ORIGINAL RESEARCH

Bibliometric Analysis of Anesthetic Drugs' Effects on Immune Function- Current Knowledge, Hotspots and Future Perspectives

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Objective: The objective of this study is to conduct a bibliometric analysis of the present status, areas of focus, and upcoming developments in the research of anesthetic drugs and their impact on immune function, along with other related research domains.

Methods: From January 1, 2008 to June 9, 2023, A thorough exploration of anesthetic drug-related literature pertaining to immune function was carried out through the utilization of the Web of Science. The bibliometric analysis was predominantly executed by means of CiteSpace, GraphPad Prism 8.0, and the acquisition of data regarding the country, institution, author, journal, and keywords associated with each publication.

Results: This study analyzed a comprehensive total of 318 publications, consisting of 228 articles and 90 reviews, to determine the publication output of anesthetic drugs on immune function. Notably, China exhibited the highest publication output with (109, 34.28%) articles. Among the institutions analyzed, Harvard University was found to be the most productive with (12, 3.77%) publications. The study findings indicate that Buggy, Donal J (5, 1.57%) and Yuki, Koichi (5, 1.57%) had the highest publication records. Anesthesiology was the most frequently cited journal with a total of (206) citations. The results also revealed that "surgery" was the most frequently used keyword, appearing (48 times), followed by "general anesthesia" (41 times) and "breast cancer" (37 times). The study has identified several current areas of interest, with a particular emphasis on "metastasis", "inflammation", "recurrence", "anesthesia technique", and "induction". It is anticipated that forthcoming research endeavors will concentrate on exploring the impacts of isoflurane, sevoflurane, and ketamine on immune function.

Conclusion: This study provided a thorough analysis of the research trends and developments in investigating the impact of anesthetic drugs on immune function, incorporating pertinent research and collaborative entities such as authors, institutions, and countries.

Keywords: anesthetic drugs, immune function, microenvironment, immunotherapy, targeted therapy

Introduction

The immune system is made up of innate and adaptive components. The innate immune system is comprised of host defenses that have survived evolutionary change through time and respond swiftly to infections without the need for a specific antigen trigger. Adaptive immunity, on the other hand, recognizes specific antigens and then stores antigen-specific immunologic "memory" to protect the host from future shocks brought on by the same pathogen (Figure 1).[1,2] The rapid growth of immunology has drawn increased attention to its impact on human homeostasis, causing the anesthesiology community, both domestically and globally, to examine the effect of anesthesia on immune function more closely.[3] Yokoyama et al found a noteworthy reduction in catecholamine levels and natural killer cell activity in the plasma of participants, concomitant with an elevation in the CD4+/CD8+ ratio, following epidural space or stellate
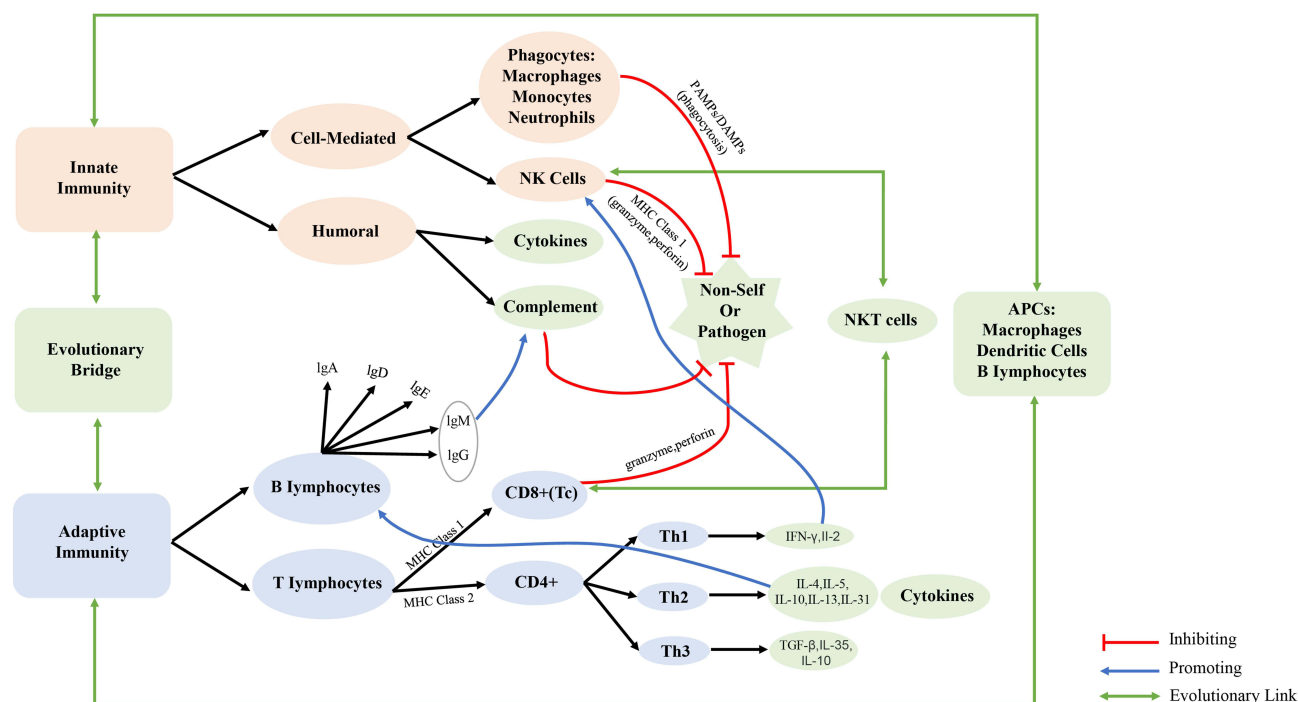
Figure 1 Overview of innate and adaptive immunities including evolutionary links between the two. APCs indicates antigen presenting cells; CD4+, cluster of differentiation 4 positive; CD8+, cluster of differentiation 8 positive; IFN-γ, interferon gamma; IgA, G, D, E, M, immunoglobulin A, G, D, E, M; IL, interleukin; MHC, major histocompatibility class; NK, natural killer; NKT, natural killer T cell; reg, regulatory T cell; Th1, T helper type 1; Th2, T helper type 2; Tc, cytotoxic T cell; TGFβ, transforming growth factor beta.

ganglion blockade.[4] In contrast to the group receiving general anesthesia, the concentrations of tumor necrosis factor TNF-α and interleukin IF-6 exhibited only marginal elevation post-surgery during total hip arthroplasty under regional anesthesia, while the cortisol level demonstrated a significant decrease.[5] In 1981, Shapiro et al[6] discovered the involvement of anesthetics in the progression and metastasis of cancer. Novac et al[7] discovered that NLRP3 and cytokine concentrations in the serum were greater after minimally invasive surgery (MIS) than before MIS in both groups of patients (Midazolam+Fentanyl - Group 1, Propofol+Fentanyl - Group 2). Presently, numerous research groups are directing their attention towards the impact of anesthetic drugs on immune function, postoperative mortality, and recurrence rate of cancer surgery patients.[8–12] A comprehensive investigation of the effect of anesthetic drugs on immune function holds significant implications for perioperative medication in patients.

Bibliometric analyses are widely utilized in academia for the purpose of quantitatively evaluating published research and predicting future trends in scientific inquiry.[13] This type of research employs mathematical and statistical tools to explicitly and statistically analyze the scientific movement, including the interrelationships between countries, institutions, authors, journals, and keywords.[14] Additionally, bibliometric analysis has been applied to mesenchymal stem cells on immunomodulatory functions,[15] single-cell sequencing on immune cells.[16] However, a bibliometric analysis of anesthetics drugs' impact on immune function has not been reported in the literature thus far. In the current study, bibliometric analysis was utilized to assess the research status of anesthetics drugs' impact on immune function over the past a decade, as well as identify the research focus and emerging topics.

Materials and Methods
Literature Searching
The present study utilized the Web of Science (WOS) core collection as the primary database. Search strategy: (((TS = (anesthetics)) OR TS = (narcotics)) OR TS = (narcotics)) OR TS = (narcotic drug)) AND (((TS = (immunity)) OR TS = (immune function)) OR TS = (immunological functioning))). English language articles or reviews published between January 1, 2008 and June 9, 2023 were included in this study.

Method

The articles obtained from the WOS search were exported in plain text format as a "txt" file that encompassed the complete record and references, and was titled "download anesthetics on immune function" and saved. The software tool, CiteSpace V (6.2.R4), was employed to conduct a visual analysis of the literature, compute centrality, and generate co-maps of countries/regions, institutions, authors, published journals, and literature citations. Additionally, co-maps, cluster maps, time maps, and emergent maps of keywords were drawn using the same software tool. The study employs a specific parameter setting, wherein the time partition spans from January 1, 2008, to June 9, 2023, with a time slice of 1 year. The "Pruning" option is utilized to verify "Pathfinder" and "Pruning sliced networks", while the remaining options retain their default settings. The visual atlas employs a node and font size to signify frequency, with the line (Edge) between nodes representing the relationship between them. The thickness of the line indicates the tightness of the relationship, while the color of the node and line signifies the distance of the year, with red denoting closer proximity.

Results

Analysis of Publication Trend

After excluding meeting sets, news, retractions, editorials, and letters, a total of 318 documents were included in this study, comprising 228 articles (71.70%) and 90 reviews (28.30%), as determined through a search of WOS (Figure 2). The annual number of publications in this field has exhibited a steady increase from 2010 to the present, with peaks observed in 2020 (30 articles), 2021 (31 articles), and 2022 (51 articles). These findings suggest that the academic community has shown a significant interest in this field, with a growing number of scholars expected to engage in research in this area in 2023 (Figure 3).
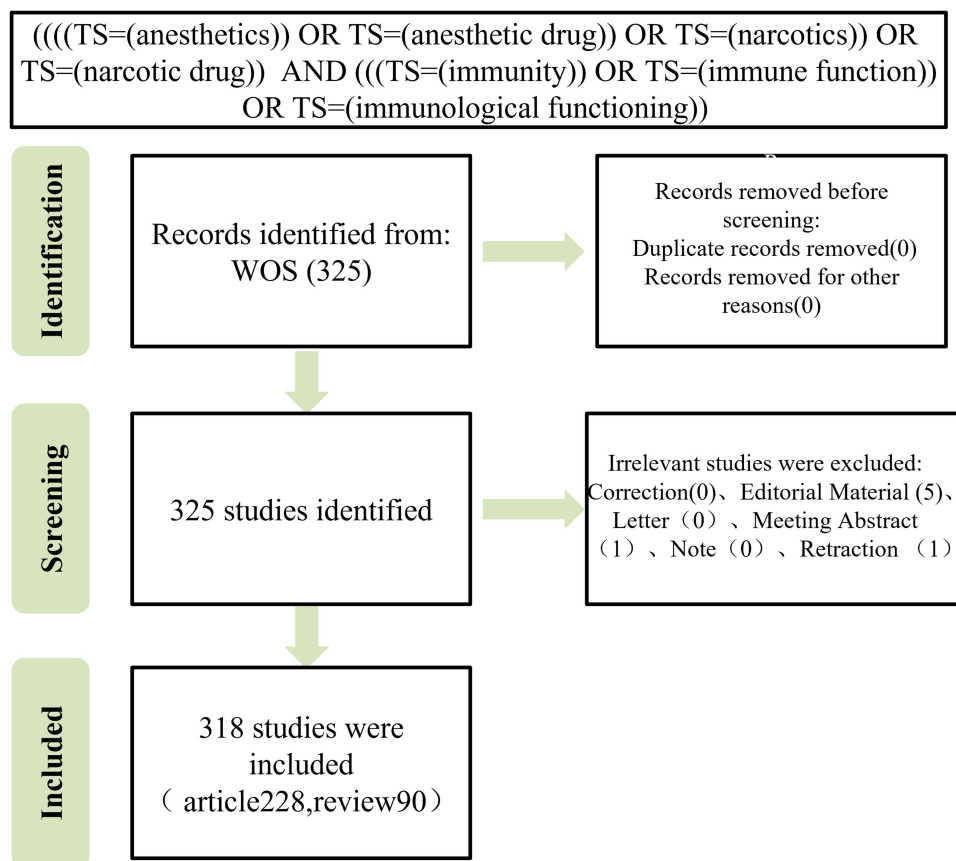

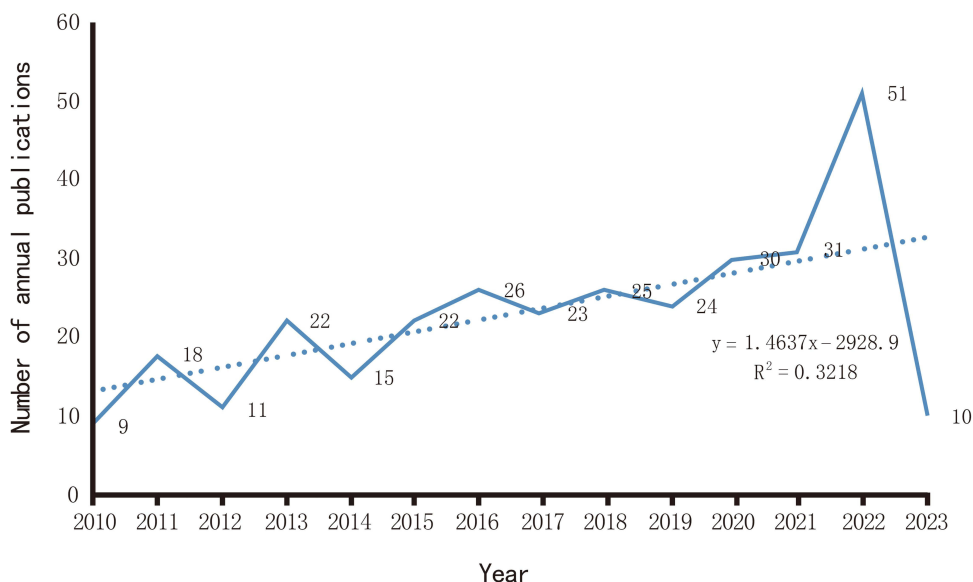**Figure 2** Flowchart depicting the process of publication selection.

$$y = 1.4637x - 2928.9$$
$$R^2 = 0.3218$$

Figure 3 The yearly quantity of publications pertaining to the impact of anesthetic drugs on immune function.

Distribution Analysis of Country/Region, Institution and Author

A comprehensive analysis of the papers published by 46 countries revealed that 82 instances of cooperation occurred among these countries/regions. Notably, China emerged as the most prolific publisher with (109, 34.28%), followed by the United States (71, 22.33%), Japan (22, 6.92%) and the United Kingdom (17, 5.35%). The concept of centrality was employed to gauge the significance of nodes within the network, with a centrality value exceeding 0.1 indicating a higher degree of cooperation and contribution among nodes. Centrality ranked first in the United States (0.68), followed by Spain (0.27) and Turkey (0.23), and fifth in the United Kingdom, indicating that the main research countries in this field are China, the United States and Japan, which cooperate closely. The centrality of China is less than 0.1, indicating that China has a high number of documents issued, but there is a lack of deepening cooperation with international countries, which should be further strengthened in the future (Figure 4A), (Table 1). In this field, 292 institutions published papers and 410 inter-agency collaborations were established. The top five universities, based on the number of papers issued, were Harvard University (12), Boston Children's Hospital (10), Harvard Medical School (9), National Institute of Health and Medicine (Inserm) (7), and Fudan University (6). The National Institute of Health and Medical Research (Inserm) and Florida State University System Center were ranked first with a centrality score of 0.01 (Figure 4B), (Table S1). The authors who issued the highest number of papers were Buggy, Donal J (5), Yuki, Koichi (5), Cata, Juan P (4), Inada, Takefumi (3), and Kubo, Kozue (3). The centrality rankings for all authors were found to be less than 0.1, suggesting that there is a need to improve collaboration between the teams of these authors (Figure 4C), (Table S2).

Analysis of Frequently Cited Journals

This study's literature incorporates sources from 293 journals, with Anesthesiology (206 citations), Anesth Analg (202 citations), and Brit J Anaesth (179 citations) being the most frequently cited. The majority of the top ten journals belong to JCR area II, with a greater number of publishers hailing from the United States and United Kingdom, such as Nature and Lancet. These findings suggest a high level of research quality and proficiency within this field (Figure S1A), (Table S3). As for the top ten cited papers in this field. According to the research conducted by Kim et al,[12] the administration of local anesthetics, specifically lidocaine, results in an increase in the activity of natural killer (NK) cells. Conversely, anesthetics such as propofol and locoregional anesthesia, which mitigate surgery-induced neuroendocrine responses by suppressing the hypothalamic-pituitary-adrenal (HPA) axis and sympathetic nervous system (SNS), may lead to reduced immunosuppression and lower rates of cancer recurrence in comparison to the use of volatile anesthetics and opioids. The findings of Sekandarzad et al[13] suggest that volatile anesthetics may promote tumor formation, while preclinical and emerging clinical evidence
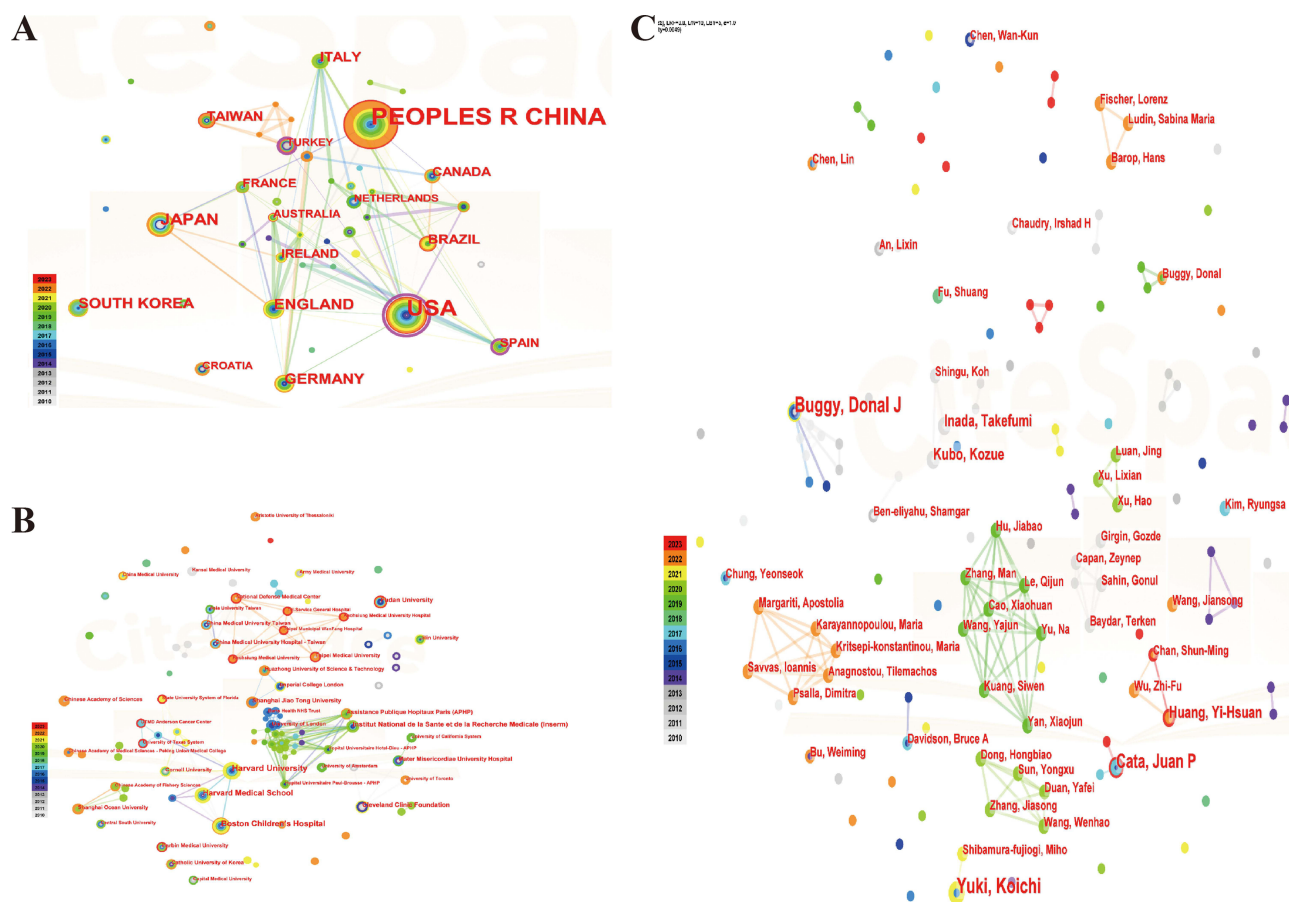
Figure 4 Distribution analysis of countries, institutions and authors. (**A**).co-occurrence map of countries; (**B**). co-occurrence map of institutions; (**C**). co-occurrence map of authors.

suggests that propofol may possess tumor protective properties. The perioperative phase in cancer patients presents a distinctive setting in which surgical stress response can result in immune suppression. The utilization of regional anesthesia techniques, in conjunction with multimodal analgesia consisting of NSAIDs, opioids, and local anesthetics, serves as a crucial component of balanced anesthesia by preventing the pathophysiologic consequences of pain and neuroendocrine stress response. It is imperative to recognize that perioperative anesthesia and analgesia can intensify immunosuppression in immunocompromised cancer patients, wherein the NK plays a pivotal role in anti-tumor immunity. In their study, Cho et al[14] conducted a comparison of the effects of two distinct anesthesia and analgesia techniques on the NK cell cytotoxicity (NKCC)

Table 1 Top 10 Countries/Regions for Publication /Centrality

No.	Publication	Country	Centrality	Country
1	109	PEOPLES R CHINA	0.68	USA
2	71	USA	0.27	SPAIN
3	22	JAPAN	0.23	TURKEY
4	17	ENGLAND	0.07	AUSTRALIA
5	15	GERMANY	0.06	ENGLAND
6	14	SOUTH KOREA	0.06	ITALY
7	11	TAIWAN	0.05	GERMANY
8	11	ITALY	0.05	CANADA
9	11	BRAZIL	0.02	IRELAND
10	10	CANADA	0.02	NETHERLANDS

in patients undergoing breast cancer surgery. The results indicated that the utilization of Propofol anesthesia in conjunction with postoperative ketorolac analgesia yielded a favorable impact on immune function by preserving NKCC, as opposed to the use of sevoflurane anesthesia and postoperative fentanyl analgesia in the same patient population (Figure S1B), (Table 2).

Analysis of Keywords

A quantitative investigation of keyword co-occurrence, which pertains to the manifestation of literature characteristic information, can be effectively utilized through keyword co-occurrence analysis to identify research hotspots within this domain. This study contained a total of 371 keywords, with surgery, general anesthesia, breast cancer, local anesthetics, and immune mechanism function being the top five keywords in frequency (occurring 48, 41, 37, 30, and 27 times, respectively). The top ten keywords in centrality were immune activation (0.22), general anesthesia (0.18), surgery (0.13), immune function (0.13), anesthesia (0.13), breast cancer (0.11), local anesthetics (0.1), local killer cell activity (0.1), anesthesia (0.1), and anesthetics (0.1) (Figure 5A), (Table S4). CiteSpace can cluster keywords based on the log-likelihood ratio algorithm based on keyword co-occurrence. Keyword clustering is a network cluster that forms interconnected network clusters for keywords with similar research topics in the research field, and each cluster is identified by header words that appear at high frequencies in the article. Clusters are numbered starting at 0, and the smaller the number, the more keywords are included. In this study, a cluster module value (Modularity, Q-value) of 0.606 > 0.3 means that the cluster structure is significant; a cluster mean profile value (Silhouette, S-value) of 0.82 > 0.7 means that the clusters are credible. The top 10 clustering labels were "breast cancer", "continuing search", "urinary inflammatory biomarkers neopterin", "tumor micro-environment", "infectious disease", "mitochondrial neutrophil", "subsequent risk", "gilthead seabream", "major spinal surgery", and "concept view". These clusters are closely connected and intertwined, indicating that there is a close connection between the clusters (Figure 5B), (Table S5). The timeline graph utilizes the historical process as its foundation, denoting significant keywords from the past on the axis. The size of the nodes represents their frequency, while the color of the nodes indicates their temporal distance.[27] The visualization illustrates the evolution of important keywords over time.

Table 2 Top 10 Most Cited Publications

| Authors	Title	First Author	Journal	Year	Citations
Biki et al[17]	Anesthetic technique for radical prostatectomy surgery affects cancer recurrence: a retrospective analysis	Biki B	Anesthesiology	2008	760
Snyder et al[18]	Effect of anaesthetic technique and other perioperative factors on cancer recurrence	Snyder GL	Brit J Anaesth	2010	653
Myles et al[19]	Perioperative epidural analgesia for major abdominal surgery for cancer and recurrence-free survival: randomised trial	Myles PS	BMJ-Brit Med J	2011	330
Sessler et al[20]	Recurrence of breast cancer after regional or general anaesthesia: a randomised controlled trial	Sessler DI	Lancet	2019	265
Kim et al[21]	Effects of surgery and anesthetic choice on immunosuppression and cancer recurrence	Kim R	J Transl Med	2018	244
Gupta et al[22]	Reduction in mortality after epidural anaesthesia and analgesia in patients undergoing rectal but not colonic cancer surgery: a retrospective analysis of data from 655 patients in Central Sweden	Gupta A	Brit J Anaesth	2011	208
Stollings et al[23]	Immune modulation by volatile anesthetics	Stollings LM	Anesthesiology	2016	206
Sekandarzad et al[24]	Perioperative anesthesia care and tumor progression	Sekandarzad MW	Anesth Analg	2017	153
Cho et al[25]	The effects of perioperative anesthesia and analgesia on immune function in patients undergoing breast cancer resection: a prospective randomized study	Cho JS	Int J Med Sci	2017	85
Mortezaee et al[26]	Enriched cancer stem cells, dense stroma, and cold immunity: Interrelated events in pancreatic cancer	Mortezaee K	J Biochem Mol Toxicol	2021	55
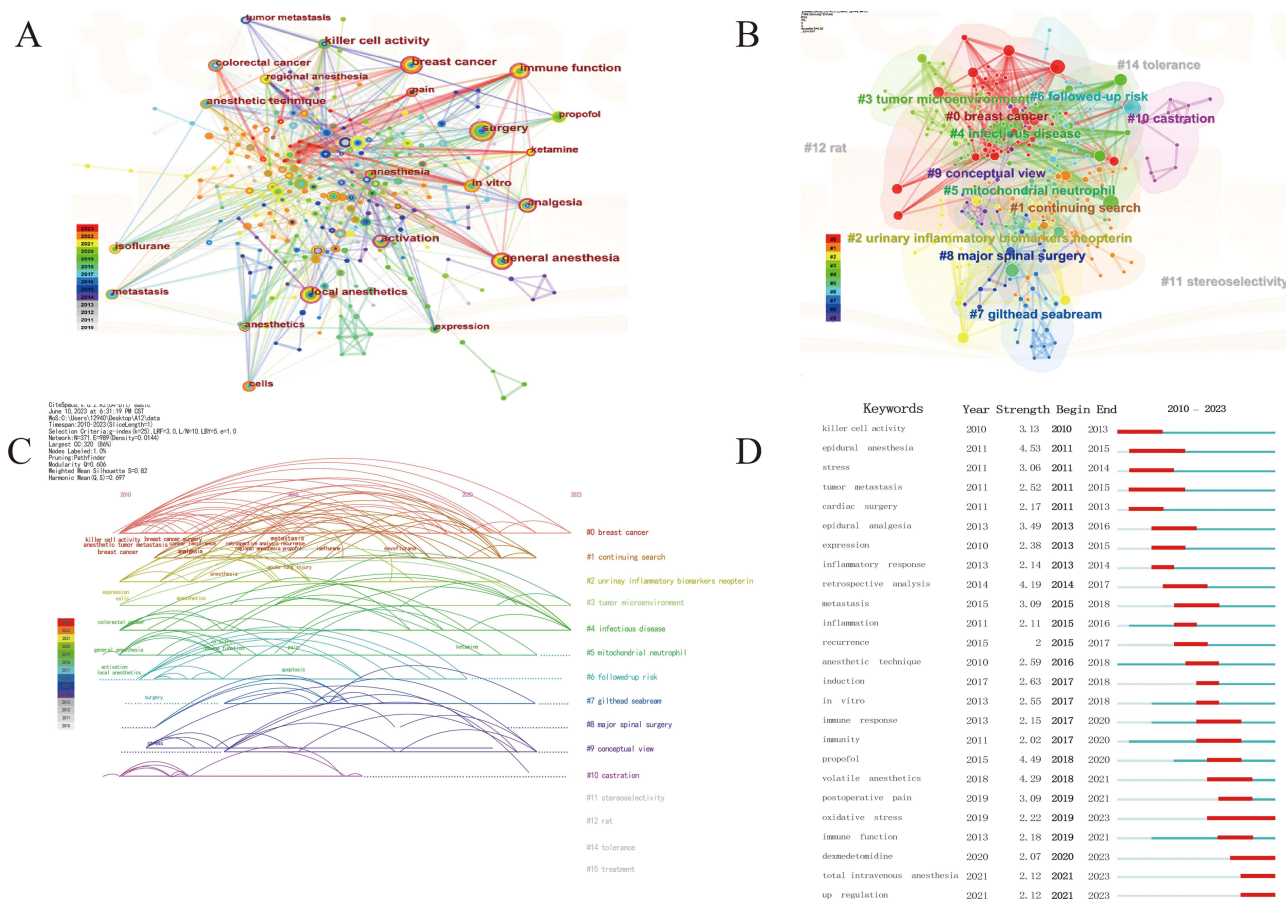
Figure 5 Analysis of keywords. (**A**). Co-occurrence of keywords; (**B**). Clustering map of keywords; (**C**). Timeline graph of keywords; (**D**). Keyword burst detection of the top 25 keywords with the strongest emergent strength.

Between 2001 and 2015, numerous researchers conducted comprehensive and systematic investigations of this disease from various perspectives. The mechanism of action pertains to the activity of killer cells, impact on immune function, and apoptosis. The disease is centered on the metastasis and recurrence of breast and rectal cancer, while the side effects are associated with acute lung injury resulting from the use of local anesthetic propofol. Symptoms, on the other hand, are related to the stress response triggered by anesthesia technique, leading to painless or painful surgery. Notably, research hotspots from 2016 to the present encompass the effects of isoflurane, sevoflurane, and ketamine on immune function (Figure 5C). An emergent word is a term that suddenly gains prominence within a specific time frame and can be utilized to identify fluctuations in subject headings, keyword usage, and trends.[28] Notably, the research frontiers from 2010 to 2015 encompassed a range of topics, including "killer cell activity", "epidural anesthesia", "stress", "tumor metastasis", "cardiac surgery", "expression", "inflammatory response", and "retrospective analysis". In contrast, the research frontiers from 2016 to 2023 focused on areas such as "metastasis", "inflammation", "recurrence", "anesthesia technique", "induction", "in vitro experimentation", "immune response", "propofol", "volatile anesthetics", "postoperative pain", "oxidative stress", "immune function", "dexmedetomidine", and "total intravenous anesthesia". (Figure 5D).

Discussion

The immune system is responsible for identifying self and foreign antigens and eliminating harmful foreign antigens from the body. The immune-inflammatory response comprises two primary components: innate and adaptive immune responses. Innate immunity serves as the initial line of defense against foreign pathogens and functions primarily through the non-specific, rapid recognition, binding, and elimination of foreign pathogens by immune cells, including natural killer (NK) cells, monocyte-macrophages, and neutrophils.[29] Simultaneously, monocytes, macrophages, and dendritic

cells function as proficient antigen presenting cells. Upon pathogenic invasion, these cells present foreign antigens' MHC-class II molecules to helper T cells, thereby stimulating their activation and eliciting immune responses.[30] Through our bibliometric analysis, we found that China exhibited the highest publication output in the field of anesthetics and immune function research, with a total of 109 articles (34.28%), followed by the United States (71, 22.33%) and Japan (22, 6.92%). Among the institutions analyzed, Harvard University was found to be the most productive, with 12 publications (3.77%), followed by Boston Children's Hospital with 10 publications (3.14%). The individuals with the most prolific publication records were Buggy, Donal J (5, 1.57%) and Yuki, Koichi (5, 1.57%), with Cata, Juan P (4, 1.26%) following closely behind. In terms of citation frequency, Anesthesiology was the most frequently cited journal, with a total of 206 citations (n=206), trailed by Anesth Analg (202) and Brit J Anaesth (179). The study revealed that the term "surgery" was the most commonly utilized keyword, appearing 48 times, followed by "general anesthesia" (41 times) and "breast cancer" (37 times). The investigation identified various contemporary topics of interest, with a primary focus on "metastasis", "inflammation", "recurrence", "anesthesia technique", and "induction". Subsequent research endeavors are expected to concentrate on the impact of isoflurane, sevoflurane, and ketamine on immune function.

The precise mechanism by which anesthetic drugs modulate immune function remains elusive. Various anesthetics have been shown to exert immunosuppressive effects via distinct pathways. The administration of local anesthetics, such as lidocaine, through epidural blockade may result in a partial inhibition of sympathetic activity, which could potentially impact the distribution of lymphocyte subsets and the activity of NK cells.[31] The disruption of signal transduction pathways may occur through various means, including the interaction between IL-6 secreting monocytes and opioid receptors present on their surface. Binding of opioids to these receptors results in a reduction in intracellular cAMP levels, which may contribute to the secretion of IL-6. Additionally, some scholars propose that morphine can exert both direct and indirect effects on immunocompetent cells by activating μ_3 opioid receptor subtypes, leading to the release of nitric oxide.[32] The immunomodulatory effects of Tramadol are primarily attributed to the activation of central mono-amine neurotransmitters through the regulated inhibition of serotonin and norepinephrine reuptake by central neurons.[33] Lipid-soluble inhalation anesthetics, namely halothane, isoflurane, and sevoflurane, have been observed to impact the membrane structure of polymorphonuclear leukocytes (PMNs), resulting in a reduction of their functionality. This effect is attributed to the weakening of the expression of the adhesion molecule CD11b and the inhibition of PMN adhesion to endothelial cells.[34] The regulation of amino acid metabolism by Etomicol and Thiopental has been observed to modify amino acid turnover in PMN cells, thereby exerting inhibitory effects.[35] Furthermore, the modulation of intracellular calcium concentration through distinct pathways by Ketamine, Thiopental Sodium, and Etomidate, achieved by adjusting calcium concentration, may also impact immune function.[36]

Local Anesthetics

Lidocaine is an amide local anaesthetic that was originally used as an antiarrhythmic agent intravenously. It was once proposed that intravenous lidocaine had an analgesic effect that could be useful in perioperative circumstances. Although lidocaine infiltration lowers the discomfort of several emergency department treatments, the impact of topical lidocaine is controversial.[37] At the same time, local anesthetics have the ability to impede numerous immunocompetent cell functions, including the suppression of NK cell activity, hindering chemotaxis, adhesion, phagocytosis, and respiratory burst of granulocytes. The incubation of NK cells with whole blood cells containing local anesthetics such as lidocaine, bupivacaine, and ropivacaine results in a significant inhibition of NK cell activity.[38] The reduction of cancer cellular migration and proliferation has been attributed to the interference with microtubular extension, cell aggregation, and reattachment by both ester- and amide-linked local anesthetics.[39]

Nonsteroidal Anti-Inflammatory Drugs

Nonsteroidal anti-inflammatory drugs (NSAIDs) are commonly utilized during the perioperative phase to provide analgesic effects and reduce opioid consumption. Additionally, they are frequently prescribed for their antipyretic, antithrombotic, anti-inflammatory, and other therapeutic benefits.[40] Rezabakhsh et al[41] highlighted the well-known effects of aspirin administration (such as inflammatory and immunological responses) in a variety of non-cardiovascular illnesses, particularly in anesthesiology. The inhibition of COX enzymes results in a reduction of both

COX-1 and COX-2 expression. The upregulation of PGE2, which is caused by the overexpression of COX-2, leads to an increase in the immunosuppressive IL-10 and a decrease in the antiangiogenic IL-1.[42]

Opioids

Opioids are acknowledged as immunosuppressive agents, with morphine serving as a prototypical example. Extended exposure to high doses of morphine can impede the proliferation of natural killer cells, T and B lymphocytes, and diminish the production of cytokines, including IL-2, IL-4, and IL-6.[43,44]

Benzodiazepines

Benzodiazepines exhibit immunomodulatory effects that are characterized by both proinflammatory and anti-inflammatory actions. These effects are observed to be dualistic in nature, with some actions promoting the immune response against infections while others inhibiting it. The activation of peripheral-type receptors is believed to modulate various immune functions such as phagocytosis, chemotaxis, cytokine production, T-cell maturation, and oxidative burst generation.[45]

Volatile Anesthetic Agents

The innate immunity is known to be affected by the volatile agent, isoflurane, sevoflurane, and halothane, as evidenced by their ability to reduce the cytotoxicity of NK cell.[46,47] Isoflurane and sevoflurane have been observed to inhibit the release of IL-1β and tumor necrosis factor α (TNF-α) from human peripheral mononuclear cells, which encompass T and B lymphocytes as well as NK cells, in response to tumor cells in clinical studies. This mechanism may potentially augment tumorigenesis.[48,49] Soleimanpour et al[50] concluded that despite the unfavorable effects of inhalational haloge-nated anesthetics (particularly halothane) on hepatic patients, they should be used when necessary. The impact on all systems, especially the immune system, must be evaluated, and appropriate preparations must be made. Yong et al[51] found that sevoflurane successfully lowered the expression level of CD4+CD25+FOXP3+ Treg cells in the peripheral blood of T2 and T3 patients with gastric cancer, giving a theoretical basis for the selection of surgical anesthetics for patients with gastric cancer.

Intravenous Anesthetics

Numerous studies have been conducted on the impact of intravenous anesthetic drugs on immunity, with particular emphasis on their effects on PMNs and cytokines.[52–54] In emergency procedural sedation, ketamine/propofol combo (ketofol) has less respiratory adverse effects than propofol alone.[55] Yu et al[56] Found that propofol may suppress T cells less effectively than sevoflurane in children with severe mycoplasmal pneumonia (SMPP). Furthermore, propofol may have a lower impact on Th cell development into Th1 cells and a better Th1/Th2 ratio preservation than sevoflurane. Subsequent investigation utilizing a human cell model revealed that propofol did not impede NK cell-mediated cytotoxicity, in contrast to sevoflurane and isoflurane which hindered LFA-1. This observation implies that although propofol hinders macrophage function, its sparing effect on NK cells may confer advantages in the management of viral and malignant conditions during the perioperative period.[46] In vitro studies have demonstrated that Etomidate has the ability to hinder eosinophil chemotaxis, thereby impeding cell-mediated innate immunity.[57] Liu et al[58] conducted a comprehensive analysis, which revealed that ketamine hinders neutrophil chemotaxis through the suppression of endothelial adhesion molecule expression in both human and rat models. In a systematic review and meta-analysis, Soleimanpour et al[59] and they discovered that dexmedetomidine (DEX) injection prior to anesthesia may have a protective effect on liver and intestinal immune function after hepatectomy with vascular occlusion. Wang et al conducted a review and meta-analysis which revealed that DEX administration results in an increase in the quantity of NK cells, B cells, and CD4+ T cells. While the count of CD8+ T cells decreased and the CD4+/CD8+ ratio increased, the Th1/Th2 ratio also significantly increased, indicating the preservation of cell-mediated immunity.[60] The regulation of cytokines by anesthetic drugs is a complex topic, with numerous and sometimes contradictory reports. This is due to the intricate nature of the inflammatory response and immune regulation mechanisms within the body. However, it is anticipated that further research will lead to a more cohesive understanding of this phenomenon.

It is evident from the available literature that researchers exhibit significant concern regarding the impact of anesthetic drugs on the immune function. This concern is aimed at facilitating the rational and effective application of diverse anesthetic drugs to different patients, with the ultimate goal of achieving optimal therapeutic outcomes. However, certain experimental findings exhibit dissimilarities or even contradictions, which could be attributed to variances in the design of basic and clinical studies, the selection of distinct tumor types, limitations of observation indicators, imbalanced overall immunity, and disparities between animal models and humans. Hence, further comprehensive investigations are imperative to unveil the correlation between anesthetic agents and immune response, and to provide guidance for perioperative pharmacotherapy in patients with clinical neoplasms and immune deficiencies.

Strengths and Limitations

This research presents the first bibliometric analysis investigating anesthetic's impact on immune function, which includes an overview, advancements, highlights, and trends. It is recommended that researchers prioritize the most recent and highly cited references and hotspots. Nevertheless, this bibliometric evaluation has certain limitations. Firstly, a time lag may have led to the exclusion of recently published articles. Secondly, the study solely examined papers from the WoS Core Collection, which may have restricted the comprehensiveness of our findings. Finally, the presence of subjective bias in data interpretation was discovered to be inherent. Nonetheless, this investigation can still function as an exemplification of the comprehensive condition and prevailing tendency of this research topic.

Conclusions

Research on the effects of anesthetics on immune functions has progressed and revealed a worldwide pattern. China and Harvard University have been identified as the most productive country and institution, respectively. Anesthesiology has emerged as the most frequently cited journal, while Buggy, Donal J has been recognized as the most productive author. The keyword "surgery" has been the most commonly utilized. Future research endeavors are anticipated to focus on the impact of isoflurane, sevoflurane, and ketamine on immune function.

Data Sharing Statement

All data analyzed were included in this paper; further requests can be consulted and data can be obtained from the correspondent author.

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Disclosure

The authors declare no competing interests.

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