The most cited reference was the article published by Nancy Sikich (2004)[22] in the *Anesthesiology*, with 437 citations, followed by Zeev N Kain (2006)[23] and Zeev N Kain (2004).[24] Notably, 4 of the pertinent articles were on *Anesthesia and Analgesia*. Additionally, Zeev N. Kain authored 3 of the top 10 cited references. Furthermore, the top 3 co-cited references

Table 5 The Top 10 Cited Articles Related to Emergence Delirium

Rank	Title	First Author	Year	Journal	IF (2021)	Citations
1	Development and psychometric evaluation of the pediatric anesthesia emergence delirium scale.	Nancy Sikich	2004	Anesthesiology	8.986	437
2	Preoperative anxiety, postoperative pain, and behavioral recovery in young children undergoing surgery	Zeev N Kain	2006	Pediatrics	9.703	405
3	Preoperative anxiety and emergence delirium and postoperative maladaptive behaviors	Zeev N Kain	2004	Anesthesia and Analgesia	6.627	350
4	A prospective cohort study of emergence agitation in the pediatric postanesthesia care unit	Terri Voepel-Lewis	2003	Anesthesia and Analgesia	6.627	255
5	Emergence delirium in children: many questions, few answers	Gorsana P Vlajkovic	2007	Anesthesia and Analgesia	6.627	249
6	Family-centered preparation for surgery improves perioperative outcomes in children: a randomized controlled trial	Zeev N Kain	2007	Anesthesiology	8.986	231
7	Dexmedetomidine: applications in pediatric critical care and pediatric anesthesiology	Joseph D Tobias	2007	Pediatric Critical Care Medicine	3.971	208
8	Pharmacological prevention of sevoflurane- and desflurane-related emergence agitation in children: a meta-analysis of published studies	S Dahmani	2010	British Journal of Anesthesia	11.719	196
9	Emergence delirium in adults in the post-anesthesia care unit	C Lepouse	2006	British Journal of Anesthesia	11.719	196
10	Single-dose dexmedetomidine reduces agitation after sevoflurane anesthesia in children	Mauricio E Ibacache	2006	Anesthesia and Analgesia	6.627	189

Table 6 The Top 10 Co-Cited Articles Related to Emergence Delirium

Rank	Title	First Author	Year	Journal	IF (2021)	Citations
1	Development and psychometric evaluation of the pediatric anesthesia emergence delirium scale.	Nancy Sikich	2004	Anesthesiology	8.986	272
2	A prospective cohort study of emergence agitation in the pediatric postanesthesia care unit	Terri Voepel-Lewis	2003	Anesthesia and Analgesia	6.627	173
3	Emergence delirium in children: many questions, few answers	Gorsana P Vlajkovic	2007	Anesthesia and Analgesia	6.627	152
4	Greater incidence of delirium during recovery from sevoflurane anesthesia in preschool boys	J Aono	1997	Anesthesiology	8.986	136
5	Preoperative anxiety and emergence delirium and postoperative maladaptive behaviors	Zeev N Kain	2004	Anesthesia and Analgesia	6.627	130
6	Emergence agitation in pediatric patients after sevoflurane anesthesia and no surgery: a comparison with halothane	Terri Voepel-Lewis	2003	Anesthesia and Analgesia	6.627	123
7	Pharmacological prevention of sevoflurane- and desflurane-related emergence agitation in children: a meta-analysis of published studies	S Dahmani	2010	British Journal of Anesthesia	11.719	116

(*Continued*)

Table 6 (Continued).

Rank	Title	First Author	Year	Journal	IF (2021)	Citations
8	A single dose of propofol at the end of surgery for the prevention of emergence agitation in children undergoing strabismus surgery during sevoflurane anesthesia	Marie T Aouad	2007	Anesthesiology	8.986	97
9	Single-dose dexmedetomidine reduces agitation after sevoflurane anesthesia in children	Mauricio E Ibacache	2006	Anesthesia and Analgesia	6.627	92
10	Emergence behavior in children: defining the incidence of excitement and agitation following anesthesia	Jennifer W Cole	2002	Pediatric Anesthesia	2.129	93

were authored by Nancy Sikich (2004),[22] Terri Voepel-Lewis (2003),[25] and Gorsana P Vlajkovic (2007),[26] as presented in Table 6.

We employed Citespace to create a visualization map of the timeline view of co-citation references analysis, which demonstrates the fluctuating pattern of research subjects over time (Figure 11). The current research focuses on topics such as #0 tonsillectomy, #2 sevoflurane, #9 pain, and #10 neurocognitive disorders located towards the rightmost end of the line. Reference citation bursts were used to demonstrate the prevalent nature of references in this field as well as their importance over time (Figure 12). According to the findings of Figure 12, Cravero J (2000)[27] and Cole JW (2002)[28] were the references with the earliest citation bursts. All the while, Moore AD (2017),[14] Aldecoa C (2017)[29], and Mason KP (2017)[9] had the current emergence of strong citation references.

Analysis of Keywords

Through keyword co-occurrence analysis, we can learn about research topics and directions in this field. We extracted 2041 keywords with VOSviewer. Table 7 displays that the top 20 keywords appear more than 75 times. The most frequently occurring keywords were “emergence delirium” (n = 343), “emergence agitation” (n = 241), “propofol” (n =

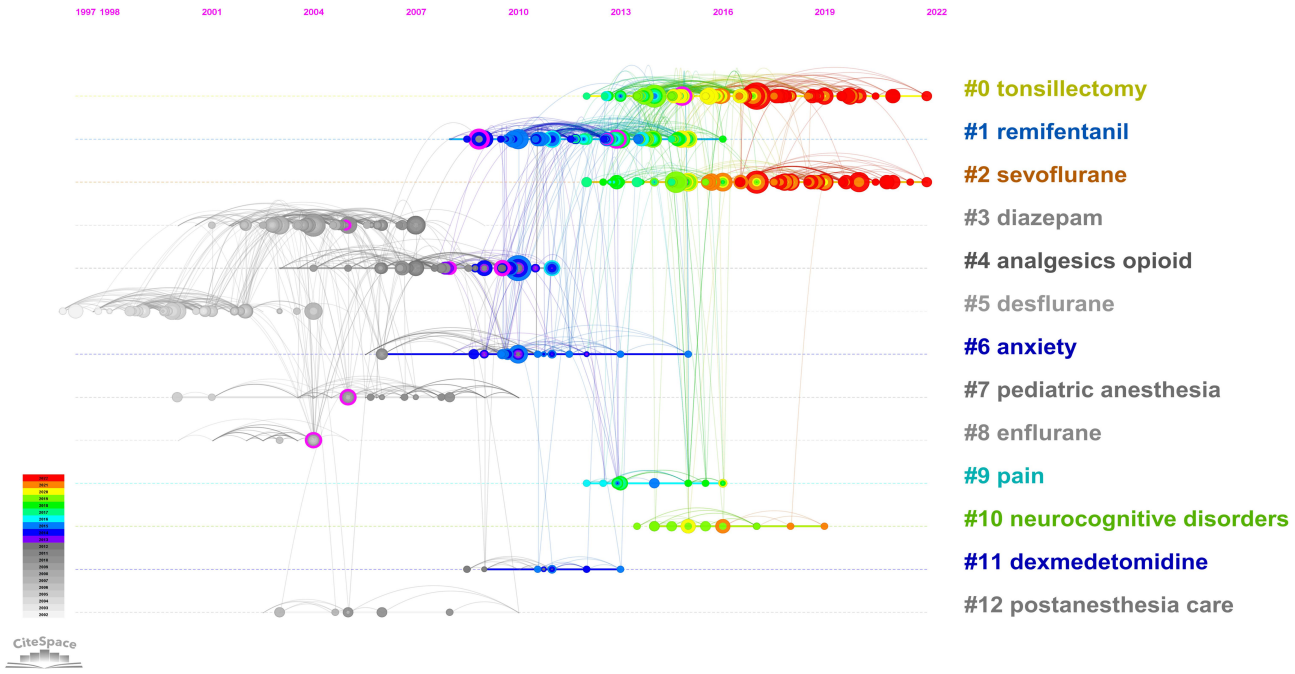

Figure 11 Citespace visualization map of timeline view of co-citation references analysis.

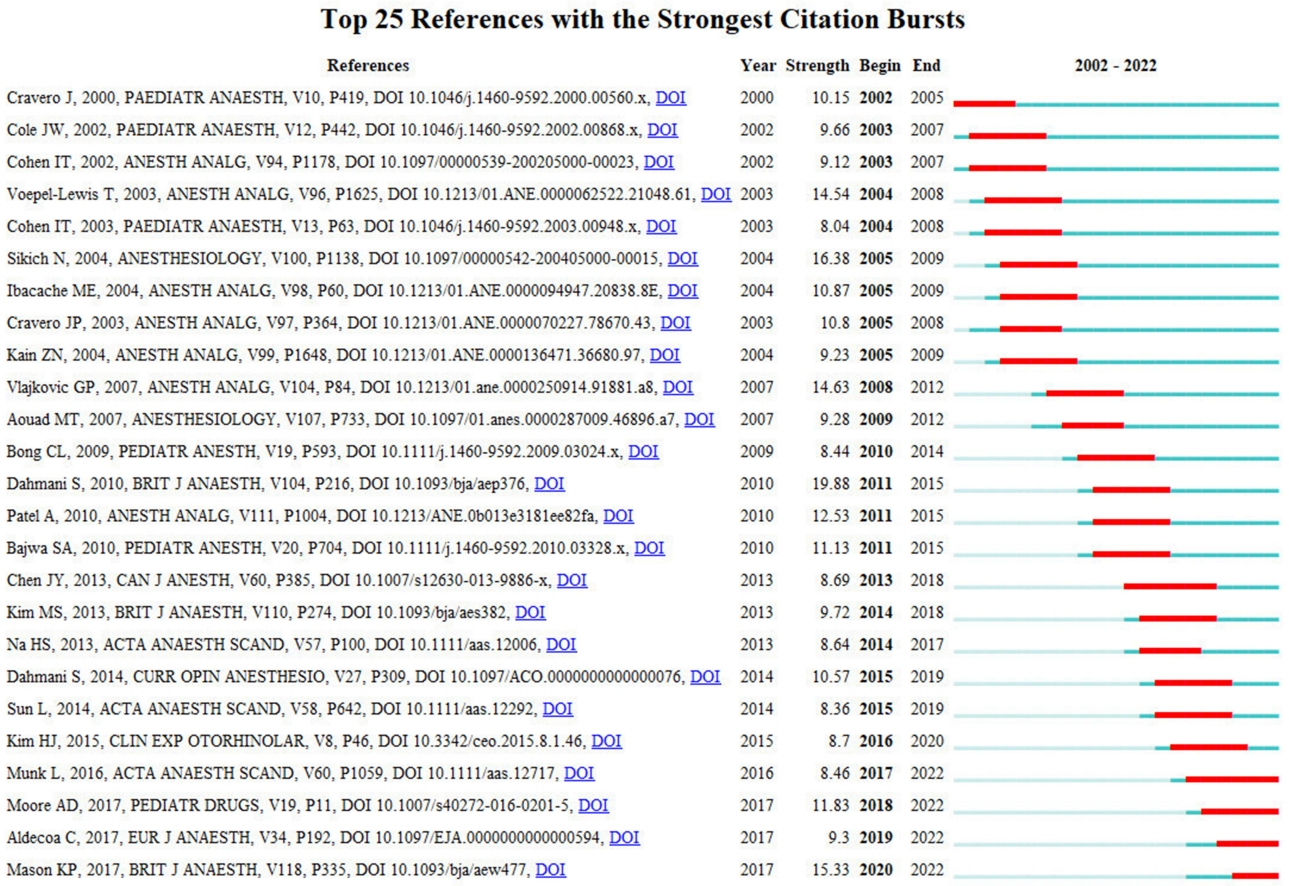

Figure 12 Top 25 references with the strongest citation bursts from 2002 to 2022 related to emergence delirium.

203), "children" (n = 193), and "surgery" (n = 174). These keywords represent the prominent topics of ED. To visually represent these high-frequency keywords, we created an overlay map of keywords (Figure 13), which obtained a total of 8 clusters with different colors. Each cluster represents a distinct research theme or topic within the field. To identify the most influential and emerging keywords in ED, we also used Citespace to analyze the citation bursts of keywords over time, as shown in Figure 14. The keywords related to ED with ongoing citation bursts until 2022 were "adult", "postoperative delirium", "risk factor", "double-blind" and "intranasal dexmedetomidine". These keywords represent the cutting-edge research topics that are currently attracting significant attention in the field of ED. Overall, our keyword analysis provides valuable insights into the research trends and directions of ED.

Table 7 The Top 20 Keywords Related to Emergence Delirium

Rank	Keywords	Occurrences	Rank	Keywords	Occurrences
1	Emergence delirium	343	11	Inhalation	158
2	Emergence agitation	241	12	General anesthesia	129
3	Propofol	203	13	Halothane	121
4	Children	193	14	Pediatric patients	119
5	Surgery	174	15	Prevention	110
6	Sevoflurane anesthesia	173	16	Recovery	105
7	Sevoflurane	172	17	Pain	96
8	Anesthesia	167	18	Midazolam	94
9	Dexmedetomidine	165	19	Desflurane	86
10	Agitation	160	20	Preoperative anxiety	79

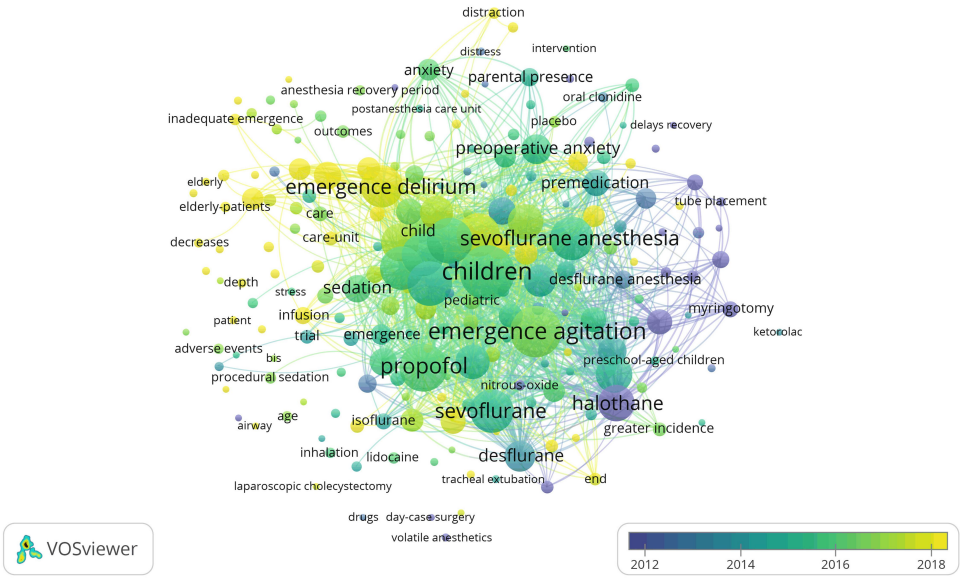

Figure 13 The co-occurrence network and keyword clusters related to emergence delirium. Minimum number of occurrences of keywords ≥5.

Discussion

General Information

The bibliometric analysis offers unique advantages over traditional reviews or meta-analyses by providing a comprehensive overview of the growth trajectory of specific research areas and identifying research priorities. This study represents the first application of bibliometric analysis to map the knowledge structure and highlight potential future research frontiers in the field of ED.

Emergence delirium is a well-known and prevalent phenomenon in children recovering from general anesthesia.[30] Additionally, it is preventable and treatable, which is a global public health issue. As seen in Figure 2, the subject of ED has seen substantial advancements in the past two decades. Nevertheless, in terms of country analysis, this research only includes 52 countries/regions, and less than half of the nations released more than 10 articles. Interestingly, despite China's consistent contribution of over 200 articles to this field, it possesses the lowest citation ratio among the top 10 countries/regions (Table 1). To improve the situation, the two elements that should be prioritized are 1) growing engagement and interaction with other countries, particularly the United States, Canada, and France, and 2) focusing intently on scientific developments to improve the publication quality.

The top 10 creative organizations mostly are from China (Table 2). This might illustrate why China has made the biggest contributions to the study in ED. It is intriguing to note that Yale University, despite being the institution with the fewest creative outputs globally, exhibits the highest citation ratio. These findings highlight the need for the establishment of scientific organizations that are of world-class caliber to improve a nation's academic position. They also show that there is a disparity in the academic resources available around the globe.

Among the top 10 creative journals, *Pediatric Anesthesia* stands out as the journal that has published the highest number of articles related to ED, highlighting the essential role in this area. Lately, significant findings in this area are more frequently published in this journal (Table 3). Notably, nearly all of the journals listed in the top 10 are from the United Kingdom and the United States, demonstrating that the United Kingdom and the United States were interested in and played an essential role in research connected to ED.

Among the top 10 creative authors, Kin, Hee-Soo was found to be the most prolific author in the field of ED, with 9 articles and 74 citations (Table 4). Furthermore, Kain, Zeev N. was the most frequently co-cited author, followed by Sikich, N and Cohen, It. Kain, Zeev N has led several clinical trials on pediatric patients and is renowned for his work in identifying risk factors for ED, such as preoperative anxiety and postoperative pain.[23,24] Meanwhile, Sikich's development of the Pediatric anesthesia emergence delirium (PAED) scale in 2004 has served as the traditional and widely used

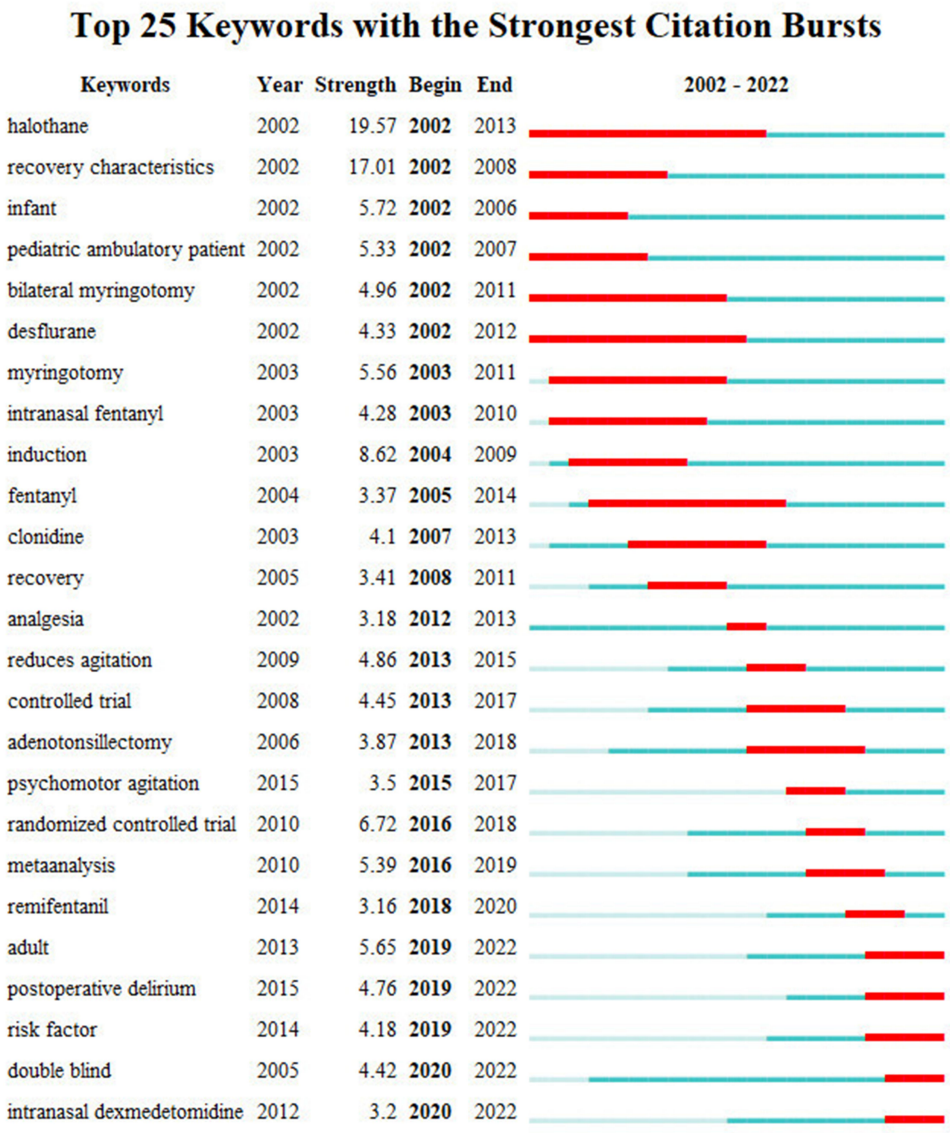

Figure 14 Top 25 keywords with the strongest citation bursts from 2002 to 2022 related to emergence delirium.

assessment tool for identifying ED.[22] This scale has contributed to the objectivity and standardization of ED evaluation, representing a significant milestone in the advancement of the field. Cohen's research on sevoflurane and propofol demonstrated that while both are fast-awakening anesthetics, only sevoflurane resulted in ED.[31] Consequently, the aforementioned papers supplied trustworthy reference value for scholars in this sector.

Knowledge Base

Co-cited analysis serves as an efficient technique for determining the degree of relationship between articles.[32,33] It is widely acknowledged that the significance of an article in a specific field correlates with the frequency of its citation by other scholarly works. The top 10 co-cited references were shown in Table 6. These related papers summarized the developments in the field of ED in the category of reviews, meta-analysis, and original articles.

In 1997, a prospective clinical study was conducted to observe the effect of sevoflurane compared to other inhalation anesthetics, which showed that sevoflurane-induced more ED.[34] Another study in 2002 found a high prevalence of inconsolable weeping or extreme restlessness in children aged 10 months to 6 years within the first 10 minutes of awakening in the post-anesthesia recovery area.[28] Voepel-Lewis et al[25] found an 18% prevalence of ED in children aged

3 to 7 in 2003, lasting 14 minutes on average but as long as 45 minutes. Clinical trials conducted by Craveo et al[27] in the same year demonstrated that sevoflurane anesthesia induced more ED than halothane, regardless of any painful trigger. This suggested that painful stimuli are not necessary to cause ED. These studies reflect the gradual recognition of the ED as a clinical problem in anesthesiology, and the transition from abstract to concrete objective analysis, indicating a growing understanding of the phenomenon. The PAED scale, created in 2004 for children over the age of 2, represents a milestone in this regard.[22] The scale has undergone psychometric validation and has been widely adopted as an assessment tool for ED.

Previous research has highlighted that rapid emergence from sevoflurane anesthesia may contribute to the occurrence of ED.[35–37] As a result, attempts have been undertaken to lessen the likelihood of ED during the awakening phase of sevoflurane anesthesia by transitioning with other anesthetics. In a clinical study conducted by Mauricio et al[38] in 2004, the safety and efficacy of dexmedetomidine in preventing ED were investigated. The results demonstrated that the administration of dexmedetomidine reduced the incidence of ED in children undergoing sevoflurane anesthesia, with no reported side effects associated with its use. Furthermore, Marie et al found that administering 1mg/kg of propofol at the end of surgery, following the cessation of sevoflurane, led to a reduction in delirium and increased parent satisfaction.[39] Numerous attempts have been made to mitigate the occurrence and severity of ED, yielding varying degrees of success.

Emerging Topics

The co-cited references timeline view provides a comprehensive examination of the development and research trends in the field of ED. As indicated in Figure 11, the research topic has switched from #3 diazepam, #5 desflurane, #7 pediatric anesthesia, and #8 enflurane transplantation to #1 remifentanil, #4 analgesics opioid, #6 anxiety, and #11 dexmedetomidine. Moreover, the emerging research clusters in this area are observed, including #0 tonsillectomy, #2 sevoflurane, #9 pain, and #10 neurocognitive disorders. This analysis highlights the changing research priorities and the emerging areas of interest in the field of ED.

The Citespace software was also used to evaluate “keywords with citation bursts” in this study. By combining the information from Figures 11 and 14, we can discern that the emerging buzzwords align with current research topics that have previously been investigated. The fact that keywords like halothane, infant, pediatric ambulatory patient, desflurane, and adenotonsillectomy are categorized as risk factors, indicating that research on risk factors of EA will continue to be the primary emphasis of this area in the foreseeable future. Furthermore, it is intriguing to observe that intranasal fentanyl and intranasal dexmedetomidine have also emerged as keywords with significant citation bursts. This suggests that there has been a surge in clinical trials focusing on the prevention of ED. The exploration of different drugs and techniques with diverse modes of action holds promising potential for achieving greater therapeutic and preventive benefits in the management of ED.

Limitations

It is crucial to acknowledge certain limitations in this study. Firstly, the reliance on the WoSCC database as the data source may have resulted in the exclusion of relevant articles from other databases. Although efforts were made to ensure comprehensive coverage, there is a possibility of missing relevant publications from alternative sources.

Furthermore, the analysis might have excluded newly published high-quality papers with low citation counts. As citation metrics take time to accumulate, recent impactful articles may not have been included in our analysis, potentially limiting the comprehensiveness of the findings.

Lastly, it is important to recognize that while CiteSpace and VOSviewer provide valuable visualization and analysis tools, they cannot fully replace the benefits of direct access to the underlying systems or databases. Although these software packages offer insights and facilitate knowledge discovery, they are limited by the data available and their algorithms.

Despite these limitations, the study provides valuable insights and a comprehensive overview of the research landscape in the field of ED. These findings contribute to our understanding of the topic and provide a foundation for further research and exploration.

Conclusion

This bibliometric study presents a comprehensive knowledge map of emergence delirium from 2002 to 2022, and it offers predictions for upcoming research topics in the field. The analysis highlights China as the leading country in terms of the number of publications, while the United States emerges as the core of the collaborative network with frequent cooperation with China. Organizational collaboration should be improved. Even though there is a lot of research demonstrating how to prevent and treat emergence delirium in clinical practice, additional fundamental research for the mechanistic study of emergence delirium is required.

Funding

There is no funding to report.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Reduque LL, Verghese ST. Paediatric emergence delirium. *Cont Educ Anaesth Crit Care Pain*. 2013;13(2):39–41. doi:10.1093/bjaceaccp/mks051
2. Demir CY, Yuzkat N. Prevention of emergence agitation with ketamine in rhinoplasty. *Aesthetic Plast Surg*. 2018;42(3):847–853. doi:10.1007/s00266-018-1103-4
3. Liu K, Liu C, Ulualp SO. Prevalence of emergence delirium in children undergoing tonsillectomy and adenoidectomy. *Anesthesiol Res Pract*. 2022;2022:1465999. doi:10.1155/2022/1465999
4. Bharadwaj S, Konar S, Akash VS, Gopalakrishna KN, Chakrabarti D, Kamath S. Emergence delirium after intracranial neurosurgery- a prospective cohort study. *J Clin Neurosci*. 2022;104:12–17. doi:10.1016/j.jocn.2022.08.002
5. Kim DH, Min KT, Kim EH, Choi YS, Choi SH. Comparison of the effects of inhalational and total intravenous anesthesia on quality of recovery in patients undergoing endoscopic transsphenoidal pituitary surgery: a randomized controlled trial. *Int J Med Sci*. 2022;19(6):1056–1064. doi:10.7150/ijms.72758
6. Viitanen H, Baer G, Annila P. Recovery characteristics of sevoflurane or halothane for day-case anaesthesia in children aged 1–3 years. *Acta Anaesthesiol Scand*. 2000;44(1):101–106. doi:10.1034/j.1399-6576.2000.440118.x
7. Kulka P, Bressem M, Tryba M. Clonidine prevents Sevoflurane-induced agitation in children. *Anesth Analg*. 2001;93(2):335–338. doi:10.1213/00000539-200108000-00019
8. Petre MA, Saha B, Kasuya S, et al. Risk prediction models for emergence delirium in paediatric general anaesthesia: a systematic review. *BMJ Open*. 2021;11(1):e043968. doi:10.1136/bmjopen-2020-043968
9. Mason KP. Paediatric emergence delirium: a comprehensive review and interpretation of the literature. *Br J Anaesth*. 2017;118(3):335–343. doi:10.1093/bja/aew477
10. Lee SJ, Sung TY. Emergence agitation: current knowledge and unresolved questions. *Korean J Anesthesiol*. 2020;73(6):471–485. doi:10.4097/kja.20097
11. Kawai M, Kurata S, Sanuki T, et al. The effect of midazolam administration for the prevention of emergence agitation in pediatric patients with extreme fear and non-cooperation undergoing dental treatment under sevoflurane anesthesia, a double-blind, randomized study. *Drug Des Devel Ther*. 2019;13:1729–1737. doi:10.2147/DDDT.S198123
12. Dahmani S, Stany I, Brasher C, et al. Pharmacological prevention of sevoflurane- and desflurane-related emergence agitation in children: a meta-analysis of published studies. *Br J Anaesth*. 2010;104(2):216–223. doi:10.1093/bja/aep376
13. Dahmani S, Delivet H, Hilly J. Emergence delirium in children: an update. *Curr Opin Anaesthesiol*. 2014;27(3):309–315. doi:10.1097/ACO.0000000000000076
14. Moore AD, Anghelescu DL. Emergence Delirium in Pediatric Anesthesia. *Paediatr Drugs*. 2017;19(1):11–20. doi:10.1007/s40272-016-0201-5
15. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: an overview and guidelines. *J Bus Res*. 2021;133:285–296. doi:10.1016/j.jbusres.2021.04.070
16. Donthu N, Reinartz W, Kumar S, Pattnaik D. A retrospective review of the first 35 years of the international journal of research in marketing. *Int J Res Mark*. 2021;38(1):232–269. doi:10.1016/j.ijresmar.2020.10.006
17. Danış F, Kudu E. The evolution of cardiopulmonary resuscitation: global productivity and publication trends. *Am J Emerg Med*. 2022;54:151–164. doi:10.1016/j.ajem.2022.01.071
18. Wang K, Cai J, Du R, Wu J. Global trends in research related to emergence delirium, 2012–2021: a bibliometric analysis. *Front Psychol*. 2023;14:1098020. doi:10.3389/fpsyg.2023.1098020
19. Liu K, Zhao S, Li J, et al. Knowledge mapping and research hotspots of immunotherapy in renal cell carcinoma: a text-mining study from 2002 to 2021. *Front Immunol*. 2022;13:969217. doi:10.3389/fimmu.2022.969217
20. Shen J, Shen H, Ke L, et al. Knowledge mapping of immunotherapy for hepatocellular carcinoma: a bibliometric study. *Front Immunol*. 2022;13:815575. doi:10.3389/fimmu.2022.815575
21. Chen C. CiteSpace II: detecting and visualizing emerging trends and transient patterns in scientific literature. *J Assoc Inf Sci Technol*. 2006;57(3):359–377. doi:10.1002/asi.20317
22. Sikich N, Lerman J. Development and psychometric evaluation of the pediatric anesthesia emergence delirium scale. *Anesthesiology*. 2004;100(5):1138–1145. doi:10.1097/00000542-200405000-00015

23. Kain ZN, Mayes LC, Caldwell-Andrews AA, Karas DE, McClain BC. Preoperative anxiety, postoperative pain, and behavioral recovery in young children undergoing surgery. *Pediatrics*. 2006;118(2):651–658. doi:10.1542/peds.2005-2920
24. Kain ZN, Caldwell-Andrews AA, Maranets I, et al. Preoperative anxiety and emergence delirium and postoperative maladaptive behaviors. *Anesth Analg*. 2004;99(6):1648–1654. doi:10.1213/01.ANE.0000136471.36680.97
25. Voepel-Lewis T, Malviya S, Tait AR. A prospective cohort study of emergence agitation in the pediatric postanesthesia care unit. *Anesth Analg*. 2003;96(6):1625–1630. doi:10.1213/01.ANE.0000062522.21048.61
26. Vlajkovic GP, Sindjelic RP. Emergence delirium in children: many questions, few answers. *Anesth Analg*. 2007;104(1):84–91. doi:10.1213/01.ane.0000250914.91881.a8
27. Cravero J, Surgenor S, Whalen K. Emergence agitation in paediatric patients after sevoflurane anaesthesia and no surgery: a comparison with halothane. *Paediatr Anaesth*. 2000;10(4):419–424. doi:10.1046/j.1460-9592.2000.00560.x
28. Cole JW, Murray DJ, McAllister JD, Hirshberg GE. Emergence behaviour in children: defining the incidence of excitement and agitation following anaesthesia. *Paediatr Anaesth*. 2002;12(5):442–447. doi:10.1046/j.1460-9592.2002.00868.x
29. Aldecoa C, Bettelli G, Bilotta F, et al. European Society of Anaesthesiology evidence-based and consensus-based guideline on postoperative delirium. *Eur J Anaesthesiol*. 2017;34(4):192–214. doi:10.1097/EJA.0000000000000594
30. Bong CL, Lim E, Allen JC, et al. A comparison of single-dose dexmedetomidine or propofol on the incidence of emergence delirium in children undergoing general anaesthesia for magnetic resonance imaging. *Anaesthesia*. 2015;70(4):393–399. doi:10.1111/anae.12867
31. Cohen IT, Finkel JC, Hannallah RS, Hummer KA, Patel KM. Rapid emergence does not explain agitation following sevoflurane anaesthesia in infants and children: a comparison with propofol. *Paediatr Anaesth*. 2003;13(1):63–67. doi:10.1046/j.1460-9592.2003.00948.x
32. Wu H, Tong L, Wang Y, Yan H, Sun Z. Bibliometric analysis of global research trends on ultrasound microbubble: a quickly developing field. *Front Pharmacol*. 2021;12:1.
33. Small H. Co-citation in the scientific literature: a new measure of the relationship between two documents. *J Am Soc Inf Sci*. 1973;24(4):265–269. doi:10.1002/asi.4630240406
34. Aono J, Ueda W, Mamiya K, Takimoto E, Manabe M. Greater incidence of delirium during recovery from sevoflurane anesthesia in preschool boys. *Anesthesiology*. 1997;87(6):1298–1300. doi:10.1097/00000542-199712000-00006
35. Veyckemans F. Excitation phenomena during sevoflurane anaesthesia in children. *Curr Opin Anaesthesiol*. 2001;14(3):339–343. doi:10.1097/00001503-200106000-00010
36. Miyasaka K. Postanaesthetic excitation and agitation. *Paediatr Anaesth*. 2003;13(7):641–642. doi:10.1046/j.1460-9592.2003.00986_2.x
37. Silva LM, Braz LG, Módolo NS. Emergence agitation in pediatric anesthesia: current features. *J Pediatr*. 2008;84(2):107–113.
38. Ibacache ME, Muñoz HR, Brandes V, Morales AL. Single-dose dexmedetomidine reduces agitation after sevoflurane anesthesia in children. *Anesth Analg*. 2004;98(1):60–63. doi:10.1213/01.ANE.0000094947.20838.8E
39. Aouad MT, Yazbeck-Karam VG, Nasr VG, El-Khatib MF, Kanazi GE, Bleik JH. A single dose of propofol at the end of surgery for the prevention of emergence agitation in children undergoing strabismus surgery during sevoflurane anesthesia. *Anesthesiology*. 2007;107(5):733–738. doi:10.1097/01.anes.0000287009.46896.a7