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ORIGINAL RESEARCH

Trends and Emerging Research Areas in Postoperative Sleep Disturbances: A Bibliometric Analysis

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Purpose: Postoperative sleep disturbance (PSD) is highly prevalent and significantly affects patient prognosis. Studies on PSD have received increasing attention, resulting in a surge in related publications. However, comprehensive analyses that can objectively reflect changes in scientific knowledge and identify the latest research trends in this field are lacking.

Methods: Articles and reviews focusing on PSD were extracted from the Web of Science Core Collection database. Bibliometrix, VOSviewer, and CiteSpace were used to conduct bibliometric analysis and map the visualization network.

Results: A total of 1,559 publications were extracted from the database, including 1,370 articles and 189 reviews. There has been a consistent increase in the number of publications, with an average annual growth rate of 16.56%, led by the United States in terms of research output. Notably, the University of Toronto was a prominent contributor. Co-cited reference network analysis revealed 17 well-structured networks (Q = 0.8174, S = 0.9441). Six major research trends were identified: mechanisms of sleep related to anesthesia, role of melatonin in sleep disturbances, pain management strategies, effects of analgesic drugs, impact of dexmedetomidine on sleep quality, and postoperative recovery. Keywords analysis highlighted the emerging roles of dexmedetomidine, neuroinflammation, and acupuncture.

Conclusion: Bibliometric analysis provides a helpful summary of postoperative sleep disturbances that have changed over time, by identifying knowledge points and developing trends. Future research should focus on integrating multidisciplinary approaches, exploring neuroinflammation, evaluating non-pharmacological interventions and long-term outcomes, which will advance scientific knowledge, enhance clinical practice, and improve patient outcomes and quality of life.

Keywords: postoperative sleep disturbances, PSD, sleep disorders, bibliometrics, CiteSpace, visual analysis, VOSviewer

Introduction

Sleep is a complex, naturally occurring physiological state essential for human health and survival. Sleep disorders are a variety of dysfunctions and disturbances that manifest during the sleep-wake process. According to the International Classification of Sleep Disorders-third edition (ICSD-3), sleep disorders are grouped into seven major categories: insomnia, sleep-related breathing disorders, central disorders of hypersomnolence, circadian rhythm sleep-wake disorders, parasomnias, sleep-related movement disorders, and other sleep disorders.[1] With disruptions in living environment, social rhythms, light patterns, and changes in biological factors, sleep disorders have become an essential public health problem and have attracted increasing interest over the past decades. It is estimated that up to 50% of primary care patients experience insomnia.[2] Due to personal and perioperative factors, sleep disturbances are more common among surgical patients.[3]

Sleep is controlled by specific brain regions and corresponding neurons, which are mainly regulated by endogenous sleep-wake cycle and homeostatic processes.[4] Based on polysomnographic monitoring, normal sleep consists of non-rapid eye movement (NREM) and rapid eye movement (REM) sleep; NREM sleep can be subdivided into stages N1, N2, and N3 according to the depth of sleep.[5,6] Immediately after surgery (especially major surgery), sleep structure is characterized by sleep deprivation, sleep fragmentation, and loss of stage N3 (slow-wave sleep) and REM sleep.[7] Patients

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usually report decreased sleep time, light sleep, increased awakenings, and frequent nightmares.[8] Postoperative Sleep Disturbances (PSD) significantly impact surgical outcomes by prolonging hospital stays, delaying recovery, increasing the risk of complications such as delirium,[3] delayed functional recovery,[9] more chronic postsurgical pain,[10] increased adverse cardiac events,[11] and worsened quality of life.[12] Individuals undergoing major surgeries, those with longer surgery durations,[13] preoperative anxiety,[14] postoperative pain,[15] or older adults are at higher risk.[15] Medications, particularly opioids and anesthetics,[15] could worsen PSD by disrupting sleep architecture and increasing sleep latency. The underlying biological mechanisms involve changes in neurotransmitters and immunological processes. Alterations in neurotransmitters, such as decreased levels of serotonin and norepinephrine,[16] contribute to disrupted sleep. Additionally, surgical trauma and sleep deprivation could trigger the release of pro-inflammatory cytokines and reduce melatonin secretion, further impairing sleep quality.[17] These mechanisms highlight the need for targeted interventions to improve postoperative sleep and overall patient outcomes. Over the past 20 years, PSD has attracted increasing attention, resulting in significant progress in the understanding of its risk factors, underlying mechanisms, and preventive strategies.

Electronic documents are indispensable to scientific researchers. However, the massive amount of available literature can be overwhelming. Extracting relevant information without effective reading and analysis strategies is a significant challenge. Bibliometric analysis, a method that integrates statistical techniques and data visualization, has gained prominence in evaluating international collaborations, citation analysis, research trends, and focal areas within a particular area.[18,19] This scientific bibliometric approach is an effective way to address this challenge.

Despite previous reviews on PSD from different perspectives,[3,10] significant gaps remain in the visualization, analysis, and trends in research priorities in the field. Therefore, the main objective of this study was to provide a bibliometric and visual analysis of a comprehensive overview of publications, trends, emerging research areas, and potential future directions in PSD, providing valuable insights for future research in this field.

Materials and Methods

Data Sources and Search Strategies

This study was approved by the Ethics Committee of the Fourth Hospital of Hebei Medical University (2023KS121). The requirement for informed consent was waived. The raw data were extracted from the Web of Science Core Collection (WoSCC) on October 24, 2023. The search keyword query as follows: TS= ("sleep disturbance*" OR "sleep disorder*" OR "sleep architecture" OR "sleep quality" OR "sleep structure" OR "sleep wake" OR "non-rapid eye movement" OR "rapid eye movement") AND TS= (postoperative OR after operation OR post-surgery OR postoperative period). To account for the database's ongoing updates, two reviewers conducted separate data searches on the same day. This data was subsequently verified independently for retrieval and deliberated upon to reach a final agreement of 0.90.[20]

Data Collection and Cleaning

The raw data were cleaned and de-duplicated with CiteSpace (Version 6.3.R1). A thesaurus file was used to correct erroneous elements before the bibliometric analysis with VOSviewer (Version 1.6.19). Finally, the cleaned data were imported into R software (Version 4.3.1), VOSviewer, and CiteSpace for bibliometric analysis.

Bibliometric Analysis

We conducted the analysis using bibliometrix R package, VOSviewer, and CiteSpace. The Bibliometrix R package is an open-source tool for performing comprehensive bibliometric analyses, which was used to analyze the overview, annual, and cumulative numbers of publications, growth trends, countries/regions, institutions, authors, and source journals. Given the nonlinear relationship between the year and the cumulative number of publications, we constructed a polynomial model to capture the growth trends. Since it was clearly cyclical over time, time series were introduced into the model to predict future developments. The rationality and validity of the model were verified using residual analysis and goodness-of-fit tests. Bibliometric networks were constructed and visualized using VOSviewer and CiteSpace. VOSviewer is a software tool used to construct and visualize bibliometric networks. It was used to construct visualization analyses of countries/regions, source journals, and co-occurring keywords; to map scientific networks; and

to display knowledge structures, collaborations, and the evolution of relationships. CiteSpace is citation visualization and analysis software developed by Prof. Chaomei Chen. Co-citation references were analyzed to evaluate the weight or influence of each reference through centrality. Different clusters of co-citation references were analyzed using the LLR algorithm. Centrality refers to the frequency with which a node acts as a link between two other nodes. A high centrality indicates greater weight or influence. Then, VOSviewer and CiteSpace were used to analyze the co-occurrence keywords, burst keywords, and co-citation reference networks.

Potential Biases Across Different Time Periods

To ensure the robustness of our analysis, we conducted a detailed assessment of potential biases that could influence the results. Publication bias occurs when studies with positive or significant results are more likely to be published than those with negative or inconclusive results are. To mitigate this bias, we used the WoSCC database, which is known for its high data quality and completeness. We then included both highly cited and less frequently cited articles to capture a broad spectrum of research. Citation bias can occur if certain studies are over-represented because of their popularity or the influence of their authors. To address this, we employed burst analysis to identify emerging research frontiers, rather than relying solely on citation counts. This approach helps to highlight novel and rapidly evolving research areas that may not yet have accumulated high citation counts. Additionally, to address self-citations and citation circles, which can artificially inflate citation counts. We detected and adjusted for excessive self-citations and citation circles using network analysis, which provides a more reliable assessment of research impact.

Sensitivity Analysis

To comprehensively understand the evolution of PSD research over time, we conducted a sensitivity analysis focusing on the period 2010–2023. This period was selected for the following reasons. Primarily, it captures the most recent trends, including the impact of the COVID-19 pandemic, which has significantly influenced the research directions and priorities. Moreover, this period coincided with a notable increase in PSD-related publications, as identified in our initial bibliometric analysis. The sensitivity analysis allowed us to concentrate on the most active and relevant research themes. Lastly, this period includes the introduction and evaluation of new interventions that have become central to PSD research. Consequently, we set the time period for the sensitivity analysis as 2010–2023. We introduced a time factor to analyze the organization and keyword overlay network mapping by using VOSviewer. Additionally, burst analysis was conducted to identify the most important references. This analysis revealed key nodes that spiked in frequency during specific periods, indicating their high value for researchers at those times. These findings help identify research frontiers and potential future trends.

Results

Overview of Publications, Analysis of Publication Output and Growth Trend Prediction

The search results from the WoSCC database totaled 1,748 publications. The number of publications is commonly used as a measure of productivity, with original articles and reviews serving as key indicators of the current state of research.[21] Therefore, non-article and non-review publications, as well as irrelevant and non-English documents, were excluded (Figure 1). This resulted in a final dataset of 1,559 publications, including 1,370 articles and 189 reviews, originating from 650 journals and involving 7,438 authors. The first publication in this dataset dates back to 1991, with a steady increase in scientific output thereafter, reaching a peak of 205 publications in 2022. International collaboration accounted for 12.44% of the articles. From 1991 to 2022, scientific interest has progressively increased, with an average annual growth rate of 16.56% in published papers. A polynomial model was then fitted to the cumulative number of publications. The polynomial model was expressed as follow: $y = 2.21x^2 - 35.85x + 148.89$ ($R^2 = 0.96$) (Figure 2A).

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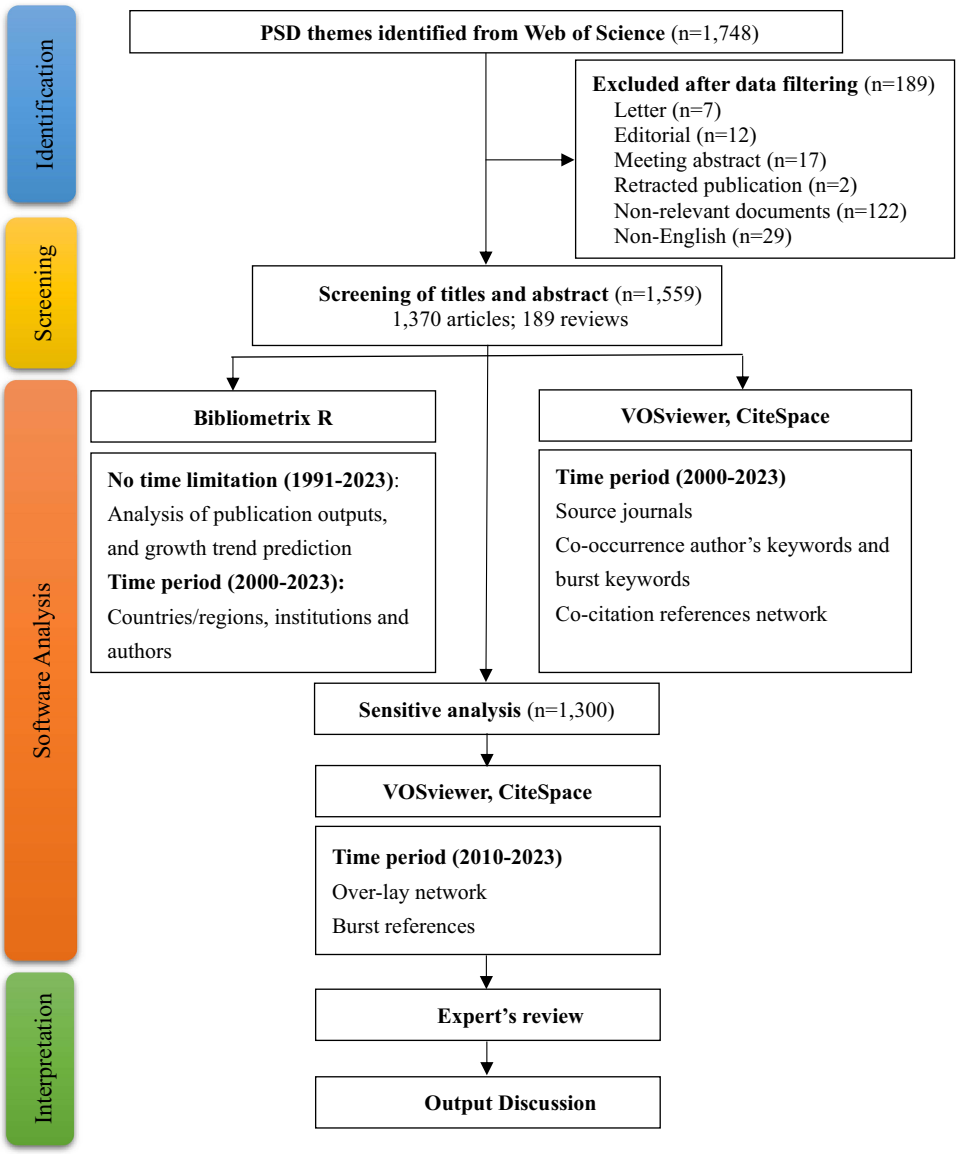

Figure 1 Flowchart of bibliometric analysis.
Abbreviation: PSD, Postoperative sleep disturbances.

Model Validation

Model fit was assessed using residual analysis and goodness-of-fit tests. The plot of residuals versus fitted trends indicates nonlinearity. The residuals were randomly distributed around the zero line, confirming the homoscedasticity assumption. The residuals showed no significant trends over time, indicating independence. The model exhibited strong explanatory power with an R^2 value of 0.96. The F-test statistic of 480.8 and a p-value of 2.2×10^{-16} ($P < 0.001$) confirmed the model's significance. The fitted polynomial regression curves were plotted along with the raw data to visually validate the fit of the model (Appendix). Overall, the polynomial model effectively captured the trends in cumulative publications over time.

Countries/Regions, Institutions and Authors

Considering that almost 95% of the papers were published post-2000 and earlier works did not meet the criteria for inclusion in the graphical network visualization, the analysis was confined to the period from January 2000 to October 2023. Consequently, 1,487 publications were included in the present study.

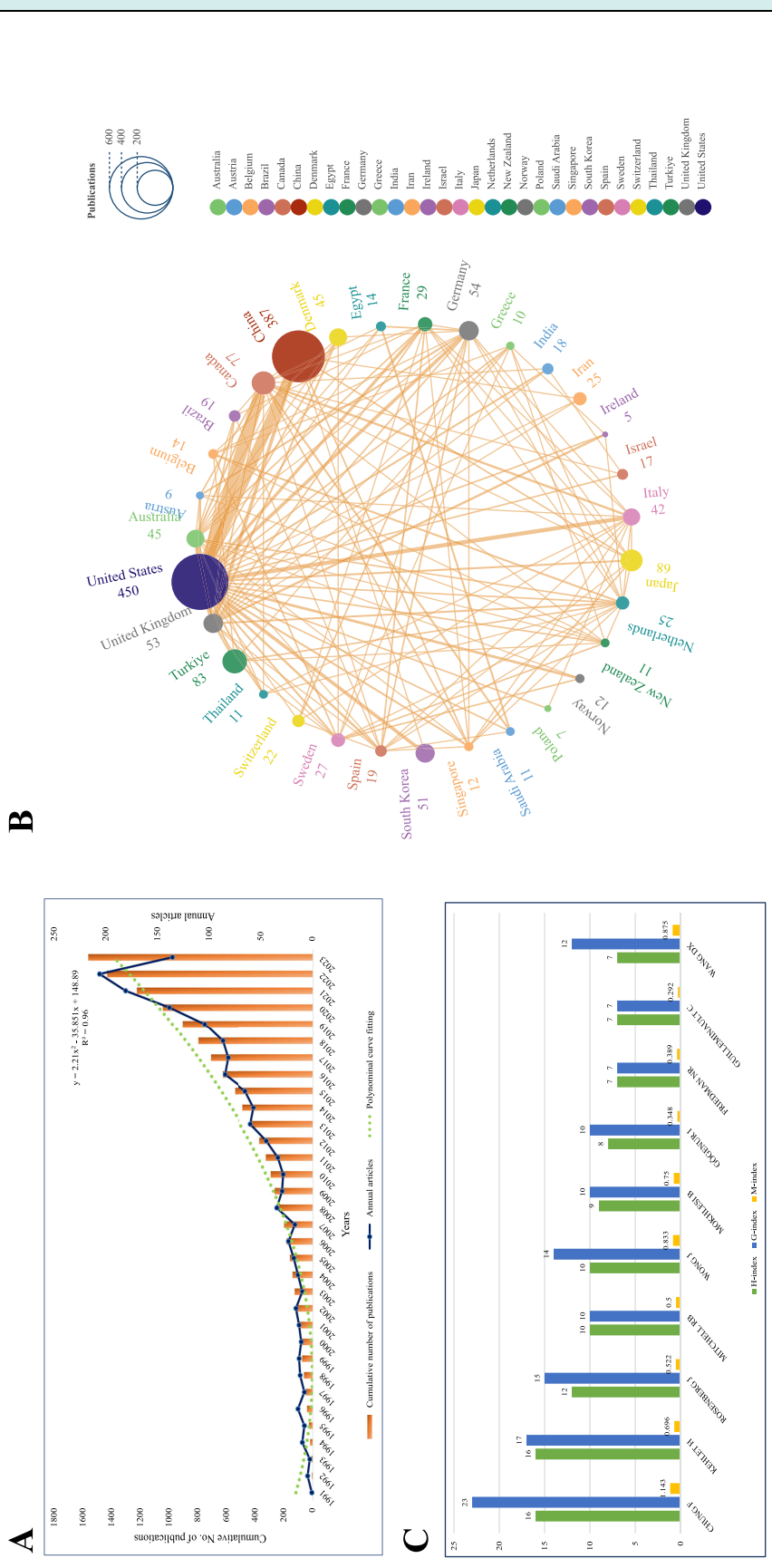

Figure 2 (**A**) Annual and cumulative number of publications. Let *y* represent the cumulative number of publications and *x* represent the time step. The time step is a sequence of integers starting from one, with each increment corresponding to a new year. (**B**) Network map of countries/regions (number of publications ≥ 5). Node size represents the number of publications, while the width of the connecting lines indicates the strength of collaboration links. China includes publications from the Chinese Mainland, Hong Kong, Macau, and Taiwan. The United Kingdom includes publications from England, Scotland, Northern Ireland, and Wales. (**C**) Top 10 authors by impact. As measured by the G index.

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From 2000 to 2023, PSD-related papers were mainly published by 1,823 institutions in 61 countries/regions. Figure 2B shows a network of countries/regions with more than five publications. The intensity of international collaboration was the highest between the United States and Canada, as well as between the United States and China. Other countries/regions have been strengthening their collaborations over time.

We analyzed the major institutions with high output in this area. As shown in Table 1, it is among the top ten institutions with the highest global output. The most productive organization was the University of Toronto (n = 72, 4.8%). US institutions occupied seven places and made outstanding contributions to the area.

Overall, there were 7,164 authors in all publications. The most productive author was Frances Chung from the University Health Network and the University of Toronto. Table 1 displays the most productive 10 authors. It would be incomplete to assess the researchers' academic output. Instead, we comprehensively assessed the authors' impact through the H-index, G-index, and M-index. Essentially, the H-index is a mixed index of publications and citations, measuring the number of publications cited in a particular set of publications.[22] These three indicators provide a comprehensive picture of academic productivity and citation quality. The top 10 influential researchers in the area of PSD (mainly referring to the G-index ranking) are shown in Figure 2C.

Source Journals

The academic journal with the most published papers on PSD was the *International Journal of Pediatric Otorhinolaryngology*, and the most co-cited journal was *Anesthesiology*. Source journal co-occurrence was categorized into the following clusters based on research direction: anesthesiology disciplinary journals (purple), sleep and circadian rhythm mechanisms (yellow), pain science-related journals (red), neuroscience journals (green) and ENT Head Neck Science and Pediatrics (blue) (Figure 3A).

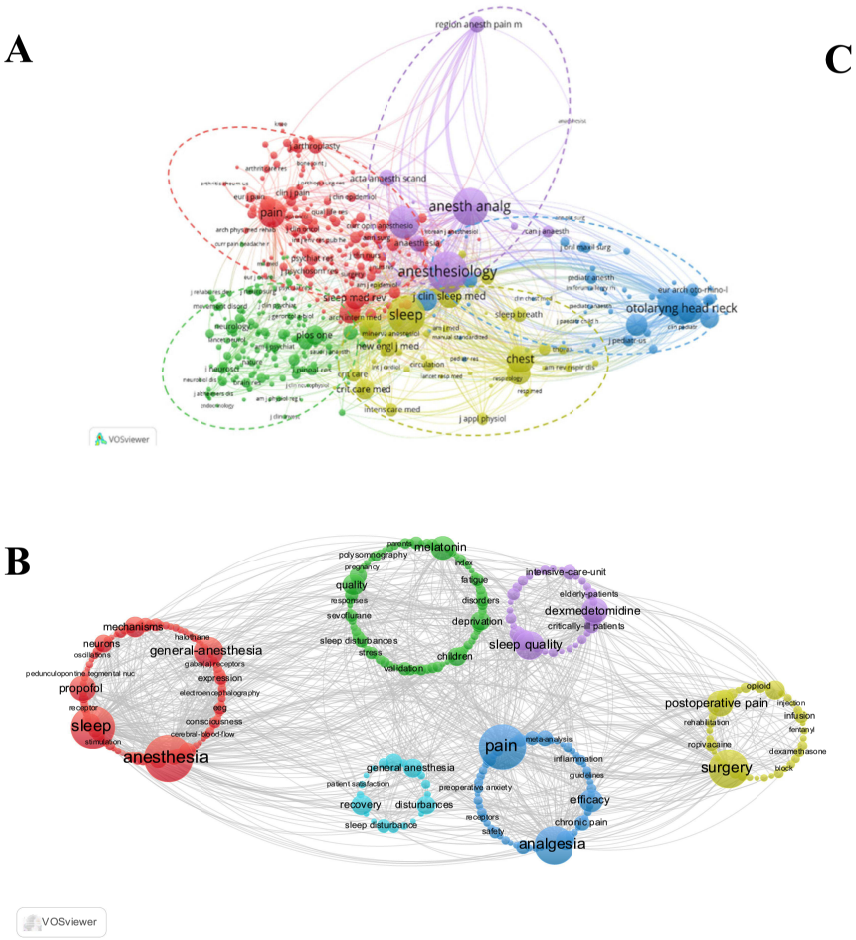
Co-Occurrence Author's Keywords and Burst Keywords

Author's keywords are an important part of an article, which in turn can represent the research topic of a publication. To explore the research hotspots of keywords, co-occurrence analysis was performed by extracting keywords with more than five frequencies of occurrence using VOSviewer and clustering visualization maps. Using co-occurrence clustering analysis, six clusters were identified based on research themes (Figure 3B). These six clusters were represented by different colors: 1) Anesthesia (red): general anesthesia, sleep, propofol, neurons, mechanisms, etc.; 2) Melatonin (green): sleep quality, children, deprivation, polysomnography, stress, etc.; 3) Pain (blue): analgesia, chronic pain, preoperative anxiety, efficacy, inflammation, etc.; 4) Surgery (yellow): postoperative pain, opioid,

Table 1 Top 10 Institutions and Authors in PSD Research (01/2000 - 10/2023)

Institutions			Authors		
Rank	**Institutions**	**No. of Publications**	**Rank**	**Authors**	**No. of Publications**
1	University of Toronto (Canada)	72	1	Chung F (Canada)	23
2	Harvard University (United States)	67	2	Kehlet H (Denmark)	17
3	University of California System (United States)	53	3	Li Y (China)	17
4	University of Copenhagen (Denmark)	49	4	Rosenberg J (Denmark)	15
5	University Health Network Toronto (Canada)	48	5	Wong J (Canada)	14
6	University of Michigan (United States)	41	6	Zhu JC (China)	14
7	University of California San Francisco (United States)	36	7	Wang Y (China)	13
8	University System of Ohio (United States)	36	8	Wang DX (China)	12
9	Harvard Medical School (United States)	35	9	Song BJ (China)	11
10	Pennsylvania Commonwealth System of Higher Education (United States)	34	10	Gögenur I (Denmark)	10

Notes: Number of publications were identified and analyzed by R software.
Abbreviations: PSD, Postoperative sleep disturbances; No., Number.



C

Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2000 - 2023
anesthesia	2000	4.73	**2000**	2009	
surgery	2001	4.12	**2001**	2009	
apnea syndrome	2002	3.73	**2002**	2009	
morphine	2001	3.53	**2001**	2014	
sleep	2000	3.24	**2000**	2009	
upper airway	2003	3.02	**2003**	2014	
randomized controlled-trial	2008	3.84	**2008**	2014	
preoperative anxiety	2005	3.68	**2005**	2014	
efficacy	2001	3.64	**2005**	2009	
responses	2005	3.5	**2005**	2009	
double-blind	2006	3.14	**2006**	2009	
secretion	2005	3.05	**2005**	2009	
positive airway pressure	2005	6.76	**2010**	2019	
bariatric surgery	2011	3.64	**2011**	2019	
surgical-patients	2010	3.23	**2010**	2019	
vegetative state	2012	2.99	**2012**	2019	
postoperative complications	2011	2.96	**2011**	2019	
expression	2016	3.79	**2016**	2023	
apnea	2000	3.63	**2015**	2019	
prevalence	2003	3.39	**2015**	2023	
validation	2017	3.14	**2017**	2023	
general anesthesia	2007	3.4	**2020**	2023	
disease	2005	3.12	**2020**	2023	
neurons	2020	2.97	**2020**	2023	
functional connectivity	2020	2.97	**2020**	2023	

Figure 3 (**A**) Analysis of source journal co-occurrence. (**B**) Author's keywords network with occurrence ≥ 5. The size of each circle corresponds to the frequency of the keyword's appearance in the literature. (**C**) Top 25 keywords with the strongest citation bursts. Citation bursts indicate keywords that have rapidly gained attention.

ropivacaine, dexamethasone, block, etc.; 5) Sleep quality (purple):dexmedetomidine, intensive-care-unit, elderly-patients, critically-ill patients, etc.; 6) Recovery (light blue):sleep disturbance, general anesthesia, patient satisfaction, etc. It can be summarized into six major research trends: sleep mechanisms associated with anesthesia, melatonin and sleep disturbances, pain management, effects of analgesic drugs, dexmedetomidine and sleep quality, postoperative recovery, respectively.

Burst detection is used to identify the emergence or decline of specific keywords. Among the top 25 burst keywords, the top ten with the highest burst intensity were positive airway pressure, anesthesia, surgery, randomized controlled trial, expression, apnea syndrome, preoperative anxiety, efficacy, bariatric surgery, and apnea. These keywords have sustained high attention over multiple years, indicating strong scholarly interest in these research areas. In recent years, emerging keywords hotspots such as "validation", "general anesthesia", "neurons" and "functional connectivity" have gained increasing attention (Figure 3C).

Most Cited Reference and Co-Citation Reference Network

Citation frequency is a measure of the approval of the scientific literature. The top 10 cited references in PSD research were listed in Table 2. Co-citation references are research methods that measure the degree of the relationship between references. In other words, it refers to being cited by other publications. The co-citation references were analyzed by clustering to identify similar themes. Using the LLR algorithm, co-citations were grouped into 17 visual clusters. Statistical data showed a well-structured cluster with Q = 0.8174 (modularity), indicating considerable cluster structure. Silhouette (S = 0.9441), indicating that the clusters were highly convincing. Among these clusters, the "preoperative sleep quality" was the most prominent (Figure 4).

Table 2 Top 10 Most Cited References in PSD Research (01/2000 - 10/2023)

Rank	Document	DOI	Local Citations	Global Citations	Title	Type	Centrality
1	Krenk L et al. Br J Anaesth. 2012.[23]	10.1093/bja/aes252	50	81	Sleep disturbances after fast-track hip and knee arthroplasty	Article	0.12
2	Chouchou F et al. Sleep Med Rev. 2014.[24]	10.1016/j.smrv.2013.07.002	42	92	Postoperative sleep disruptions: a potential catalyst of acute pain?	Review	0.00
3	Baugh RF et al. Otolaryngol Head Neck Surg. 2011.[25]	10.1177/0194599810389949	38	637	Clinical practice guideline: tonsillectomy in children	Practice Guideline	0.05
4	Su X et al. Curr Opin Anaesthesiol. 2018.[8]	10.1097/ACO.0000000000000538	36	80	Improve postoperative sleep: what can we do?	Review	0.01
5	Su X et al. Lancet. 2016.[26]	10.1016/S0140-6736(16)30580–3	35	432	Dexmedetomidine for prevention of delirium in elderly patients after non-cardiac surgery: a randomised, double-blind, placebo-controlled trial	Article	0.05
6	Cronin AJ et al. Sleep. 2001.[15]	10.1093/sleep/24.1.39	34	101	Postoperative sleep disturbance: influences of opioids and pain in humans	Article	0.00
7	Gögenur I et al. Br J Anaesth. 2008.[27]	10.1093/bja/aem340	32	66	Circadian distribution of sleep phases after major abdominal surgery	Article	0.00
8	Chung F et al. Anesthesiology. 2014.[28]	10.1097/ALN.0000000000000041	32	115	Factors associated with postoperative exacerbation of sleep-disordered breathing	Article	0.10
9	Gong L et al. J Arthroplasty. 2015.[29]	10.1016/j.arth.2015.02.020	30	57	Sleep Quality Effects Recovery After Total Knee Arthroplasty (TKA): A Randomized, Double-Blind, Controlled Study	Article	0.08
10	Roland PS et al. Otolaryngol Head Neck Surg. 2011.[30]	10.1177/0194599811409837	29	310	Clinical practice guideline: Polysomnography for sleep-disordered breathing prior to tonsillectomy in children	Practice Guideline	0.03

Notes: Local citations and global citations were identified and analyzed by R software. The centrality of each reference within the citation network was assessed using CiteSpace.

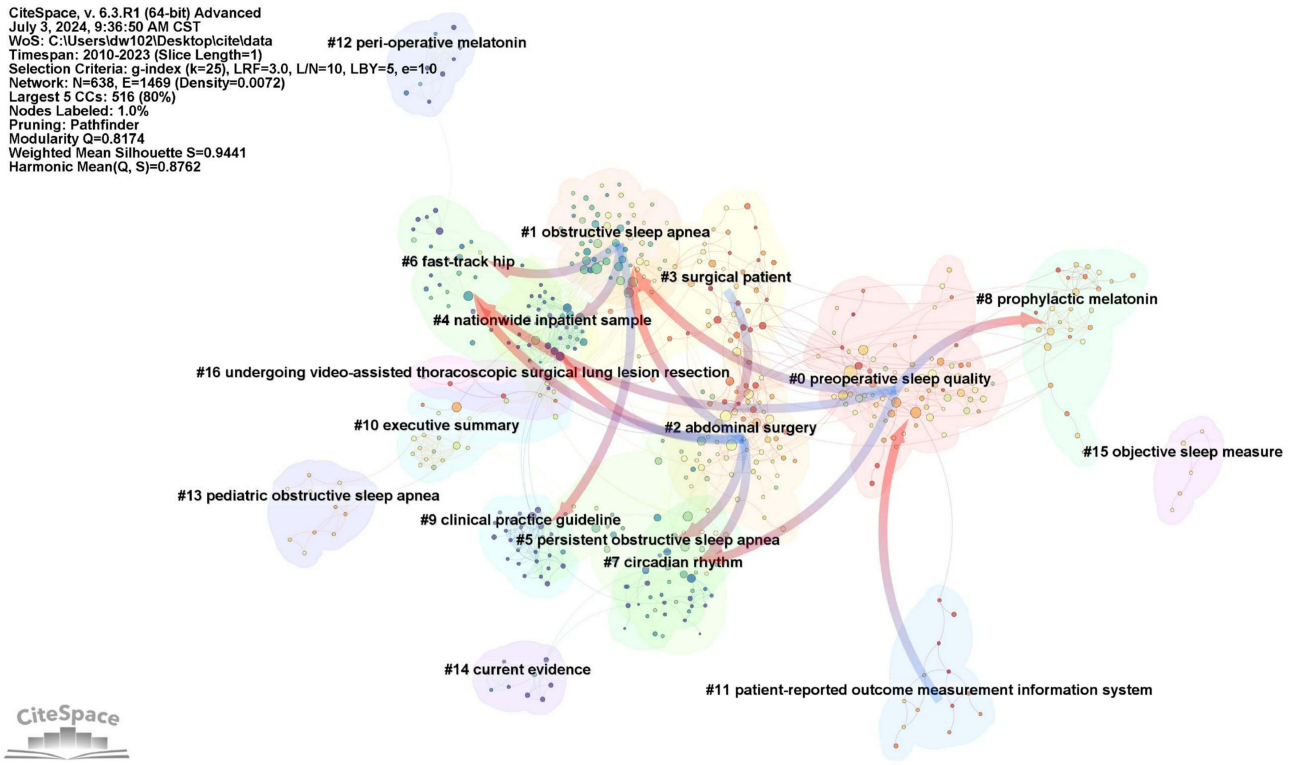


Figure 4 Co-citation analysis and visual clustering. The co-citations were visualized into 17 clusters, each representing a thematic or conceptual area within postoperative sleep disturbances research.

Sensitive Analysis

Over-Lay Network

Approximately 90% of the literature has been published after 2010. Accordingly, sensitivity analysis was performed from 2010 to 2023. Then, a time-based dimension was introduced to explore research trends and quantify the change over a given period. Therefore, we identify different institutions' productivity and keywords that have emerged in different historical periods.

Studies from the University of Copenhagen and Stanford University were conducted around 2014. Institutions such as the University of Toronto and the University of Pennsylvania mainly produced studies around 2016. In recent years, more contributions have been made by the Mayo Clinic, the Cleveland Medical Center, and research institutes from China such as Peking University, China Medical University, Capital University of Medical Sciences, and Fudan University (Figure 5A). Trends in the publication journals from different sources were showed in Figure 5B. This visualization highlights citation dynamics and journal influence across disciplines. The citing papers were predominantly from journals in medicine, clinical medicine, molecular biology, immunology, and neurology. The cited papers were mainly from journals in health, nursing, medicine, molecular biology, psychology, education, and social sciences.

In recent years, hot research keywords include dexmedetomidine, neuroinflammation, sleep quality, acupuncture, electroacupuncture, cancer, inflammation, enhanced recovery, and perioperative management. This demonstrated that researchers gradually focused on the deep-rooted mechanisms of PSD, preventive medications, and preventive practices (Figure 5C).

Burst References

CiteSpace was used to analyze the burst references. The top 25 references with the strongest burst over 2010–2023 were presented (Figure 6). Among the top 25 references, the main research areas were sleep-related neuroscience and clinical research on PSD. All references had burst times from 2010 to 2019. In terms of the time period, 10 publications became

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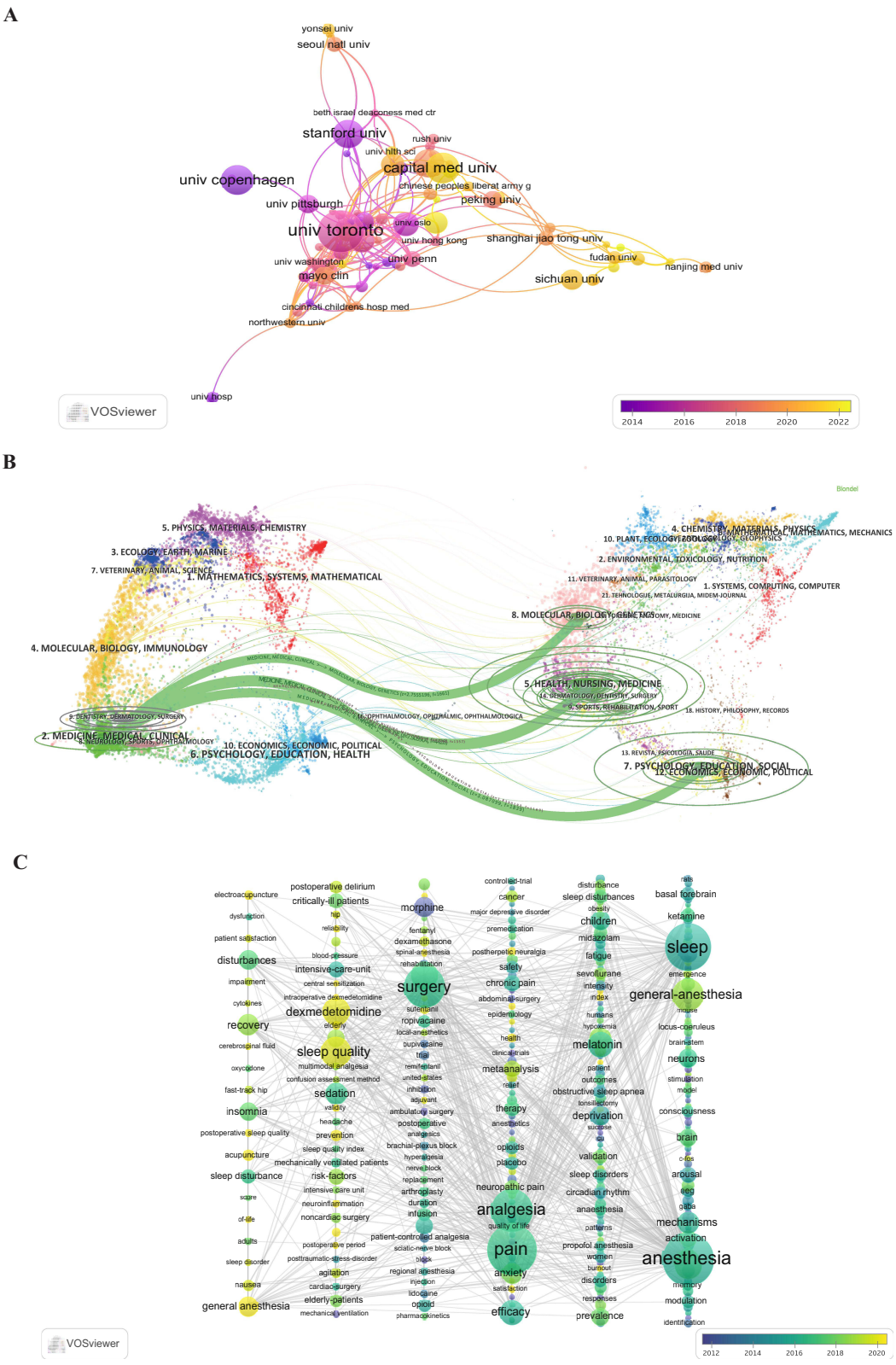

Figure 5 (**A**) Trends in institutional publication over time. The trends highlight the contributions of different institutions over the study period and reveal the evolving landscape of institutional involvement. (**B**) Dual-layer citation map of citing and cited journals. Disciplines of citing journals (left) and cited journals (right). Curves represent citation connectors. The vertical axis of the ellipse indicates the number of publications, while the horizontal axis indicates the number of authors. (**C**) Co-occurring keywords overlay visualization. The overlay feature allows for the identification of key topics and their evolution over time.

Top 25 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2010 - 2023
Liao P, 2009, CAN J ANAESTH, V56, P819, DOI 10.1007/s12630-009-9190-y, DOI	2009	7.32	2010	2015	
Bhattacharjee R, 2010, AM J RESP CRIT CARE, V182, P676, DOI 10.1164/rccm.200912-1930OC, DOI	2010	6.15	2010	2015	
Krenk L, 2010, ACTA ANAESTH SCAND, V54, P951, DOI 10.1111/j.1399-6576.2010.02268.x, DOI	2010	5.55	2010	2015	
Peppard PE, 2013, AM J EPIDEMIOL, V177, P1006, DOI 10.1093/aje/kws342, DOI	2013	6.75	2013	2018	
Krenk L, 2012, BRIT J ANAESTH, V109, P769, DOI 10.1093/bja/aes252, DOI	2012	5.99	2013	2018	
Baugh RF, 2011, OTOLARYNG HEAD NECK, V144, PS1, DOI 10.1177/0194599810389949, DOI	2011	5.92	2013	2015	
Singh M, 2013, BRIT J ANAESTH, V110, P629, DOI 10.1093/bja/aes465, DOI	2013	4.94	2013	2018	
Chung F, 2014, ANESTHESIOLOGY, V120, P287, DOI 10.1097/ALN.0000000000000040, DOI	2014	4.9	2014	2018	
Mokhlesi B, 2013, CHEST, V144, P903, DOI 10.1378/chest.12-2905, DOI	2013	4.85	2013	2018	
Su X, 2016, LANCET, V388, P1893, DOI 10.1016/S0140-6736(16)30580-3, DOI	2016	6.77	2016	2021	
Inouye SK, 2014, LANCET, V383, P911, DOI 10.1016/S0140-6736(13)60688-1, DOI	2014	6.35	2016	2021	
Gross JB, 2014, ANESTHESIOLOGY, V120, P268, DOI 10.1097/ALN.0000000000000053, DOI	2014	6.19	2016	2018	
Mutter TC, 2014, ANESTHESIOLOGY, V121, P707, DOI 10.1097/ALN.0000000000000407, DOI	2014	5.35	2016	2018	
Alexopoulou C, 2014, ANESTHESIOLOGY, V121, P801, DOI 10.1097/ALN.0000000000000361, DOI	2014	4.94	2016	2018	
Abdelsattar ZM, 2015, SLEEP, V38, P1205, DOI 10.5665/sleep.4892, DOI	2015	4.94	2016	2018	
Su X, 2018, CURR OPIN ANESTHESIO, V31, P83, DOI 10.1097/ACO.0000000000000538, DOI	2018	10.49	2019	2023	
Luo ZY, 2019, J ORTHOP SURG RES, V14, P0, DOI 10.1186/s13018-019-1446-9, DOI	2019	7.88	2019	2023	
Dolan R, 2016, ANN MED SURG, V6, P1, DOI 10.1016/j.amsu.2015.12.046, DOI	2016	6.23	2019	2021	
Wang JP, 2019, MEDICINE, V98, P0, DOI 10.1097/MD.0000000000017708, DOI	2019	6.08	2019	2023	
Chen AF, 2016, J ARTHROPLASTY, V31, P330, DOI 10.1016/j.arth.2015.07.044, DOI	2016	5.91	2019	2021	
Wesselius HM, 2018, JAMA INTERN MED, V178, P1201, DOI 10.1001/jamainternmed.2018.2669, DOI	2018	5.7	2019	2023	
Mitchell RB, 2019, OTOLARYNG HEAD NECK, V160, PS1, DOI 10.1177/0194599818801757, DOI	2019	5.51	2019	2023	
Manning BT, 2017, ORTHOPEDICS, V40, PE636, DOI 10.3928/01477447-20170411-01, DOI	2017	5.45	2019	2021	
Todd OM, 2017, J AM GERIATR SOC, V65, P949, DOI 10.1111/jgs.14685, DOI	2017	5.37	2019	2023	
Gong L, 2015, J ARTHROPLASTY, V30, P1897, DOI 10.1016/j.arth.2015.02.020, DOI	2015	5.07	2019	2021	

Figure 6 Top 25 references with the strongest citation bursts. Year: The year of the publication first appeared. Begin: The year of the citation burst began. End: The year of the citation burst ended. Strength: The intensity of the increase in citations.

burst references starting in 2019. Most of these publications were clinical studies or reviews, with the highest burst strength of 10.49.

Discussion

This study provided a comprehensive bibliometric and visual analysis of publications related to PSD, identifying key trends, emerging research areas, and potential future directions. The findings reveal a substantial increase in research output over the past two decades, reflecting growing interest in this field. By clarifying the current landscape of PSD research, this analysis offers valuable insights to guide future investigations and inform the development of targeted interventions.

By analyzing publication growth, the steady increase in the cumulative number of publications has attracted considerable interest and is progressing rapidly. The body of knowledge has expanded notably, with a particular surge observed post-COVID-19 pandemic. PSD research peaked in 2022. In this study, a polynomial model was chosen to fit the publication growth trend due to its ability to capture non-linear patterns and complex growth dynamics. Other models —such as linear (limited to constant growth rates), exponential (assuming constant percentage growth), and logarithmic (suitable for initial rapid growth followed by stabilization) — were less suitable for the data's varying growth rates and non-linear nature. The polynomial model's residual analysis and high goodness-of-fit confirm its effectiveness in capturing the data's structure. It predicts that the cumulative number of publications will reach 1,608 in 2025 and 1,729 in 2026.

The United States leads in PSD research publications, largely due to contributions from institutions like Harvard University, the University of California System, and the University of Michigan. These institutions have a long-standing foundation and strong influence in the field. The University of Toronto was also prominent, with a focus on sleep disorders influenced by environmental, social, and biological factors. Mayo Clinic, Cleveland Clinic, and Chinese institutes showed rising trends in this area. International collaborations, especially between the US and Canada, are increasing, potentially driven by the 2017 Nobel Prize in Medicine for circadian rhythm research. Frances Chung, a top author in PSD research, has extensively studied sleep disorders in surgical patients. Her work highlights that preoperative apnea-hypopnea index (AHI), age, and opioid dosage were positively correlated with postoperative AHI.[28] Sleep architecture is disrupted postoperatively, particularly in the N1 stage, with the greatest breathing disruption in the N3 stage.[7] A high preoperative Pittsburgh Sleep Quality Index (PSQI) score is a risk factor for postoperative sleep disturbances.[3]

The influence of journals correlates with the impact of their articles. The top three journals by publication count were *International Journal of Pediatric Otorhinolaryngology, Anesthesia & Analgesia*, and *Otolaryngology-Head and Neck Surgery*. The most cited journals were *Anesthesiology, Sleep*, and *Anesthesia & Analgesia*, highlighting anesthesia and neuroscience fields' significant contributed to PSD research. Journals like *Chest, Laryngoscope*, and *Otolaryngology-Head and Neck Surgery* also published high-quality studies. Multidisciplinary journals, with their broad readership, promoted interdisciplinary collaboration.

Keyword analyses provide valuable insights into emerging research directions, continuing research interests, clinical significance of keywords and disease epidemiology. In the early days, the main keywords focused on basic and clinical studies related to the subject headings of surgery,[13] melatonin,[14] tramadol,[31] postoperative analgesia,[15,32] and pain.[33] Basic studies demonstrated that changes in sleep arousal may serve as an indicator of chronic neuropathic pain following peripheral nerve injury.[34] Meanwhile, clinical studies revealed that sleep disturbances following general anesthesia were positively correlated with increased opioid consumption.[31] Different anesthetics may influence various endogenous sleep-wake substances,[35] with their regulatory mechanisms potentially depending on the specific type of anesthetic. Moreover, both surgery and regional anesthesia have been shown to reduce postoperative REM sleep.[36] With improved understanding from basic and clinical research, research themes have shifted significantly, driven by evolving clinical needs and scientific advancements. Although exogenous melatonin has shown some efficacy in reducing sleep latency in primary insomnia and delayed sleep phase syndrome, as well as regulating sleep-wake patterns in patients compared to placebo,[37] its impact on PSD remains modest and inconsistent across diverse patient populations. Interestingly, 27.5% of melatonin users reported insomnia as a reason for taking the supplement.[38] However, melatonin supplementation may moderately increase sleep propensity and is generally less effective than prescription sleep medications.[39] Given its limited ability to address the multifactorial nature of PSD, research on melatonin has declined in favor of more targeted interventions. Conversely, recent high-frequency co-occurrence keywords include "dexmedetomidine", "neuroinflammation" and "acupuncture". Dexmedetomidine has garnered increasing research attention due to its multifaceted benefits in improving postoperative outcomes. It effectively reduced pain, anxiety, and delirium while enhancing sleep quality.[26,40,41] Acting as a highly selective α2 receptor agonist, it interacts with the locus coeruleus—a brain region central to sleep regulation[42]—thereby promoting endogenous sleep pathways and inducing a sleep state similar to natural N2 sleep.[43] Additionally, dexmedetomidine has been shown to attenuate pro-inflammatory cytokines, which are implicated in neuroinflammation and PSD.[44] However, the underlying mechanism of PSD may be related to neuroinflammation.[45] Pro-inflammatory and anti-inflammatory cytokines played important roles in circadian rhythm regulation, with TNF-α levels correlating with decreased sleep quality and IL-1β as a potential biomarker for circadian dysregulation.[17] Neuroinflammation studies suggest that targeting cytokine pathways could mitigate PSD, offering a novel therapeutic approach. Acupuncture, an ancient Chinese technique, has shown promise in improving postoperative sleep quality through modern modalities like electroacupuncture (EA) and transcutaneous electrical acupoint stimulation (TEAS).[46] These interventions modulate the autonomic nervous system and reduce pain. While neuroinflammation-targeting therapies are still in early stages, acupuncture has demonstrated significant potential in reducing delirium and enhancing sleep quality in

postoperative patients.[47] The rise of acupuncture reflects a growing interest in non-pharmacological interventions, driven by the need for holistic and patient-centered care.

The findings of this study align with existing literature in several key aspects. The progressive increase in PSD-related publications in research output are consistent with prior study,[3,10] which have also identified a growing interest in PSD over recent years. Additionally, the identification of major research trends, such as the impact of anesthesia and analgesic drugs on sleep,[35] aligns with well-established themes in the field. However, this study also revealed several novel insights. The emerging focus on neuroinflammation[48] as a potential mechanism underlying PSD represents a significant shift from earlier research, which primarily concentrated on pharmacological and clinical aspects. Furthermore, the study emphasizes the potential of non-pharmacological interventions, advocating for integrative approaches that combine both pharmacological and non-pharmacological strategies. These findings highlight the evolving nature of PSD research and the need to integrate multidisciplinary perspectives.

Our study had some limitations. First, the data were obtained from the Web of Science Core Collection, a widely used and recommended database for bibliometric analysis because of its high data quality and completeness. However, this limited the scope of bibliometric analysis, potentially resulted in an incomplete view of the research landscape. Second, many studies from non-English databases may not be indexed. Future research could benefit from the inclusion of additional databases to improve comprehensiveness. Finally, the bibliometric analysis method itself is based on publications. It is inherently subject to the effects of potential publication and citation bias. Researchers could enhance the accuracy by incorporating preprints, accounting for indexing delays, combining qualitative assessments, and refining search strategies.

Conclusion

Scientific publications on PSD have increased annually over the past two decades. Future research should focus on integrating multidisciplinary approaches, exploring neuroinflammation, evaluating non-pharmacological interventions, and long-term outcomes, which will advance scientific knowledge, enhance clinical practice, and ultimately improve patient outcomes and quality of life.

Highlights

- This study provides a comprehensive bibliometric analysis of postoperative sleep disturbances (PSD).
- With an average annual growth rate of 16.56% in the number of publications, scientific interest has been steadily increasing.
- The analysis highlights the emerging roles of dexmedetomidine and acupuncture in improving postoperative sleep quality and the increasing focus on neuroinflammation as a potential mechanism underlying PSD.

Data Sharing Statement

The data can be downloaded from the following link: https://www.webofscience.com/wos/.

Ethics Approval and Declaration of Helsinki

The study was approved by the Ethics Committee of the Fourth Hospital of Hebei Medical University (2023KS121) and conducted according to the Declaration of Helsinki.

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Author Contributions

Conception and study design: Wei Du and Huiqun Jia. Execution and investigation: Wei Du, Xi Qiao and Wei Liu. Acquisition of data: Wei Du, Xi Qiao and Wei Liu. Analysis and interpretation: Chao Li, Wei Liu and Huiqun Jia. Funding acquisition: Wei Du. All authors took part in drafting, revising or critically reviewing the article; gave final

approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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