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Twenty years of research on total intravenous anesthesia (TIVA): bibliometric analysis and visual mapping with Web of Science data

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ABSTRACT

Aims: This study aims to determine the leading articles, countries, institutions, authors, funding sources and scientific collaborations by examining the scientific literature related to total intravenous anesthesia (TIVA) using bibliometric methods. It also aims to reveal the thematic structure and research trends of the field using keyword analysis.

Methods: A total of 494 English-language articles published in the Web of Science Core Collection (WoSCC) database were examined. Publication trends were evaluated using citation analyses, co-citation networks, and keyword co-occurrence analyses. Bibliometrix and VOSviewer programs were used for the analyses. In addition, thematic trends and keyword evolution were analyzed with Sankey diagrams and trend analysis.

Results: In total, 494 articles and 195 journals from 54 countries were evaluated. The most productive countries are the USA, China and South Korea, while institutions such as the National Defense Medical Center and Tri-Service General Hospital have come to the fore. Wu ZF, Lai HC and Lee MS have been identified as the most prolific authors. Anesthesiology has been the most cited journal, while pediatric anesthesia has been the most prolific journal. Among the most frequently used keywords were propofol, TIVA and anesthesia. After 2019, it has been observed that the interest in areas such as cancer surgery and recovery issues has increased. The studies of Nimmo and Wu ZF have been among the important references highlighting the oncological and postoperative advantages of TIVA.

Conclusion: This bibliometric study examines the scientific studies in the field of TIVA between 2003 and 2023. During this time, the number of publications has increased, and the USA has come to the fore as the country with the highest number of publications and citations. China and South Korea, on the other hand, are following the United States. National Defense Medical Center and Tri Service General Hospital are the prominent institutions. The most active authors are Wu ZF, Lai HC and Lee MS; Wu ZF in particular is the leader in both the number of publications and citations. Anesthesiology is the most cited and pediatric anesthesia is the most active journal. After 2019, there has been an increasing interest in the topics of "obstructive sleep apnea," "recovery," and "cancer surgery". The Sankey diagram indicates that topics such as "rocuronium," "cerebral oxygen saturation" and "surgery" were more focused during this period.

Keywords: Total intravenous anesthesia, bibliometric analysis, TIVA, propofol, anesthesia, volatile free anesthesia

INTRODUCTION

Total intravenous anesthesia (TIVA) is a method in which the anesthesia process is completely provided with intravenous drugs. TIVA, which was first started to be used in the 1870s, has become widespread especially with the introduction of propofol into clinical use in the early 1980s.[1] In traditional anesthesia methods, intravenous agents are usually used for anesthesia induction, while maintenance is usually provided with inhalation agents. In TIVA, both induction and maintenance are performed entirely with intravenous agents.[2] This approach reduces air pollution caused by inhalation agents in operating rooms.[3] Initially introduced for pediatric patients in the 1990s, it provides a safe option, particularly in airway management procedures, by reducing the risk of delirium during emergence and preventing respiratory complications such as laryngospasm, bronchospasm, and reactivity. This method, which is preferred in cases such as neuromuscular diseases, nuclear myopathies and muscular dystrophy, stands out with its minimal intervention and cost-effectiveness in neurological monitoring during surgery.[4,5] In addition, TIVA, which increases patient comfort by reducing nausea and vomiting after surgery, is increasingly widely used in pediatric patients today.[6] However, side effects such as infection, pain during injection, bradycardia and hypotension may be observed during TIVA administration, especially related to the use of propofol.[7,8] In addition, it has been shown in studies that in cases where monitors measuring the

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depth of anesthesia, such as BIS, are used, patient-based dose adjustment should be made and the optimal dose should be carefully determined.[9]

Bibliometric analysis is a critical tool for understanding research trends, evaluating academic achievement, and determining future research directions in the field of medicine. This analysis method contributes to the emergence of innovative and potential research areas in health sciences by measuring productivity and impact.[10] Bibliometrics determines the relevant journals, articles, authors and themes by systematically examining academic outputs and thus serves as a guide for defining our discipline. Developing a comprehensive understanding of the field provides an opportunity to monitor trends and decipher existing research gaps, while at the same time fostering a sense of belonging among those working in this field. In this way, bibliometric analysis stands out as an important tool that both directs scientific developments and strengthens the identity of the discipline.[11]

TIVA is a widely used technique in clinical anesthesia practice and is frequently encountered as a subject of study in the literature. However, literature reviews indicate that studies aimed at evaluating scientific publications related to TIVA using bibliometric methods are limited. This study aims to determine the leading articles, countries, institutions, authors, funding sources and scientific collaborations by examining the scientific literature related to TIVA using bibliometric methods, as well as to reveal the thematic structure and research trends of the field through keywords.

METHODS

Ethics

Ethics committee approval was not required because publicly available data was used.

Working Design

This study has been designed as a bibliometric research that examines the scientific publications published in the Web of Science Core Collection (WoSCC) database in the last 21 years between 2003 and 2023 on the topic of TIVA using bibliometric analysis methods. The aim of this study is to Decipher the scientific publications published in the WoSCC database. Since only publicly available data were used in the study, ethics committee approval was not required.

Data Sources, Registration and Search Strategy

The data were collected using the advanced search features of the WoSCC database. In order to select the articles in our study, author keywords (author keywords, AK) and title (title, TI) searches were performed. The following expressions have been deconstructed using Boolean operators in the search process:

TI=(total IV anesthesia) OR AK=(total IV anesthesia) OR TI=(volatile free anesthesia) OR AK=(volatile free anesthesia) OR TI=(TIVA) OR AK=(TIVA) OR TI=(TIVA) OR AK=(TIVA).

In this way, the most appropriate articles related to TIVA to be used in our research have been determined. In order to prevent data loss and to avoid being affected by future changes, bibliometric data for all articles in the WoSCC database were downloaded along with their references on September 25, 2024. For each article, detailed information such as publication year, title, country, institution, journal, DOI, author name and author keywords are transferred to Microsoft Excel and recorded.

In order to ensure data consistency, the determined studies were examined manually. Data with different spelling styles (for example, journal, country, institution, author name, keywords) are standardized in Excel and exported in BibTeX file format. The standardization of the data was carried out by two independent researchers in order to increase the reliability. In contradictory cases, the final decision was made by taking the opinion of a third researcher.

Inclusion Criteria

Scientific publications published in the WoSCC database between 2003 and 2023 were included in our study about TIVA. The articles in the English language and included in the science citation index expanded (SCI-Expanded) are defined as "article" and "review article" type articles.

Exclusion Criteria

Studies showing decoherence between non-human studies (for example, animal and veterinary research) and title and subject content were excluded.

Data Analysis and Statistical Analysis

In this study, in which the scientific contributions and effects in the field of TIVA were evaluated, regression analysis was performed to show the increase of studies by years. The countries, institutions, journals and authors contributing to TIVA research have been ranked according to the number of publications and the number of citations, and the leading individuals and organizations in the field have been identified.

In order to examine the literature related to TIVA, a co-citation network was established by using the 50 publications that received the most citations. The centrality criteria for this network were obtained with the Bibliometrix program, and the visual representation of the network was obtained with the VOSviewer program. Within the scope of document co-citation analysis, each article was grouped in a cluster and PageRank, betweenness and closeness centrality criteria were used to evaluate their roles and effects within the network. PageRank is calculated according to the number of links received by each article and the importance of these links. A high PageRank value has shown that an article is frequently referenced and establishes relationships with articles in other clusters. Betweenness refers to the degree to which an article acts as a bridge between articles in different clusters. The high betweenness value has shown that that article plays a key role in the flow of information and provides links between articles in different clusters. Closeness shows the average distance of an article from other articles on the network. A high closeness

value indicates that the article is centrally located among the articles in the network and provides quick access to other articles. A visual map of the co-citation of the studies related to TIVA was created with the VOSviewer co-citation analysis. In the created image, different clusters are shown in different colors, which helped us decipher the studies related to TIVA and the connections between these studies.

Keywords Co-Occurrence analysis was performed based on the most commonly used author keywords related to TIVA, and the degree of centrality and interaction capacity of each keyword in the network were evaluated using PageRank, betweenness and closeness criteria. In addition, the relationships between the words were visualized with the Keywords Co-Occurrence analysis performed with Bibliometrix. In order to decipher the evolution of the studies related to TIVA, trend topics analysis and Sankey diagram were used to determine the trending words between 2003-2023.

RESULT

Between 2003 and 2023, the 1.180 articles originally identified from the Web of science core collection on TIVA were reduced to 494 articles as a result of the exclusion criteria determined (**Figure 1**).

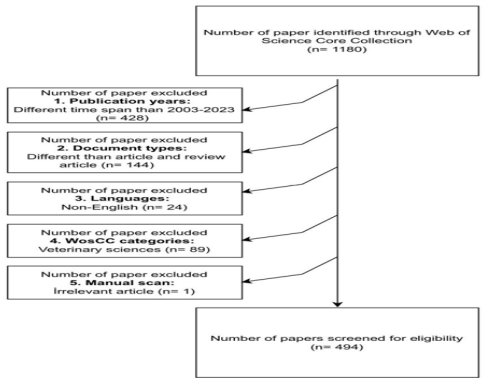

Figure 1. Flow chart

These studies were published in 195 different journals with the participation of 497 institutions and 2.544 authors from 54 countries, and 218 studies were funded by various organizations. It has been observed that publications and citations related to TIVA have increased between 2003 and 2023, and the highest number of publications was reached in 2021 (**Figure 2**).

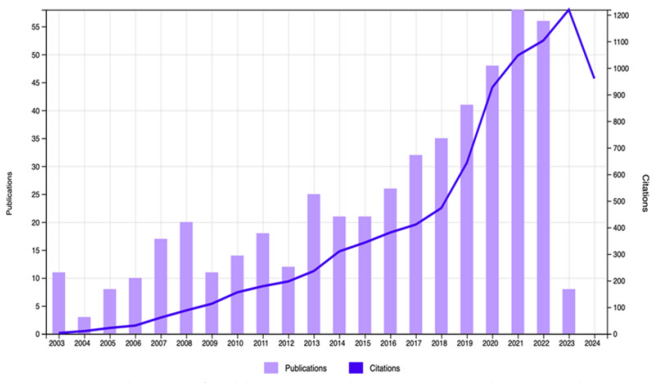

Figure 2. Distribution of publications and citations related to TIVA by year

Regression analysis applied to examine the change in the number of publications by year showed that the number of publications related to TIVA showed a continuous increase between 2003 and 2023, and there was an increase in the number of articles by 1.92 every year (**Figure 3**).

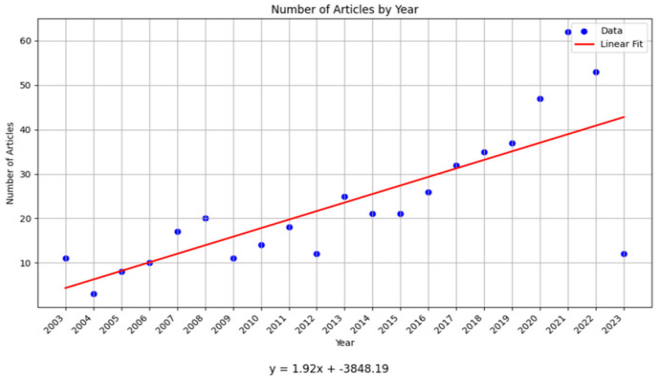

Figure 3. Linear regression analysis of the number of publications related to TIVA over the years

When the distribution of TIVA publications by country is examined, it is seen that the USA has been the most productive country with 101 publications in the last 20 years (**Table 1**). The United States was followed by China with 80 publications and South Korea with 15 publications, respectively. The most productive institutions are the National Defense Medical Center and Tri Service General Hospital with 15 publications each, followed by Seoul National University with 13 publications. While Pediatric Anesthesia was the most prolific journal, this journal was followed by Journal of Clinical Anesthesia with 25 publications and Medicine with 15 publications. The most prolific authors were Wu ZF with 15 publications, Lai HC with 12 publications and Lee MS with 10 publications.

The number of citations of countries, institutions, journals and authors related to TIVA between 2003 and 2023 was examined in **Table 2** and the 10 articles that received the most citations were examined in **Table 3.** China is one of the most cited countries with 19.2%. China is followed by the USA with 18% and Italy with 7.5%. The most cited journal is Anesthesiology with 9.91%, followed by Anesth Analg with 8.8% and Brit J Anesth with 8%. Wu ZF stands out among the most cited authors with 1.6%. Wu ZF is followed by Lai HC with 1.4% and Lee MS with 1.3%. The study titled "Guidelines for the Safe Practice of TIVA: Joint Guidelines from the Association of Anesthetists and the Society for Intravenous Anesthesia", published in the journal "Anesthesia" in 2019 and written by Nimmo AF et al., has been the most cited article.

In this study, a document co-citation network was created for the 50 most cited publications in TIVA literature. The centrality metrics of the publications and the structure of the field were examined by clustering analysis (**Table 4**). According to the results of clustering analysis 1. in the cluster, the article written by Wigmore TJ and colleagues in the journal Anesthesiology in 2016 is ranked first with a PageRank of 0.04 and a betweenness value of 428.22. In the

Table 1. Countries, institutions, journals and authors with the highest productivity in TIVA-related research

	Country	n (%)	Affiliations	n (%)	Journal	n (%)	Author	n
1	Usa	104 (21.1)	National Defense Medical Center	15 (3)	Pediatric Anesthesia	34 (6.9)	Wu Zf	15 (3)
2	China	80 (16)	Tri Service General Hospital	15 (3)	Journal of Clinical Anesthesia	25 (5.1)	Lai Hc	12 (2.4)
3	South Korea	50 (10.1)	Seoul National University Snu	13 (2.6)	Medicine	24 (4.8)	Lee Ms	10 (2)
4	Italy	40 (8.)	University of Texas System	12 (2.4)	Journal of Neurosurgical Anesthesiology	19 (3.8)	Lu Ch	8 (1.6)
5	Turkey	38 (7.7)	Capital Medical University	10 (2)	Journal of Cardiothoracic and Vascular Anesthesia	18 (3.6)	Anderson Bj	7 (1.4)
6	Germany	33 (6.7)	University of Colorado System	10 (2)	Journal of Anesthesia	16 (3.2)	Ansermino Jm	6 (1.2)
7	Canada	25 (5.)	University of Melbourne	10 (2)	Bmc Anesthesiology	13 (2.6)	Riedel B	6 (1.2)
8	Japan	22 (4.4)	Sichuan University	9 (1.9)	Anesthesia and Analgesia	12 (2.4)	Bagshaw O	5 (1)
9	Taiwan	22 (4.4)	University of British Columbia	9 (1.9)	Plos One	12 (2.4)	Boon M	5 (1)

Table 2. Countries, institutions, journals and authors with the highest number of citations in TIVA-related research

	Country	n (%)	Journal	n (%)	Author	n (%)
1	China	321 (19.2)	Anesthesiology	1592 (10)	Wu Zf	80 (1.6)
2	USA	301 (18)	Anesth Analg	1407 (8.8)	Lai Hc	68 (1.4)
3	Italy	125 (7.5)	Brit J Anaesth	1270 (8)	Lee Ms	63 (1.3)
4	Turkey	104 (6.2)	Pediatr Anesth	463 (2.9)	Lu Ch	51 (1)
5	South Korea	99 (6)	Anaesthesia	444 (2.8)	Lin C	39 (0.9)
6	Germany	74 (4.4)	Acta Anaesth Scand	344 (2.1)	Huang Ys	38 (0.8)
7	Canada	70 (4.2)	J Clin Anesth	235 (1.5)	Lin Kt	38 (0.8)
8	UK	66 (4)	Eur J Anaesth	211 (1.3)	Lou Ys	36 (0.7)
9	Australia	61 (3.7)	Can J Anaesth	186 (1.2)	Wong Cs	36 (0.7)
10	Japan	52 (3.1)	J Cardiothor Vasc An	184 (1.2)	Bagshaw O	33 (0.7)

Table 3. Top 10 publications by average citation number (citation/year after publication)

	Title	Journal	First author	Publication year	Number of citation
1	Joint guidelines from the association of anaesthetists and the society for intravenous anaesthesia	Anaesthesia	Nimmo, AF	2019	170
2	Volatile anesthetics versus total intravenous anesthesia for cardiac surgery	New England Journal of Medicine	Landoni, G	2019	161
3	Global onco-anesthesia research collaboration group. Anesthetic technique and cancer outcomes: a meta-analysis of total intravenous versus volatile anesthesia	Canadian Journal of Anesthesia	Yap, A	2019	151
4	Propofol-based total intravenous anesthesia is associated with better survival than desflurane anesthesia in colon cancer surgery	Anesthesiology	Wu, Zf	2018	141
5	Heart rate variability during total intravenous anesthesia: effects of nociception and analgesia. Auton Neurosci	Autonomic Neuroscience-Basic & Clinical	Jeanne, M	2009	129
6	The effect of the total intravenous anesthesia compared with inhalational anesthesia on the surgical field during endoscopic sinus surgery	American Journal of Rhinology	Wormald, PJ	2005	128
7	Remimazolam: non-clinical and clinical profile of a new sedative/anesthetic agent	Frontıers in Pharmacology	Kilpatrick, GJ	2021	115
8	Ultrasound-guided multilevel paravertebral blocks and total intravenous anesthesia improve the quality of recovery after ambulatory breast tumor resection	Anesthesiology	Abdallah, Fw	2014	114
9	Neuroendocrine stress response and heart rate variability: a comparison of total intravenous versus balanced anesthesia	Anesthesia and Analgesia	Ledowski, T	2005	114
10	Influence of nociceptive stimulation on analgesia nociception index (Anı) during propofol-remifentanil anaesthesia	British Journal of Anaesthesia	Gruenewald, M	2013	112

same cluster, the article published by Wu ZF and colleagues in the journal Anesthesiology in 2018 ranked seventh with a closeness value of 0.03 and a betweenness value of 232.65. 3. in the cluster, the article published by Kataria BK and others in the journal Anesthesiology in 1994 has the highest PageRank value (0.04) in this cluster and was found to be 0.00 and 0.002 in the betweenness and closeness criteria, respectively. In an article published by McFarlan CS and others in the journal pediatric anesthesia in 1999, the PageRank value was found to be 0.03, closeness value was found to be 0.002 and betweenness value was found to be 9.07002E.

In this study, the keyword co-occurrence network created using author keywords frequently used in publications on the topic of TIVA was also examined by network centrality criteria and clustering analysis (**Table 5**). It has become the most frequently used key term in TIVA literature.[2] This term, which is included in the cluster, has been repeated 327 times. This term has assumed the most central role in the literature with a betweenness value of 678.66. At the same time, the word "tiva" has 0.02 closeness and 0.21 PageRank values. Another keyword in the same cluster, "inhalation anesthesia", was used 57 times. It has been seen that the term "inhalation

Table 4. Centrality criteria of influential publications

	Title	Cluster	Betweenness	Closeness	PageRank
1	Wigmore TJ, Mohammed K, Jhanji S. Long-term survival for patients undergoing volatile versus iv anesthesia for cancer surgery: a retrospective analysis. Anesthesiology. 2016	3	428.22	0.004	0.04
2	Kataria BK, Ved SA, Nicodemus HF, et al. The pharmacokinetics of propofol in children using three different data analysis approaches. Anesthesiology. 1994	1	0.00	0.002	0.04
3	McFarlan CS, Anderson BJ, Short TG. The use of propofol infusions in paediatric anaesthesia: a practical guide. Paediatr Anaesth. 1999	1	9.07	0.002	0.03
4	Absalom A, Amutike D, Lal A, White M, Kenny GN. Accuracy of the 'Paedfusor' in children undergoing cardiac surgery or catheterization. Br J Anaesth. 2003	1	1.03	0.002	0.03
5	Marsh B, White M, Morton N, Kenny GN. Pharmacokinetic model driven infusion of propofol in children. Br J Anaesth. 1991	1	7.21	0.002	0.03
6	Minto CF, Schnider TW, Egan TD, et al. Influence of age and gender on the pharmacokinetics and pharmacodynamics of remifentanil. I. Model development. Anesthesiology. 1997	1	232.65	0.004	0.03
7	Wu ZF, Lee MS, Wong CS, et al. Propofol-based total intravenous anesthesia is associated with better survival than desflurane anesthesia in colon cancer surgery. Anesthesiology. 2018	3	0.91	0.003	0.03
8	Enlund M, Berglund A, Andreasson K, Cicek C, Enlund A, Bergkvist L. The choice of anaesthetic--sevoflurane or propofol--and outcome from cancer surgery: a retrospective analysis. Ups J Med Sci. 2014	3	10.23	0.004	0.03
9	Yoo S, Lee HB, Han W, et al. Total intravenous anesthesia versus inhalation anesthesia for breast cancer surgery: a retrospective cohort study. Anesthesiology. 2019	3	0.75	0.003	0.03
10	Jun IJ, Jo JY, Kim JI, et al. Impact of anesthetic agents on overall and recurrence-free survival in patients undergoing esophageal cancer surgery: a retrospective observational study. Sci Rep. 2017	3	0.63	0.003	0.03

Table 5. Top 20 most used author keywords and centrality metrics

	Author keywords	n	Cluster	Betweenness	Closeness	PageRank
1	Tiva	327	2	678.66	0.02	0.21
2	Propofol	137	3	170.18	0.02	0.12
3	Anesthesia	106	3	85.36	0.02	0.08
4	Remifentanil	58	3	12.52	0.01	0.05
5	İnhalation anesthesia	57	2	11.55	0.01	0.04
6	Sevoflurane	42	3	3.39	0.01	0.04
7	Pediatric anesthesia	30	3	2.08	0.01	0.03
8	Bispectral index	27	3	6.03	0.01	0.02
9	Target-controlled infusion	24	3	0.75	0.01	0.02
10	Dexmedetomidine	22	3	0.86	0.01	0.02
11	Desflurane	21	2	0.55	0.01	0.02
12	Neuromonitoring	20	2	0.75	0.01	0.02
13	Motor evoked potentials	18	2	1.11	0.01	0.02
14	Analgesia	17	2	0.06	0.01	0.01
15	Recovery	17	3	0.51	0.01	0.02
16	Cancer surgery	14	2	0.26	0.01	0.02
17	Pharmacokinetic	14	5	0.03	0.01	0.02
18	Volatile anesthetics	13	2	0.15	0.01	0.01
19	Postoperative nausea and vomiting	12	3	0.00	0.01	0.01
20	Cardiac surgery	11	2	0.12	0.01	0.01

anesthesia" has a betweenness of 11.55, closeness of 0.01 and PageRank value of 0.04.

In TIVA studies, "propofol" was the second most frequently used keyword, being used 137 times. According to the results of the clustering analysis of "propofol" 3. it took place in the cluster and exhibited a high centrality with a betweenness value of 170.18. This word, which has a closeness value of 0.02 and a PageRank value of 0.12, is an important component of studies in the field of TIVA. The keywords found in the same cluster include "remifentanil," "inhalation anesthesia" and "sevoflurane," and these words were used 58, 57 and 42 times, respectively. "Remifentanil" acquires a certain centrality with a betweenness value of 12.52, while "inhalation anesthesia" and "sevoflurane" have lower betweenness values (11.55 and 3.39, respectively).

The Paper Co-Citations analysis of the most influential studies in the literature related to TIVA has divided it into three main clusters (**Figure 4**). In this image, the works in the green cluster, especially Wigmore TJ and Wu ZF publications, are seen in the central location. The blue cluster is represented by authors such as Minto CF and McFarlan CS. The red cluster contains publications by Gupta and Apfel.

Keywords Co-Occurrence analysis of keywords has been performed in the literature related to TIVA (**Figure 5**). This analysis reveals the central positions of keywords such as

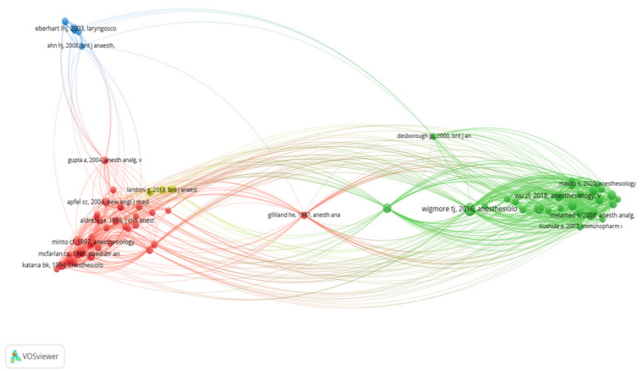

Figure 4. TIVA paper co-citations

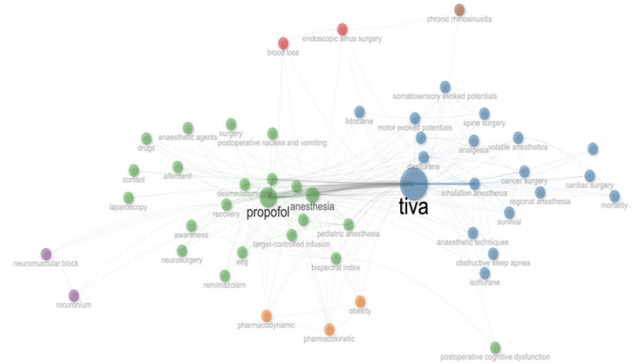

Figure 5. Keywords co-occurrence

"tiva," "propofol" and "anesthesia" in the literature and their connections with various related terms.

In this analysis, the associated words were divided into five different groups. In the blue cluster, the keywords "TIVA" and "propofol" were prominent. In the green cluster, the words "anesthesia" and again "propofol" were included. In the orange cluster, the terms "obesity" and "pharmacodynamic" appeared at the forefront. In the red cluster, the words "endoscopic sinus surgery" and "blood loss" attracted attention. Finally, the words "spine surgery" and "motor evoked potentials" stood out in the gray cluster.

Trend topics analysis has been performed to determine the key terms indicating the trends over time in the literature related to TIVA (**Figure 6**). It is observed that the words obstructive sleep apnea, remimazolam, ketofol, inhalation anesthesia, recovery, cancer surgery, volatile anesthetics, EEG, mortality and pharmacokinetic have come to the fore in the last 5 years.

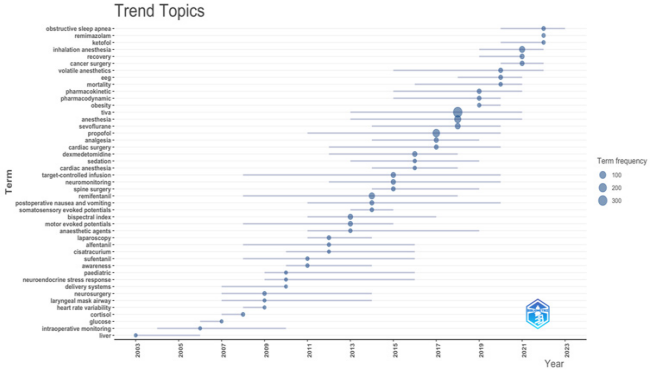

Figure 6. Trend topics

A Sankey diagram has been made in the TIVA literature, segmented at five-year intervals, showing how the key issues have evolved and are related to each other over the past 20 (**Figure 7**). Between the years 2003-2008, the terms 'neuromoniteurization' and 'inhalational anesthesia' came to prominence. Between 2009 and 2013, 'TIVA' appeared as an important theme, and topics such as 'emergence delirium', 'endoscopic sinus surgery' and 'neuromuscular block' attracted more attention. Between 2014 and 2018, 'TIVA' continued as a central theme, while terms such as 'analgesia,' 'cancer surgery,' 'target controlled infusion' and 'cerebral oxygen saturation' came to the fore more. During the years 2019-2023, 'TIVA' is still a subject of attention, but the terms 'surgery,' 'endoscopic sinus surgery,' 'rocuronium,' 'inhalational anesthesia' and 'analgesia' have been used frequently.

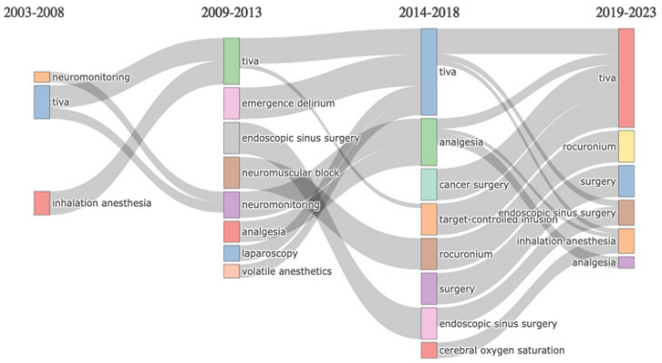

Figure 7. Sankey diagram

Centrality criteria, which are widely used in bibliometric analyses, have played an important role in the analysis of citation networks.[15]

DISCUSSION

There was a significant increase in TIVA-related publications between 2003 and 2023, with the highest number published in 2021. The findings of the bibliometric analysis reveal that there was a strong worldwide interest in TIVA-related research during this period and that this interest was supported not only in academic circles, but also through projects funded by various organizations. The most published countries about TIVA are the USA, China and South Korea, respectively, while the National Defense Medical Center and Tri Service General Hospital attract attention among the leading institutions of these countries. While the most prolific authors include Wu ZF, Lai HC and Lee MS, Wu ZF's top ranking in both publication and citation numbers shows his influential contributions in this field. The most cited journal is Anesthesiology, followed by Anesthesia & Analgesia and the British Journal of Anesthesia. This situation shows that authors prefer journals of American and European origin more for publishing, and these journals also stand out as the journals with the highest citation.

F. Nimmo et al.'s[1] study published in the journal Anesthesia, in order to ensure the safe application of TIVA in the practice of general anesthesia, the study in which Nimmo et al.recommended that all anesthesia and intensive care specialists be provided with education, training and practical experience on TIVA, has been the study that has received the most references in this literature.

The study of Landoni et al.[12] showed that volatile anesthetics in coronary artery bypass grafting surgeries did not make a significant difference on 1-year mortality compared to TIVA, but there was no difference in 30-day mortality and one-year mortality rates. These important findings have caused a wide resonance in the field of study and have attracted attention as the second most cited study in the literature.

A meta-analysis by Yap et al.[13] evaluating the effect of anesthesia technique on long-term outcomes in patients undergoing cancer surgery showed that propofol-based TIVA may have positive effects on recurrence-free survival and overall survival compared to inhalational volatile anesthesia. This study stands out as the third most cited study in the field.

A retrospective study by Wigmore TJ and colleagues[14] found that those who were administered volatile INHA in patients undergoing cancer surgery had a higher risk of death compared to those who received propofol-based TIVA. This study shows that it is frequently referenced with a high PageRank value, plays a key role in the information flow with a high betweenness value, and occupies a central position in the network with a high closeness value, providing quick access to other articles.

Similarly, Wu ZF's[15] study, in which he examined the effect of the type of anesthesia (propofol or desflurane) on survival in colon cancer surgery, reported that propofol anesthesia was associated with better survival compared to desflurane. This study, which is included in the same cluster as the work of Wigmore et al.[14], has also gained an important place in the literature with its high PageRank, betweenness and closeness values and has assumed a central role in the flow of information. In the VOSviewer images created by the Web of Science Paper Co-Citation analysis, it is seen that these studies are grouped in a green cluster and form a strong network of relationships based on studies co-cited in this cluster, consisting of studies conducted in patients with TIVA-related cancer.

Kataria's[16] study, in which she examined the pharmacokinetics of propofol in children using different data analysis methods, revealed that the pharmacokinetics of propofol are best described by a three-compartment model, and weight is an important variable in this model. This study, which is included in the red color cluster in the literature, has been frequently referenced with its high PageRank value and has been placed in a central position in the network with its high closeness value, providing quick access to other articles.[16]

In the study, which aims to create a practical guide for the use of propofol infusion in children, it was emphasized that higher propofol infusion rates are required in children compared to adults. This study reveals that it is frequently referenced in the literature with a high PageRank value, plays a key role in the flow of information with a high betweenness value, and is in a central position in the network with a high closeness value.[17]

In general, it was considered that these studies were included in the same cluster because they focused on pediatric patients.

Keywords co-occurrence network analysis has been used to automatically extract meaningful information from a large set of literature.[18] In the analysis conducted with VOSviewer, it is thought that propofol and its application areas (general anesthetic agents, postoperative nausea, pediatric anesthesia, target controlled infusion) are focused on the green cluster, TIVA, desflurane, inhalational anesthesia and survival studies in cancer surgery are focused on the blue cluster. Pharmacokinetic, pharmacodynamic and obesity studies are thought to be included in the orange cluster, blood loss, endoscopic sinus surgery and chronic rhinosinusitis in the red cluster, neuromuscular block and rocuronium in the purple cluster, and cognitive dysfunction studies after surgery in the light green cluster.

Trend topics analysis is often used to show the change of research topics over time.[19] When we examine the evolution of research areas related to TIVA, it is seen that terms such as "delivery systems", "cortisol" and "neurosurgery" came to the fore in the early 2000s, and terms such as "target-controlled infusion", "propofol", "pharmacokinetic" and "volatile anesthetics" became the focus in later years. Since 2019, it is noteworthy that topics such as "obstructive sleep apnea," "recovery" and "cancer surgery" have been studied with increasing interest.

The Sankey diagram has been used in similar studies to illustrate the evolution of literature over time.[20,21] In our study, topics such as "inhalation anesthesia," "neuromonitoring" and "TIVA" were prominent with the Sankey diagram in the period 2003-2008, while links with areas such as "endoscopic sinus surgery," "emergence delirium" and "neuromuscular block" increased in the period 2009-2013. In the period 2014-2018, orientation to application areas such as "cancer surgery," "target-controlled infusion" and "analgesia" has been observed. In the period 2019-2023, more specific issues such as "rocouronium," "cerebral oxygen saturation" and "surgery" were focused on. We think that the information obtained from trend topics and Sankey diagrams indicates that TIVA research is becoming more specific and focused.

Limitations

Among the strengths of this study is that it offers guidance to studies in this field due to a comprehensive dataset and visualization of data. The limitations are that studies in other databases and in different languages are excluded due to the examination of English-only publications in the WoSCC database. Being a retrospective analysis, it may not fully reflect the latest developments in the field of TIVA. In addition, although bibliometric analyses evaluate scientific productivity, they cannot measure the scientific quality and clinical effects of articles. However, this study provides valuable guidance to scientists who will conduct research in the field of TIVA.

CONCLUSION

This bibliometric analysis has revealed the scientific productivity and research trends in the TIVA literature between 2003 and 2023. During this period, when the number of publications is constantly increasing, it has been seen that the United States is the leader in terms of both publications and citations, while China and South Korea are following the United States. Among the leading institutions, National Defense Medical Center and Tri Service General Hospital

attract attention. The most prolific authors are Wu ZF, Lai HC and Lee MS, and Wu ZF's superiority in both the number of publications and citations shows his important contributions to the field. The most cited journal has been Anesthesiology, and the most prolific journal has been Pediatric Anesthesia.

Trend Topics analysis showed that after 2019, interest in topics such as "obstructive sleep apnea," "recovery," and "cancer surgery" increased, while the Sankey diagram showed that the focus on specific topics such as "rocuronium," "cerebral oxygen saturation," and "surgery" increased during this period.

ETHICAL DECLARATIONS

Ethics Committee Approval
Ethics committee approval was not required because publicly available data was used.

Informed Consent
Informed consent was not required because publicly available data was used.

Referee Evaluation Process
Externally peer-reviewed.

Conflict of Interest Statement
The authors have no conflicts of interest to declare.

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Author Contributions
All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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