

Bibliometric Analysis of the Top-100 Cited Articles on Postoperative Delirium

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Objective: Postoperative delirium (POD), a common complication affecting short- and long-term prognosis in elderly patients, leads to a heavy burden on social economy and health care. The main purpose of this study is to conduct a bibliometric analysis of the 100 most frequently cited articles on POD.

Methods: "Postoperative delirium" and its synonyms were searched in the Web of Science (WoS) core database. The top-100 cited articles were automatically selected by sorting the records in descending order. Key information such as author, journal, article type, publication year, citations, since 2013 usage count, institution, country, and keywords were extracted and analyzed. VOSviewer software was applied to do the visualization analyses of institution co-operation, author interaction, author co-citation, and keywords co-occurrence. The CiteSpace software was used to analyze keywords burst.

Results: Most articles were published by authors and institutions in the United States of America (USA). Inouye was the most influential author of this field. The journals that recorded these articles had a high impact factor (IF), with a highest IF of 168.9 and an average IF of 18.04. Cohort studies were the main document type in this field (42 publications), followed by randomized controlled trial (RCT) and systematic reviews or meta-analysis (18 and 14, respectively). The 10 keywords with the highest appearance were "delirium", "risk-factors", "surgery", "confusion assessment method", "elderly patients", "hip fracture", "intensive care unit", "cardiac surgery", "general anesthesia", and "risk". Moreover, "double blind" and "cardiac surgery" were the most recent booming keywords.

Conclusion: We indicated the current research status and tendency of POD by analyzing the 100 most influential articles on POD. The USA is the leader in this field. Prospective study is the preference for authors to cite. Cardiac surgery remains the primary research carrier and the hotspots in the near future may be double-blind studies.

Keywords: bibliometric analysis, postoperative delirium, psychiatry, postoperative cognitive disorder, top-100

Introduction

Postoperative delirium (POD), a common complication in elderly surgical patients, is characterized by acute and fluctuating change of mental state with insufficient awareness and attention. POD can increase the incidence of other postoperative complications, which prolongs hospital stay, increases medical care costs, and impacts the prognosis.¹⁻³

A study that included over 20000 elderly patients from 30 hospitals indicated that the overall incidence of POD was approximately 12%.⁴ Furthermore, it was estimated that more than 312 million patients worldwide underwent surgery in 2012, with a dramatic increase of 33.6% in the past 8 years.⁵ The worldwide trend of aging is not slowing down, with the proportion of the aged population estimated to reach up to 16% in 2050, which means that there will be more elderly patients undergoing surgical procedures.⁶ Although much effort has been devoted to research on POD, there are no specific preventive measures. More studies are still needed.

Bibliometric analysis is a method for evaluating academic output, research trends, and research impact and is widely used in the evaluation of scientific research performance in certain fields. Highly cited articles can indicate vital signals

about the research status and trends in a certain field. Until now, there have been abundant original investigations and secondary studies focusing on the mechanisms, risk factors, prediction, prevention, and treatment of POD. A bibliometric analysis of POD was published last year, in which studies from 2000–2020 were included.⁷ However, a number of novel articles emerged after 2020, including top studies published in *JAMA*, *JAMA Surgery*, and the *British Journal of Anesthesiology*.^{8–10} These studies not only provide vital guidance on practice but also bring new hotspots in the POD field. In view of the important practical significance of POD and insufficient measures, we qualitatively and quantitatively analyzed the 100 most frequently cited articles on POD. We hope to help researchers gain a better understanding of the current situation and trends of POD, and further related studies in the future can do more to the prevention of POD.

Methods

Database and Retrieval Tactics

Web of Science (WoS), a popular database for evaluating the output, quality, and laws of scientific research development, was selected as the data source. We used the formula “postoperative delirium (Title), post-anesthesia delirium (Title), or post-surgery delirium (Title)” to search in WoS Core Collection. The print citation index database was not excluded. Data acquisition was conducted on 7 November 2023.

Data Collection and Analysis

Considering that there may be some classic articles that were published decades ago, we did not restrict the publication year. Firstly, we sorted the searched articles by setting the citation frequency in descending order. The first 100 articles were selected for analysis. Key items such as author, article title, source title (journal name), publication year, keywords, institution, country/region, citation times, 180-day usage count, and since 2013 usage count of the top-100 cited articles were automatically extracted. Secondly, items such as publication type, evidence level of the articles, and the impact factor (IF) of the journals were identified and extracted by two investigators, respectively. Finally, disagreements of the two investigators were rechecked and resolved by discussion and consultation.

The usage count, a parameter of the level of interest in a specific item on the WoS platform, reflects the number of times the article has met a user’s information demands as demonstrated by clicking links to the full-length article at the publisher’s website (via direct link or open-Url) or by saving the article for use in a bibliographic management tool (via direct export or in a format to be imported later). Namely, the usage count is not the same with citation times. To some extent, it is more likely to represent the quality of articles and has been used in bibliographic analyses.¹¹ The usage counts for the different versions of the same item on the WoS platform are unified. The usage counts are updated daily.

Publications were firstly divided into original and secondary studies by data source. The studies were then classified by study design, namely randomized controlled trial (RCT), cohort study, case-control study, cross-sectional study, case report, and case series, etc. To give a more intuitive cognition of evidence level, we finally allocated the studies into a high-level group (no less than grade 2 in the Oxford Centre for Evidence-Based Medicine (OCEBM)¹² system) and a low-level group.

For those that did not provide keywords, Keywords Plus, a function of WoS to optimize literature retrieval and improve the accuracy and relevance, was used to replenish.¹³ Therefore, the keywords in the present study were actually composed of author keywords and Keywords Plus. Journal IF (version 2022) was acquired from the WoS.

Study Instruments

VOSviewer, which was developed by Van Eck and Waltman, can be used to construct and view bibliometric maps.¹⁴ In the present study, VOSviewer (version 1.6.19) was used to draw diagrams for keywords co-occurrence, author co-operation, author co-citation, and institution cooperation. CiteSpace, a tool developed by Chen, can produce figures to visually present the relationships between scientific literatures.¹⁵ CiteSpace (version 6.1. R6) software was used to visualize theme burst. The specific parameters in CiteSpace were set similar to those used in a previous study.¹⁶ Besides, Excel was used for the basic analyses.

Results

In total, 1890 articles on POD were found in the WoS core database on 7 November 2023. The top-100 cited ones are shown in the [Supplementary Sheet 1](#).

Citation Times and Publication Year

The selected articles were published between 1981 and 2022. As shown in [Figure 1](#), with a number of 11, 2011 was the most productive year for highly cited articles. Citations ranged from 83 to 718 in the WoS Core Collection. However, the usage of these articles was relatively low with the highest count of 140 and the lowest count of 3 since January 2013. The highest usage count was 20 in the last 180 days. The above-mentioned information could be found in the [Supplementary Sheet 1](#). We also displayed the 10 most frequently cited articles in [Table 1](#) and the 10 most constantly used articles since January 2013 in [Table 2](#) respectively.

Study Type

All the 100 articles were clinical related studies. There were 73 original studies and 27 secondary studies. As shown in [Figure 2A](#), there were 2 retrospective database analysis studies, 14 reviews, 18 randomized controlled trials (RCTs), 1 pilot study, 9 meta-analysis or systematic review studies, 4 guidelines, 42 cohort studies, 3 case-control studies, and 7 case reports or case series studies. Furthermore, 73 studies had high-level evidence, whereas 27 studies had low-level evidence ([Figure 2B](#)).

Country/Region and Institution

Information on the author, institution, and country of the articles was analyzed. The United States of America (USA) was the most productive country with 54 top-100 cited articles ([Table 3](#)). Germany ranked second (13), followed by Canada (9), the United Kingdom (UK) (7), China (7), Denmark (6), and the Netherlands (6) ([Table 3](#)). The top-10 institutions of publication counts are presented in [Figure 3A](#). Harvard University, with 16 articles devoted to the greatest contribution of the 100 publications. The second is the University of California with 14 publications, while Johns Hopkins University and Beth Israel Deaconess Medical Center came third with 9 publications. We also analyzed the co-authorship of organizations using VOSviewer. [Figure 3B](#) shows the network visualization of the organizations' co-authorships. The 207 organizations formed 52 clusters, and different colors represent different clusters, as shown in [Figure 3B](#). In the figure, nodes refer to organizations, circle color refers to clustering, and link thickness refers to co-authorship strength. For example, Harvard University, Beth Israel

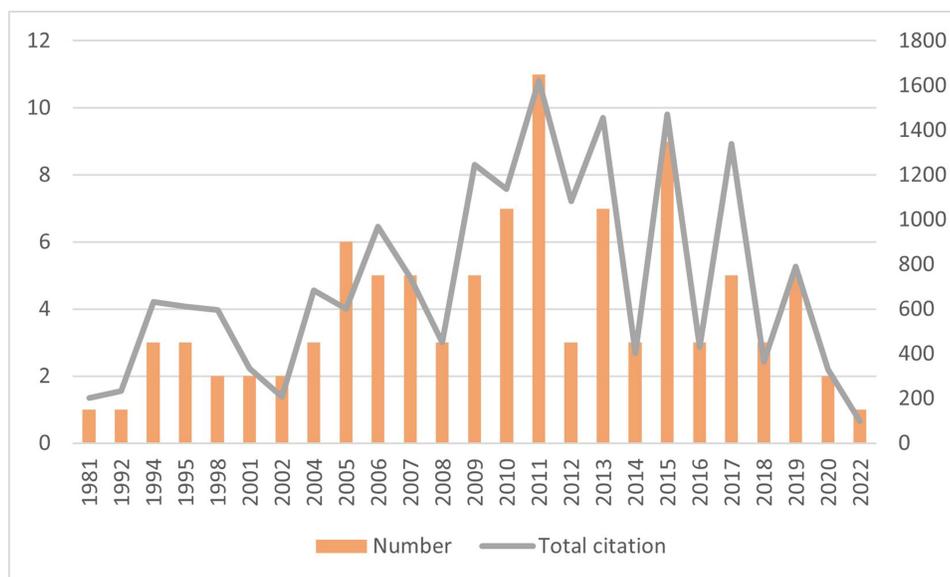


Figure 1 Distribution of the 100 articles by publication year.

Table 1 Information of the 10 Most Frequently Cited Articles

Article Title	Citation	IF ₂₀₂₂	Study Type
Cognitive trajectories after postoperative delirium	718	158.5	Cohort study
European society of anaesthesiology evidence-based and consensus-based guideline on postoperative delirium	553	3.6	Guideline
Bis-guided anesthesia decreases postoperative delirium and cognitive decline	436	3.7	RCT
Postoperative delirium in the elderly risk factors and outcomes	417	10.1	Cohort study
Preoperative anxiety and emergence delirium and postoperative maladaptive behaviors	378	5.9	Cohort study
The relationship of postoperative delirium with psychoactive medications	372	120.7	Case-control study
Postoperative delirium: acute change with long-term implications	337	5.9	Review
Monitoring depth of anaesthesia in a randomized trial decreases the rate of postoperative delirium but not postoperative cognitive dysfunction	333	9.8	RCT
The impact of postoperative pain on the development of postoperative delirium	303	5.9	Cohort study
Postoperative delirium - a review of 80 primary data-collection studies	298	17.333	Meta-analysis

Abbreviation: RCT, randomized controlled trial.

Table 2 The 10 Most Frequently Used Articles Since January 2013

Article Title	Since 2013 Usage Count	IF ₂₀₂₂
European society of anaesthesiology evidence-based and consensus-based guideline on postoperative delirium	140	3.6
Bis-guided anesthesia decreases postoperative delirium and cognitive decline	137	3.7
American geriatrics society abstracted clinical practice guideline for postoperative delirium in older adults	92	6.3
Effect of regional vs general anesthesia on incidence of postoperative delirium in older patients undergoing hip fracture surgery the raga randomized trial	91	120.7
Cognitive trajectories after postoperative delirium	90	158.5
Biomarkers of postoperative delirium and cognitive dysfunction	81	4.8
Effect of electroencephalography-guided anesthetic administration on postoperative delirium among older adults undergoing major surgery the engages randomized clinical trial	75	120.7
Postoperative delirium: perioperative assessment, risk reduction, and management	74	9.8
Monitoring depth of anaesthesia in a randomized trial decreases the rate of postoperative delirium but not postoperative cognitive dysfunction	68	9.8
Intraoperative ketamine for prevention of postoperative delirium or pain after major surgery in older adults: an international, multicentre, double-blind, randomised clinical trial	64	168.9

Deaconess Medical Center, Hebrew Rehabilitation Center for Aged, Brown University, Mount Sinai Hospital, and Brigham and Women's Hospital formed blue clusters and had a strong co-authorship, while the University of California, Purdue University, and Duke University constructed the yellow cluster. The largest cluster included 20 items and the smallest cluster included 1 item.

Author Analyses

The Top-11 authors was presented in the [Table 4](#). Marcantonio Edward R published 11 articles and ranked No. 1 in terms of article number, followed by Leung Jacqueline M (10) and Inouye Sharon K (9). The 11 authors all come from the USA. To better reflect the contribution and influence of author's research, we also analyzed the co-citation of authors by VOS viewer and presented the network visualization in [Figure 4](#). Inouye Sharon K had the most citations and strongest co-citation strength. Marcantonio Edward R also had a strong interaction with other researchers.

Journal, if and JCR Category Quartile

These articles came from 47 journals, top journals such as Lancet, New England Journal of Medicine, JAMA-Journal of the American Medical Association, and the British Medical Journal. The highest IF was 168.9, while the lowest was

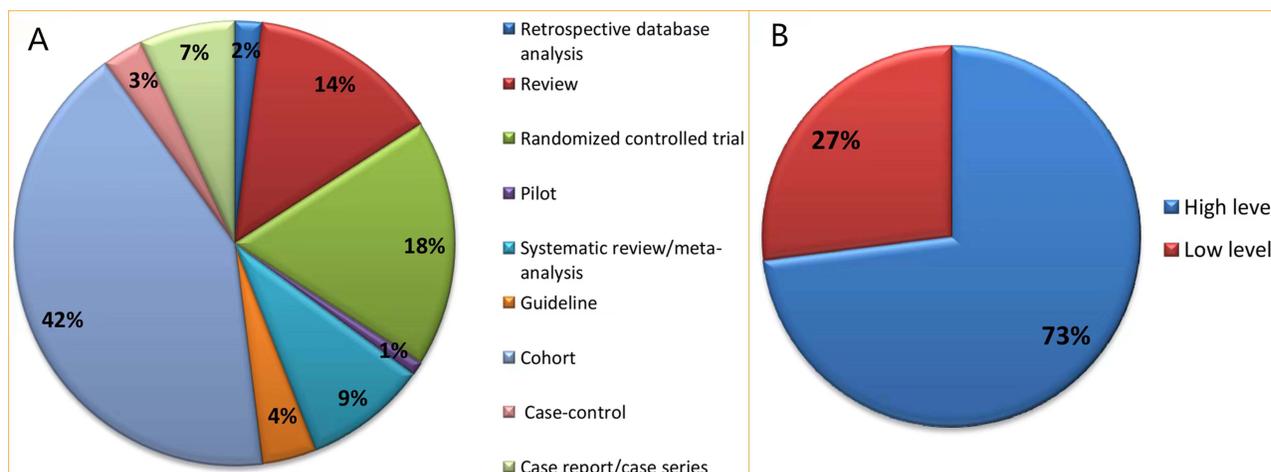


Figure 2 Proportion of the study types. **(A)** proportions for different designed studies. **(B)** proportions for study with different evidence levels.

1.018. The mean IF of these journals was 18.04. The JCR categories included: (1) Anaesthesiology, (2) Surgery, (3) Geriatrics & Gerontology, (4) Medicine, General & Internal, (5) Gerontology, (6) Psychiatry, (7) Critical care medicine, (8) Cardiac & Cardiovascular systems, (9) Respiratory system, (10) Clinical neurology, (11) Orthopedics, (12) Multidisciplinary sciences, (13) Psychology, (14) Peripheral vascular disease, and (15) Neurosciences. Except 1 journal did not have a location in JCR Category Quartile system, 30 journals were in the Q1 zone, 10 in Q2, 5 in Q3, and 1 in Q4. Besides, the top-10 journals on IF are shown in Table 5.

Keywords Analyses

Finally, we conducted a co-occurrence analysis of all keywords through VOSviewer to reveal the impacts and trends. The more frequently a keyword is used, the closer relationship will be between the two keywords in co-occurrence analysis. The minimum number of occurrences of a keyword was set as 3 and 84 keywords were screened out. The keywords formed six clusters and the network visualization of keywords co-occurrence is shown in Figure 5A. The keyword with the highest appearance (31) and link strength (193) was “delirium” (Figure 5B). The top-10 co-occurrence keywords also included “risk-factors”, “surgery”, “confusion assessment method”, “elderly patients”, “hip fracture”, “intensive care unit”, “cardiac surgery”, “general anesthesia”, and “risk” (Figure 5B). In order to better understand the trends in research topics over time, we used CiteSpace to analyze the keywords burst. In Figure 6, 25 keywords with the highest burst strength are shown in the first column. The keywords with the longest citation burst duration are “open-heart surgery” and “prognosis”. They were widely focused from 1992–2005. In the most recent years, “double blind” and “cardiac surgery” have become booming research topics. It is worth noting that this was the second outbreak of the keywords “cardiac surgery”.

Table 3 The 10 Countries/Regions with Most Publications

Country/Region	Publications	Total Citations	Average Citations
USA	54	10,437	193.28
Germany	13	2567	197.46
Canada	9	1366	151.78
China	7	1333	190.43
UK	7	1581	197.63
Denmark	6	1200	200
Netherlands	6	1290	215
Switzerland	5	1129	225.8
Italy	4	1088	272
Sweden	3	452	150.67

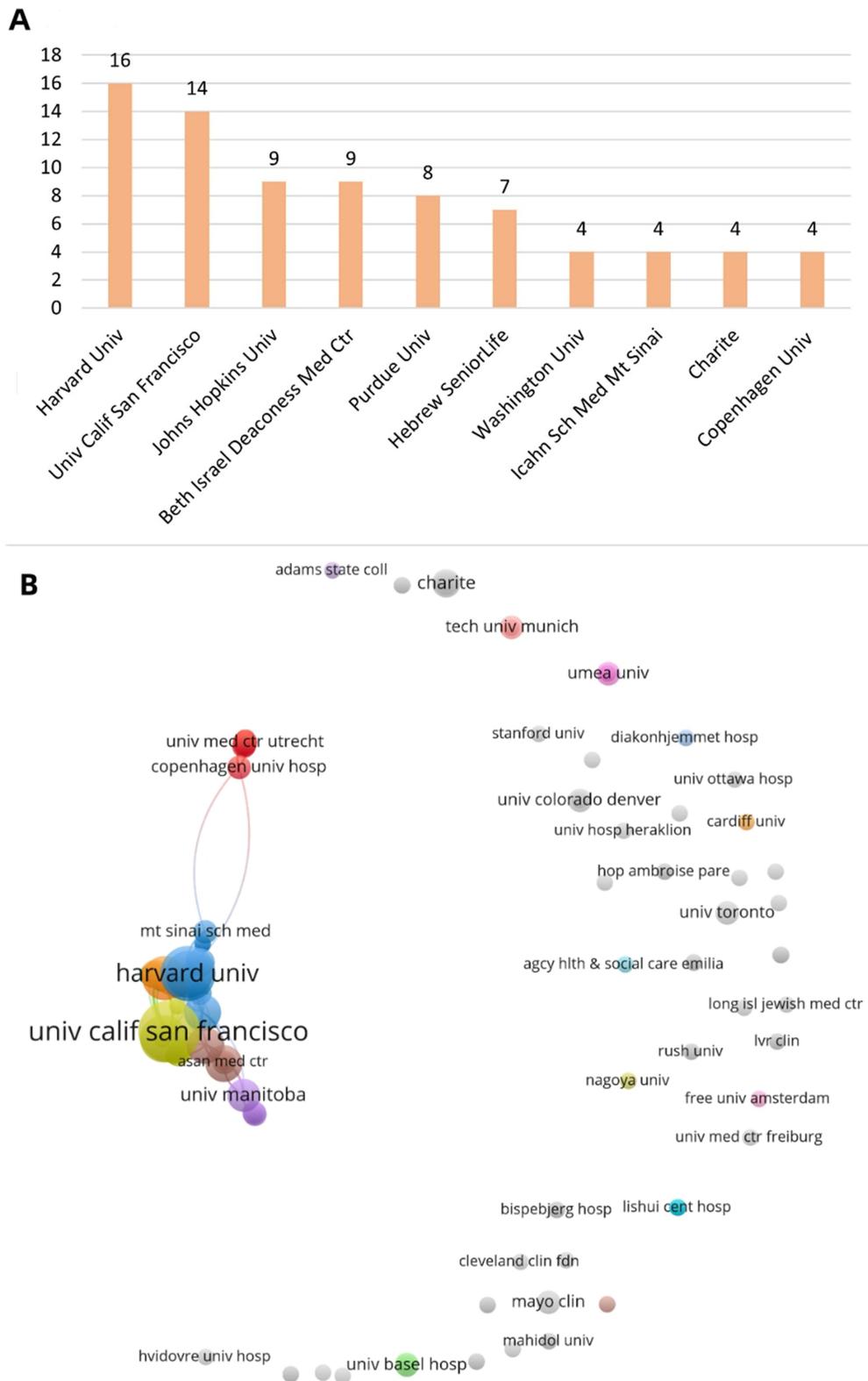


Figure 3 The visualized analyses of institution. **(A)** the top-10 institution with publications. **(B)** organization cooperation network.

Table 4 The Top-11 Authors by Publication Counts

Author	Publications	Institution
Marcantonio, Edward R	11	Harvard University
Leung, Jacqueline M	10	University of California
Inouye, Sharon K	9	Harvard University
Sands, LP	8	Purdue University
Sieber, Frederick E	7	Johns Hopkins University
Avidan, Michael S	5	Washington University
Gottschalk, Allan	4	Johns Hopkins University
Jones, Richard N	4	Harvard University
Orav, EJ	4	Harvard University
Ben abdallah, Arbi	3	Washington University
Goldman, L	3	University of California

Discussion

In the present study, we searched the articles on POD in the WoS database and selected the top-100 cited ones to do bibliometric analysis. We mainly analyzed the total citations, publication year, usage count, study type, author, institution, country/region, journal, and keywords.

The citation count of an article is regarded as a symbol of contribution to the scientific field. Analysis of the most frequently cited articles is able to help readers understand the research status, discover hotspots, and identify trends in a certain problem.¹⁷ The top-1 cited article was published in 2012 and entitled “Cognitive trajectories after postoperative delirium”,¹⁸ in which POD was determined to cause cognitive disability after cardiac surgery. This study transferred a message that POD was not only an acute complication, but also a risk factor for long-term injury. The top-1 used article since 2013 was published in 2017 and entitled “European Society of Anaesthesiology evidence-based and consensus-based guideline on postoperative delirium”.¹⁹ This study provided powerful advice on the prevention and treatment of POD, which is vital to clinical practice. Analyses of publication year indicated that the number of high-quality studies

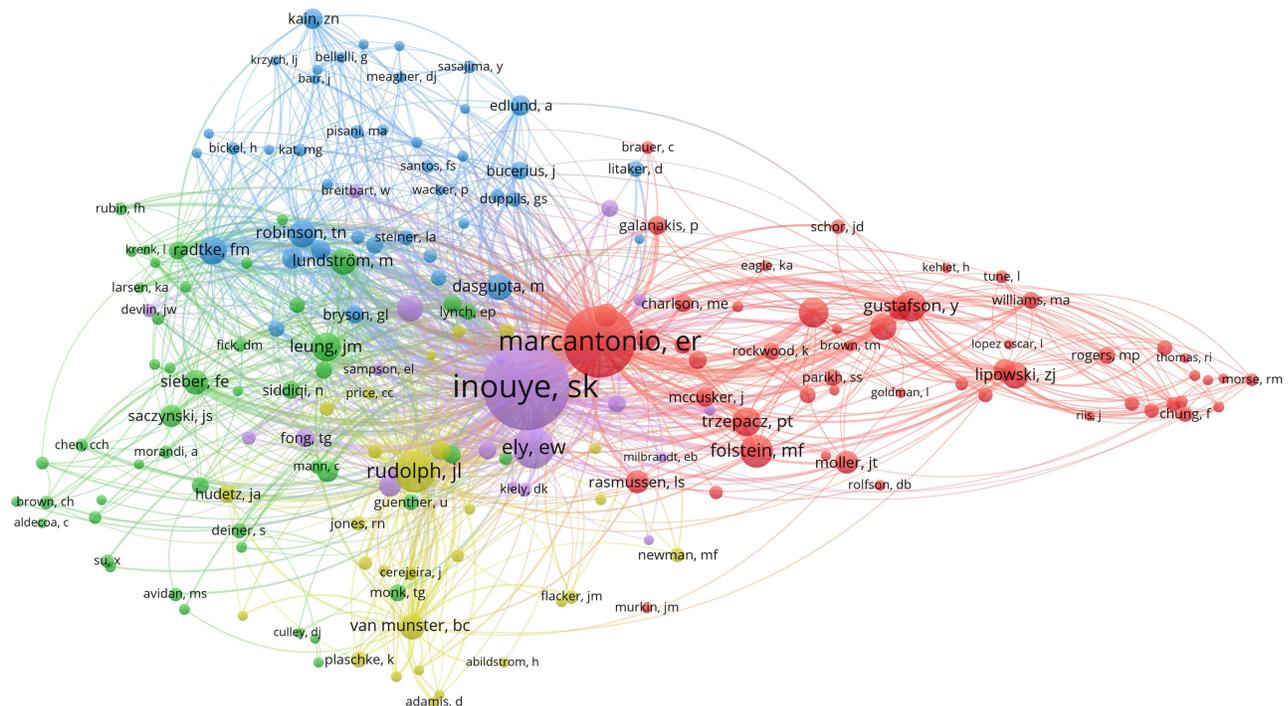


Figure 4 Network visualization of author co-citation. Co-citation: The relatedness of items is determined based on the number of times they are cited together.

Table 5 Top-10 Journals on if

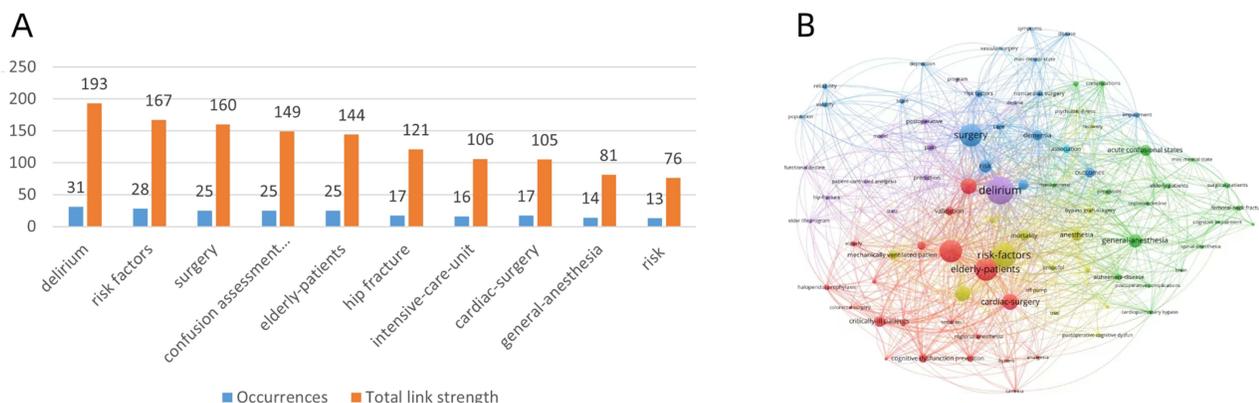
Journal	IF ₂₀₂₂	Publications	JCR Category
Lancet	168.9	2	Medicine, general and Internal
New England Journal of Medicine	158.5	1	Medicine, general and Internal
JAMA-Journal of the American Medical Association	120.7	5	Medicine, general and Internal
British Medical Journal	107.7	1	Medicine, general and Internal
Intensive Care Medicine	38.9	1	Critical care medicine
Archives of Internal Medicine	17.333	1	Medicine, general and Internal
JAMA Surgery	16.9	2	Surgery
Critical Care	15.1	3	Critical care medicine
Anaesthesia	10.7	1	Anesthesiology
Annals of Surgery	10.1	2	Surgery

tended to be stable, but the proportion of articles from the last 5 years was only 11%. Newly published articles need time to be cited might be a reason. However, the usage count was relatively low when compared with the citation count, which means that researchers still need to explore more interesting, significant, and meticulously designed studies.

Through the analyses of countries and institutions, we found that the USA published the most articles, cooperated with several top-10 countries and would continue to play a dominant role in researches on POD. The proportion of articles published by the top 10 countries was more than 90%. The countries with greater contributions were mainly concentrated in North America and Europe. The contribution of China is also increasing. Researches on POD from developing countries have been widely carried out. We counted the number of articles published by the authors and analyzed the co-citation of each author. Inouye had the most citations and published 3 articles with an IF above 100 among the top-100 articles. In an article published by Inouye and Maybrier on Lancet,²⁰ a multicenter international randomized trial suggested that intraoperative administration of a single subanesthetic dose of ketamine did not prevent delirium, but might cause harm by inducing negative experiences.

All of the top-100 cited articles on POD were clinical-related studies. The study type is determined by the study design. The results of our study indicated that a large proportion of the 100 studies had a high level of evidence, which is similar to a previous bibliometric analysis of delirium.¹⁶ We failed to classify the studies by level of evidence that proposed by the OCEBM.¹² Because some studies were difficult to allocate to a specific level. For example, a meta-analysis by Janssen et al²¹ included 31 RCTs and 4 before-and-after studies. According to the study design of 4 before-and-after studies, the before-and-after study was based on cohort studies.^{22–25} However, meta-analysis of RCTs and cohort study was not matched with grading criteria. So, we allocated this study into the high-level of evidence group.

The co-occurrence analysis of all keywords could help analyze development trends and hotspots in the field. The focuses of POD researches were risk factors and type of operation. It's no doubt that preoperative assessment of risk

**Figure 5** Information of keywords co-occurrence. (A) Keywords co-occurrence network. (B) Top-10 keywords of total link strength.

Top 25 Keywords with the Strongest Citation Bursts

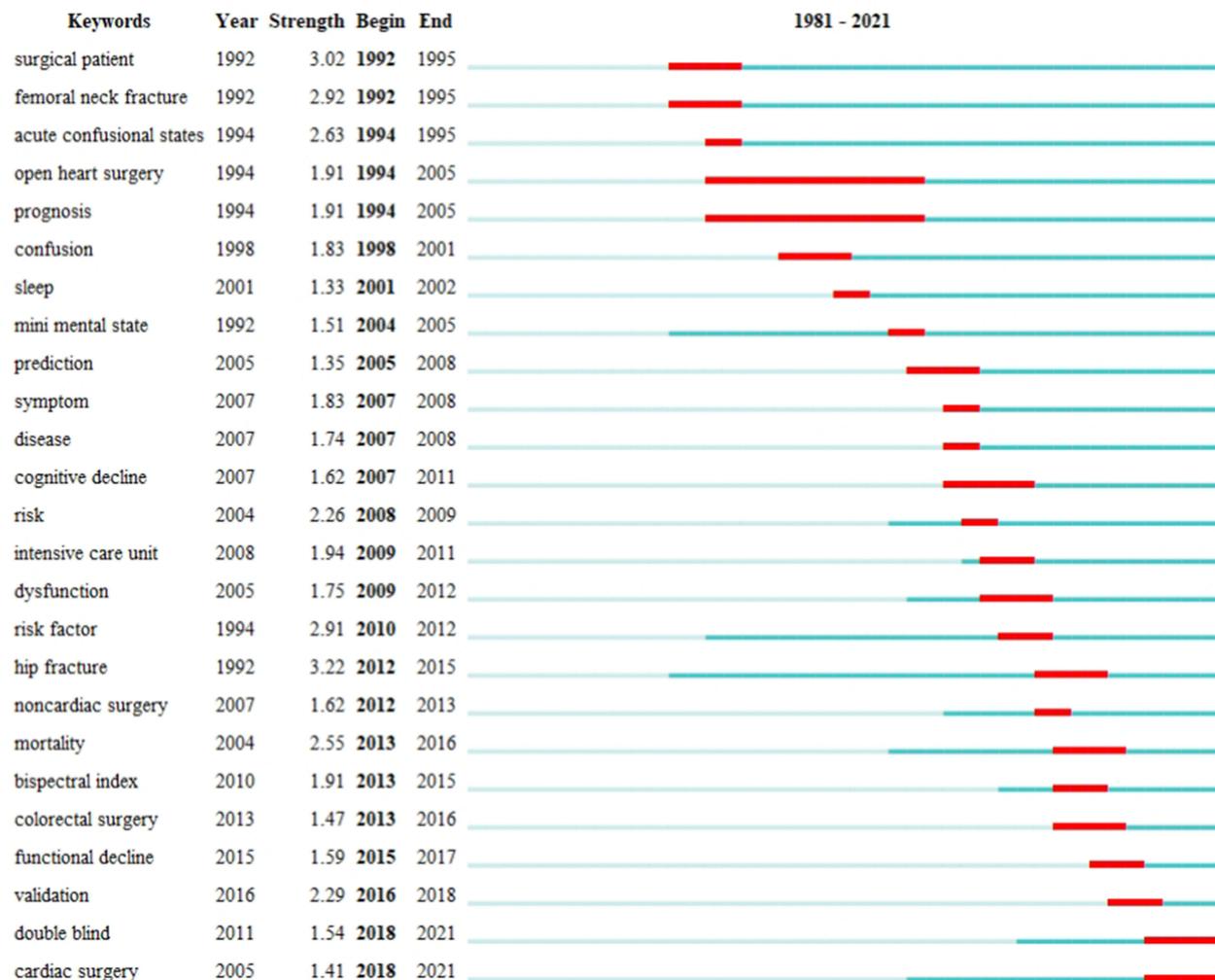


Figure 6 Top-25 keywords with the strongest citation bursts. Year, the year that a keyword was firstly cited; strength, the citation burst strength of keywords; begin and end, the duration of keywords burst.

factors may help with preventing POD. Common risk factors such as tobacco exposure, the need for vascular surgery, advanced age, cognitive impairment, greater preoperative functional limitations, a history of preoperative delirium, heart failure, total hip arthroplasty, and morphine usage were more likely to induce delirium after surgery.^{26–28} The factors leading to POD were too complex and could have a serious complication for the patients. Thus, researchers can explore the prevention of POD aiming at various risk factors. Efforts of preventing POD have expanded through recent investigation of novel pharmacological and non-pharmacological strategies.²⁹ Non-pharmacological interventions include behavioral interventions, monitoring devices, rehabilitation, environmental adaptations, psychological and social support, medication reductions, complementary and alternative medicine, and system and process changes.³⁰ As for pharmacologic treatment, dexmedetomidine has been accepted as a promising agent, not only for the prevention but also for the treatment of ICU-delirium.^{31,32} However, a RCT conducted by Stacie et al³³ suggested that intraoperative dexmedetomidine did not prevent POD. Future trials are warranted to refine the evidence regarding the role of dexmedetomidine in preventing or treating delirium. Besides, acetaminophen, ramelteon, gabapentin, statins, clonidine, and melatonin also show some promise as prophylactic agents for POD.^{34,35} Pharmacological treatment as an effective prevention method may become a hotspot of POD research.

The surgery type for POD investigation mainly focused on major heart surgeries. The reason may be that cognitive impairment is common after a cardiac surgery.¹⁸ With two bursts, cardiac surgery may continue to be a preferential mediator for POD researches. However, non-cardiac surgery, such as hip fractures and colorectal surgery, has become a trending research topic.

In addition, we analyzed the IF, JCR, category and JCR category quartiles of the journals to reflect the level of these articles, show the importance of POD, and help researchers make a better choice of submission. There were 9 articles from 4 journals with an IF above 100. The latest one was published in the JAMA -Journal of the American Medical Association.⁸ In this clinical study, intravertebral anesthesia without sedation got comparable incidence of POD to that of general anesthesia for elderly patients who underwent hip fracture surgery. Thus, POD might not be a consideration for the choice of the anesthesia method. Besides, more than 80% of the journals were located in the Q1 and Q2 zone of the JCR category.

Limitations

There are some limitations worth noting in the present study. Firstly, the citation and usage count of articles are updated daily, some articles with low citations published in the last few years may become highly cited ones. Considering this factor, the bibliometric analysis of articles on POD should be updated in the future to identify the latest trends. Secondly, we searched for articles in the WoS Core Collection. Articles from other databases may be omitted, which is inevitable in bibliometrics.

Conclusion

We conducted the analyses of top-100 cited articles on POD from different perspectives. On the basis of these analyses, we identified the current orientation and hotspots of POD. Risk factors and prevention of POD may continue to be hot research directions. Double-blind clinical trials based on cardiac surgery may still be the mainstream of researches on POD. Moreover, major orthopedic and abdominal surgeries are applicable candidates.

Supplements

Supplementary Sheet 1, bibliometric characteristics of the 100 articles.

Data Sharing Statement

The authors state that all relevant data are included in this article and [supplementary file](#).

Acknowledgments

This paper has been uploaded to Research Square as a preprint: <https://www.researchsquare.com/article/rs-3887909/v1>.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; 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 confirm that they have no conflicts of interest in this study.

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