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Immunomodulatory Effects of General Anesthetics: A Systematic Review of their Impact on Immune Response and Perioperative Outcomes / Efectos Inmunomoduladores de los Anestésicos Generales: Una Revisión Sistemática sobre su Impacto en la Respuesta Inmunológica y los Resultados Perioperatorios

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ABSTRACT

Introduction: general anesthetics play a crucial role in surgical procedures by ensuring analgesia, hypnosis, and muscle relaxation. However, their influence on the immune system, especially in perioperative and oncological contexts, requires further exploration. Although it has been known for over a century that anesthetics can affect the immune system, their specific mechanisms are still not fully understood. It is postulated that volatile anesthetics, such as sevoflurane and isoflurane, may be associated with immunosuppression, decreasing NK cell activity and reducing the production of proinflammatory cytokines; while intravenous anesthetics, such as propofol, through their antioxidant properties, may better preserve immune function. Recent studies, even in minimally invasive surgeries that do not involve high surgical stress, show alterations in inflammasomes such as NLRP3 and in proinflammatory cytokines such as IL-10 and TNF-α, demonstrating that these drugs exert specific immunomodulatory effects. This project aims to analyze how these agents modulate the immune response and their impact on clinical outcomes, such as postoperative infections and tumor recurrence. While studies present somewhat conflicting results, partly due to the wide variety of variables in the subjects (such as the use of NSAIDs as adjuvants, different types of cancer, or the use of beta-blockers), extensive randomized clinical trials point to a trend in how anesthetics act and their consequences on the immune system.
Objective: the overall objective is to determine the immunomodulatory effects of general anesthetics on the immune response and perioperative outcomes of surgical and oncological patients. Specific objectives include analyzing the immunological differences between volatile and intravenous anesthetics, evaluating their impact on immune cells and cytokines, and identifying clinical implications related to infectious complications and tumor recurrence.
Method: a systematic search will be conducted in scientific databases such as Scopus, Web of Science, and PubMed, using keywords and Boolean operators to identify relevant studies. The terms will include: “general anesthesia,” “immune response,” “volatile anesthetics,” “propofol,” “cancer recurrence,” and “tumor microenvironment.” Articles evaluating the impact of general anesthetics on immunological parameters (such as NK cells and cytokines) and clinical outcomes (such as infectious complications and tumor recurrence) will be analyzed. The collected data will be synthesized to establish patterns and significant differences among the various types of anesthetics.

Keywords: General Anesthesia; Immunomodulation; Oncologic Surgery; Propofol; Perioperative Immunity.

RESUMEN

Introducción: los anestésicos generales desempeñan un rol crucial en procedimientos quirúrgicos al garantizar analgesia, hipnosis y relajación muscular. Sin embargo, su influencia en el sistema inmunológico, especialmente en contextos perioperatorios y oncológicos, requiere mayor exploración. Aunque se sabe desde hace más de un siglo que los anestésicos pueden afectar el sistema inmune, sus mecanismos específicos aún no se comprenden completamente. Se postula que los anestésicos volátiles, como el Sevoflurano e Isoflurano, podrían estar asociados con inmunosupresión, disminuyendo la actividad de células NK y reduciendo la producción de citoquinas proinflamatorias; mientras que los intravenosos, como el Propofol, mediante su propiedad antioxidante, podrían preservar mejor la función inmunológica. Estudios recientes, incluso en cirugías mínimamente invasivas, que no implican un elevado estrés quirúrgico, muestran alteraciones en inflamasomas como NLRP3 y en citoquinas proinflamatorias como IL-10 y TNF-α, evidenciando que estos fármacos ejercen efectos inmunomoduladores específicos. Este proyecto tiene como propósito analizar cómo estos agentes modulan la respuesta inmune y su impacto en los resultados clínicos, como infecciones postoperatorias y recurrencia tumoral, que, si bien los estudios presentan resultados un tanto conflictivos, en parte a la gran variedad de variables que presentan los sujetos (como uso de AINEs como coadyuvantes, diferentes tipos de cánceres, o uso de beta bloqueantes) los extensos ensayos clínicos aleatorizados nos orientan a una tendencia de cómo los anestésicos actúan, y sus consecuencias en el sistema inmune.
Objetivo: el objetivo general será determinar los efectos inmunomoduladores de los anestésicos generales en la respuesta inmunológica y los resultados perioperatorios de pacientes quirúrgicos y oncológicos. Los objetivos específicos incluirán analizar las diferencias inmunológicas entre anestésicos volátiles e intravenosos, evaluar su impacto en células inmunes y citoquinas, e identificar implicancias clínicas relacionadas con complicaciones infecciosas y recurrencia tumoral.
Método: se realizará una búsqueda sistemática en bases de datos científicas como Scopus, Web of Science y PubMed, utilizando términos clave y operadores booleanos para identificar estudios relevantes. Los términos incluirán: “general anesthesia”, “immune response”, “volatile anesthetics”, “propofol”, “cancer recurrence” y “tumor microenvironment”. Se analizarán artículos que evalúen el impacto de los anestésicos generales en parámetros inmunológicos (como células NK y citocinas) y en resultados clínicos (como complicaciones infecciosas y recurrencia tumoral). Los datos recopilados se sintetizarán para establecer patrones y diferencias significativas entre los diferentes tipos de anestésicos.

Palabras clave: Anestesia General; Inmunomodulación; Cirugía Oncológica; Propofol; Inmunidad Perioperatoria.

INTRODUCTION

Objectives

General Objective

To describe the scientific evidence on the immunomodulatory effects of general anesthetics and their impact on the perioperative management of surgical and oncology patients.

Specific Objectives

- To describe infectious recurrences in postoperative cases of patients anesthetized

with intravenous and/or volatile anesthetics.

- To describe and analyze tumor recurrence and/or environments that favor metastasis in patients anesthetized with intravenous and/or volatile anesthetics.
- To describe the immunomodulatory effects of general anesthetics and the preference for using a particular type of drug according to its immune effect and the patient's clinical context.

General anesthetics have revolutionized modern medicine by enabling surgical procedures that would otherwise be unfeasible or traumatic for the patient. Since their introduction in the 19th century, their development has improved safety and comfort during surgery by inducing a controlled state of unconsciousness, analgesia, and muscle relaxation. Currently, the choice of an anesthetic depends on multiple clinical and surgical factors, as well as the patient's profile. Although their main objective is intraoperative anesthetic management, it is increasingly recognized that their influence extends beyond mere loss of consciousness, impacting physiological processes such as inflammation, the immune response, and, in some instances, even tumor progression.

The influence of general anesthetics on the immune system has generated particular interest in recent decades, given that they can modulate key immune responses, both innate and adaptive.[1,2] This relatively recent interest is growing every day, providing new studies and clinical trials that help us better understand their role in immunomodulation.[3,4,5,6] General anesthesia can be administered with inhaled anesthetics, intravenously, or through a combination of both. These forms of administration have been shown to modulate the immune system, affecting its regulatory balance, particularly in perioperative settings.[7,8,9,10] In this context, the effects of general anesthesia, accompanied by surgical stress, potential transfusions, postoperative pain, hyperglycemia, and hypothermia. May suppress immunity and activate the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system,[11] where general anesthetics affect both innate and adaptive immunity (including cellular and humoral mediators), influencing the expression and secretion of inflammatory mediator genes.[12] In particular, the use of so-called volatile (inhaled) anesthetics such as Sevoflurane, isoflurane, or desflurane, especially in low doses, affects the populations of different cells of both the innate and adaptive immune systems, such as neutrophils or T lymphocytes, where a decrease in specific values is observed 2 hours after administration and a significant increase 24 hours later.[13] General anesthetics play a fundamental role in the response, concentrations, and relationships of different cells and cytokines in the immune system. The literature reports immunomodulatory mechanisms of general anesthetics:

- Volatile anesthetics or IA (Inhaled Anesthetics): Agents such as sevoflurane and isoflurane are associated with immunosuppression, decreasing NK cell activity, and reducing theproduction of proinflammatory cytokines (IL-6, TNF-α) (07_revisionmba).[14]
- Intravenous anesthetics or TIVA (Total Intravenous Anesthesia): Propofol, widely used in total intravenous anesthesia (TIVA), has antioxidant and immunoprotective properties, better preserving immune function (07_revisionmba).

In the oncological context, anesthetics can influence disease progression, favoring contexts with greater susceptibility to specific treatments or decreasing tumor recurrences. For example, volatile anesthetics have been shown to increase tumor angiogenesis and decrease cell apoptosis. In contrast, some intravenous anesthetics (such as propofol) may reduce these effects, favoring a less aggressive tumor microenvironment and, therefore, a more susceptible tumor to different lines of treatment.[6] On the other hand, there are retrospective and prospective clinical studies

that explored the influence of anesthesia on tumor recurrence, suggesting that the use of regional anesthesia or intravenous anesthetics could preserve immune function.

And improve long-term oncological outcomes. Although the evidence is not yet entirely conclusive, the current results are highly suggestive.[1] Despite the immunological changes that both TIVA and IA anesthetics can induce,[15,16,17,18,19] the patient's clinical, environmental, and etiological context would be key indicators of the type of anesthetic we should choose for a surgical procedure, taking into account the patient's immunocompetence or immunocompromise.[20,21] The objective of this study is to explore and compare, based on a review of the current literature, the immunomodulatory effects of general anesthetics, with special emphasis on their implications in the perioperative oncology context and in the modulation of cellular immunity.[22,23]

METHOD

Study design

Given the abundant scientific literature on the subject, the research results will be synthesized through a systematic review. If the quantitative data are sufficiently standardized, a meta-analysis will be performed.

This systematic review will be conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.

Study population

Scientific articles addressing the immunomodulatory effects of general anesthetics and their impact on the perioperative management of surgical and oncology patients between January 2000 and November 2024 will be included.

Inclusion Criteria

- Original articles classified as IMRyD that develop cohort studies, clinical trials, other systematic reviews, and meta-analyses.

Exclusion Criteria

- Review articles, scientific letters/letters to the editor, clinical cases, editorials, original articles corresponding to preclinical studies, and observational studies.

Selection and Sample Size

A search will be conducted in PubMed, Scopus, and Web of Science from January 2000 to March 2025. Abstracts of cohort and case-control studies evaluating the immunomodulatory effects of general anesthetics and their impact on the perioperative management of surgical and oncology patients will be selected.

Operational description of variables

The articles will analyze, as main variables, indicators of clinical improvement and disease remission (both clinical and laboratory).

Resources required

A notebook and a desktop computer with an internet connection will be used to conduct this research, with access to the Scopus, Web of Science, and PubMed databases via a paid

subscription.

Theoretical framework

General anesthetics play a crucial role in modern medicine, allowing complex surgeries to be performed by inducing unconsciousness, analgesia, and amnesia. However, as already mentioned, their use is also associated with side effects on the immune system, which can significantly influence postoperative recovery.

And patient prognosis. General anesthetics affect both types of immunity. Studies have shown that these agents can alter immune cell function, cytokine production, and the balance between proinflammatory and anti-inflammatory responses. Surgical stress increases the body's stress response, reduces immune system effectiveness, and promotes the release of inflammatory mediators. In turn, in healthy patients and short surgeries, trauma and surgical stress are primarily responsible for changes in cytokines, even more so than anesthetics, while in immunocompromised patients, prolonged administration of anesthetics can aggravate their clinical condition, as it alters the Cytokine balance. An alteration in this balance implies a decrease in the CD4+/CD8+ T lymphocyte ratio, which reduces the cytotoxic capabilities of these cells to destroy pathogens or cancer cells (although the latter is more the territory and function of NK cells). In the context of certain cancers (e.g., gastric cancer), the adaptive immune response is compromised in terms of both count and functionality. In a setting where surgery is therapeutic, the effects of surgical stress on the immune system mentioned above should not be underestimated, as general anesthetics inhibit hypothalamic signals. An alternative (where possible) is epidural anesthesia in oncological contexts to reduce this "down-regulation," favor the immune system, and reduce surgical stress. The reduction of pro-inflammatory cytokines, the maintenance of cytokine balance, and the maintenance of the aforementioned immune cell counts promote better therapeutic outcomes and prognoses for patients, especially in Immunocompromised patients, where the aim is to avoid further compromising the patient's pro-inflammatory and general immune status.[19,23]

General anesthetics modulate the secretion of key cytokines, including interleukin-6 (IL-6), tumor necrosis factor alpha (TNF-α), and interleukin-10 (IL-10), among others. For example, inhaled anesthetics such as sevoflurane can reduce the production of pro-inflammatory cytokines, while other agents such as propofol have anti-inflammatory properties that promote the production of IL-10.

Different anesthetics have varying effects on immune cells. For example:

- Neutrophils: anesthetics can alter the chemotaxis and phagocytosis of these cells, affecting their ability to respond to infections.
- T and B lymphocytes: the proliferative activity of these cells may decrease after exposure to specific agents, compromising adaptive immunity.
- NK cells: these cells are susceptible to anesthetics, with reductions in their cytotoxic activity associated with the use of drugs such as opioids.

Regulation of TLR Receptors and ncRNAs

Toll-like receptors (TLRs) play a key role in innate immunity by recognizing pathogen-associated molecular patterns (PAMPs) and damage-associated molecular patterns (DAMPs). In situations such as surgery, infection, or even ischemia, these receptors are activated and can trigger systemic inflammatory responses. It has been shown that general anesthetics can influence these pathways, mainly by regulating non-coding RNAs (ncRNAs), such as microRNAs

and lncRNAs. A specific example is sevoflurane, which modulates miR-181a expression, which is directly involved in TLR4 signaling.[19] This interaction can have both positive and negative effects on the immune response and outcomes after surgery. On the one hand, it can decrease the production of proinflammatory cytokines such as TNF-**α** or IL-6, which are often associated with tumor progression, as they promote processes such as the migration or survival of malignant cells. This action could improve the tumor microenvironment and reduce the risk of excessive inflammation. However, the other side must also be considered. If this modulation is excessive, it could overly suppress the immune response, making it challenging to eliminate tumor cells that remain circulating or are released during surgery.

Comparison of Anesthetics

Inhaled Anesthetics

- Sevoflurane: reduces macrophage activation and the production of inflammatory cytokines such as IL-6 and TNF-α.[23] Still, it can also induce inflammatory neuronal injury in some contexts and, in turn, may have a proangiogenic effect, increasing HIF-1α expression.
- Isoflurane: similar to sevoflurane, it inhibits NK cell cytotoxicity and decreases ischemia-reperfusion-induced inflammation.
- Desflurane: reduces lymphocyte concentration, the CD4+/CD8+ ratio, and the total percentage of CD4+ cells 2 hours after administration, although there is a slight increase in all of these 24 hours later.[13]

Intravenous anesthetics

- Propofol: may have fewer immunosuppressive effects, as it has marked anti-inflammatory effects, with reductions in TNF-α expression and increases in IL-10. In addition, it enhances NK cell activity under specific conditions.[1]
- Ketamine: inhibits neutrophil migration and macrophage function, as well as CRP and TNF-α, but may induce proinflammatory effects at high doses.[21]

RESULTS

During surgical stress, cellular immunity is suppressed, leading to decreased activity of Th1 cells (a subpopulation of T lymphocytes) and NK cells. Anesthetics contribute to this immunosuppression by altering the balance between proinflammatory and anti-inflammatory cytokines.[2,7] Considering these factors, the debate over TIVA vs. IA is critical when performing surgical therapy. Propofol may have protective effects against cancer cells and metastasis, as it attenuates immunosuppression by maintaining NK cell and CD8+ T lymphocyte function; improvements in anesthetic techniques in recent years further support these effects.[12,24] On the other hand, recent research has shown that anesthetics can modulate immune signaling through specific molecular mechanisms, such as the regulation of microRNAs and lncRNAs involved in the TLR pathway, as we have already explored. This interaction suggests an active role for certain anesthetics in epigenetic regulation of innate immunity, with potential clinical benefits in the perioperative setting.[19]

As already mentioned, propofol has a more favorable immunomodulatory profile than an intravenous anesthetic. Ketamine's effect on the immune system inhibits NK cells and has a proapoptotic effect on T lymphocytes, ergo it is not Recommended for oncology;[22] however, in infectious contexts, Ketamine can be very useful. Based on the fact that Propofol is recommended (for all the reasons mentioned above) in both surgical and infectious oncological cases, Ketamine

has a faster and more potent effect in controlling excessive systemic inflammation (by decreasing TNF-α, IL-6, and NO), making it an excellent anti-inflammatory and very useful in cytokine storms, and therefore the drug of choice in severe infectious and/or inflammatory contexts. However, it is suggested that its effects can be a double-edged sword, given that in specific contexts, such as immunocompromise or severe/advanced sepsis, its immunomodulatory effects may not yield optimal results, where Propofol would again be the intravenous anesthetic of choice.[3,6,22]

Opioid-Free Anesthesia (OFA)

Other studies suggest that opioid-free anesthesia (OFA) has gained attention due to the immunosuppressive effects of traditional opioids. Opioids act on multiple areas of the immune system, such as leukocytes, macrophages, mast cells, lymphocytes, and NK cells, where they tend to have.

Clinical Implications and Preferences for Use

Anesthetic-induced immune modulation may influence cancer progression. For example, reduced NK cell cytotoxicity is associated with an increased risk of metastasis in cancer patients. The use of propofol as an intravenous anesthetic in patients undergoing gastric cancer resection, it was associated with better preservation of immune function in the immediate postoperative period, compared to inhaled agents. In particular, lower PD-L1 (programmed death-ligand 1) expression and better recovery of CD8+ T lymphocytes were reported, suggesting less immunosuppression and a potentially favorable impact on antitumor surveillance. These findings reinforce the hypothesis that the type of anesthesia may influence the tumor microenvironment and long-term oncological outcomes.[25]

In the context of critical illnesses such as COVID-19, the ability of anesthetics to modulate inflammation may have significant implications for patient prognosis. As mentioned above, the clinical context is of vital importance for the selection of anesthetics in patients undergoing surgery or in infectious conditions, where the immune response is excessive, or the infection itself causes Immunosuppression, as well as to develop specific therapeutic strategies that improve recovery and outcomes across various clinical contexts. We therefore demonstrate that, as the best overall option, propofol is the best anesthetic for any surgical procedure and in infectious contexts. Sevoflurane: this translates into less immune suppression, less tumor promotion, and greater lymphocyte preservation, which is especially important in cancer patients. This occurs through the reduction of IL-6, inhibition of COX-2, and an increase in IFN-γ and IL-10 (in a protective, non-immunosuppressive context); therefore, we could say that Propofol protects against postoperative immune dysfunction, preserves lymphocytes, and thus plays a key role in the development of the disease.[1,10] On the other hand, Sevoflurane suppresses NK cell and T lymphocyte function, increasing the risk of recurrence and limiting the body's natural immunoprotective response. Not only that, but it also increases the expression of HIF-1α (a protein that acts under hypoxic conditions, where it is usually degraded rapidly), favoring oncological contexts and being proangiogenic.[4] Propofol is the drug of choice in surgical oncology due to its lower risk of tumor spread and reduced recurrence; it is more "balanced" and may even play an immunoprotective role by inhibiting proangiogenic pathways.

Therefore, although research suggests that TIVA would be the drug of choice in oncology, and with Propofol presenting so many supposed benefits, Ketamine could also be considered, as it also hasa two-sided effect, although the predominant result is immunosuppression, which is no small matter in Patients with cancer or infections. The OFA proposes using alternative agents,

such as ketamine and dexmedetomidine, to preserve both analgesia and innate and adaptive immunity, thereby reducing the risk of disease and tumor recurrence in specific contexts. The proposed alternative may be handy, apart from in infectious processes, in obese patients, those with allergies, or those with a history of opioid abuse. Although there is no clear and definitive evidence on OFA, it could be recognized that immunocompromised patients or those in fragile conditions could benefit from avoiding opioids.[17] In these contexts, as we briefly discussed earlier, constant monitoring is essential, as the effects of ketamine could immunosuppress the patient and generate a life-threatening syndrome, depending on the context (especially in infections). The use of ketamine in surgical oncology is not recommended due to its effect on NK cell activity; however, as already mentioned, it could be beneficial in other contexts.[22] Assessing the immune impact should be part of the anesthetic decision-making process, evaluating the patient's overall context and the potential implications in the perioperative setting a certain degree of immunomodulation. Knowledge of anesthetics' immunomodulatory effects enables clinicians to select agents based on each patient's immune status and specific needs, thereby optimizing surgical and postoperative outcomes. In the context of COVID-19 infection, severe cases often lead to a cytokine storm, and the inflammatory balance is vital for patient survival. Severe cases of COVID-19 often lead to ARDS (adult respiratory distress syndrome), and in such cases, special considerations must be taken into account. It is postulated that propofol could be helpful, as it activates pro-resolution mediators (such as lipoxins), helping to moderate lung damage without compromising the immune system. On the other hand, it is suggested that special care should be taken with etomidate (a short-acting carboxylated imidazolium derivative hypnotic with anesthetic and amnesic effects, but no analgesic impact) should be taken, since, although it is known for its cardiovascular stability, it suppresses adrenal c r function, which would increase the risk or worsening of ARDS, leading to multiple organ dysfunction and poorer inflammatory resolution.[21] General anesthetics have profound effects on the immune system, with significant clinical implications. Understanding these mechanisms allows not only to mitigate associated risks.

CONCLUSIONS

After thoroughly analyzing the available evidence, it is clear that Propofol is the best anesthetic option for protecting the patient's immune response, especially in the context of oncological surgery. The studies reviewed consistently show that Propofol not only exerts its anesthetic effects effectively but also has a positive impact on the immune system. Unlike other agents such as Sevoflurane or Ketamine, Propofol reduces the release of inflammatory mediators. It protects key cells such as NK cells, which could translate into a lower probability of tumor recurrence. Even in situations where other anesthetics may have a role, such as Ketamine in septic contexts, the evidence is clear: in cancer patients, Propofol remains the safest option. For all these reasons, and given the growing importance of immune care in the perioperative period, this study argues that Propofol should be the anesthetic of first choice, constantly adapting to each case the patient's profile and the best available scientific evidence.

BIBLIOGRAPHIC REFERENCES

1. Esteve N, Ferrer A, Mora C, Gómez G, Ribera H, Garrido P. ¿Influye la anestesia en los resultados de la cirugía oncológica? SciELO Espana. 2014;21.

2. Higuera Matas A. Estudio de los efectos psiconeuroendocrinos en la edad adulta de un tratamiento crónico con el agonista cannabinoide CP55, 940 en ratas adolescentes de ambos sexos. 2008.

3. Monterroza JJG, Camargo KVC, Rojas MAM, Díez LN, Arias JFT, Díaz MFC. Ventajas y desventajas de la técnica de anestesia balanceada Vs. la anestesia total intravenosa-TIVA-en el pronóstico de la cirugía de cáncer frente a la recaída. Sci Educ Med J. 2021;4:67-78.

4. Morales Coria S. Estudio del sistema cannabinoide endógeno en ratas Lewis y Fischer 344: un modelo animal de vulnerabilidad genética al consumo de drogas. 2016.

5. Moranta Mesquida D. Efectos conductuales y modulación de la síntesis de monoaminas y de la vía de quinasas mitogénicas en cerebro de rata tras tratamientos con cannabinoides y etanol. 2005.

6. Morfín Maciel BM, Castillo Morfín BM. Teofilina, una nueva mirada a un medicamento antiguo. Rev Alerg Mex. 2010;57.

7. Núñez Carranza AE. Efecto del agonista cannabinoide WIN 212-2 en ratas de las cepas Lewis y Fischer 344 en un modelo de CPP. Universidad Autónoma de Nuevo León; 2012.

8. Prieto Castillo AM. Impacto antes y durante la pandemia COVID-19 en la tendencia de consumo para psicofármacos en Colombia: un análisis de series de tiempos interrumpidas. Universidad Nacional de Colombia; 2023.

9. Ruiz Cerda E. Caracterización y selección de suspensiones celulares de Cenchrus ciliaris L. por tolerancia a salinidad. Universidad Autónoma de Nuevo León; 1998.

10. Sánchez-Pedrosa G, Garutti I, Moraga FJG, Orozco HD. Diseminación tumoral perioperatoria. 2. Efectos de la anestesia y analgesia. Elsevier. 2012;59.

11. Schneemilch CE, Hachenberg T, Ansorge S, Ittenson A, Bank U. Effects of different anaesthetic agents on immune cell function in vitro. Eur J Anaesthesiol. 2005;22(8):616-23. DOI: 10.1017/s0265021505001031.

12. Kurosawa S, Kato M. Anesthetics, immune cells, and immune responses. J Anesth. 2008;22:263-77.

13. Cocelli LP, Ugur MG, Karadasli H. Comparison of effects of low-flow sevoflurane and desflurane anesthesia on neutrophil and T-cell populations. Curr Ther Res. 2012;73(1-2):41-51.

14. Liu Y, Liu L, Xing W, Sun Y. Anesthetics mediated the immunomodulatory effects via regulation of TLR signaling. Int Immunopharmacol. 2021;101:108357. DOI: 10.1016/j.intimp.2021.108357.

15. Indunil K, Sau B, Asoka J. Effects of Anesthesia and Analgesia on Immunomodulation and Cancer Recurrence: A Review. Res Gate. 2024. DOI: 10.13140/RG.2.2.15744.44809.

16. Novac MB, Boldeanu L, Rotaru LT, Dijmărescu AL, Șerbănescu M, Radu L, et al. The perioperative effect of anesthetic drugs on the immune response in total intravenous anesthesia in patients undergoing minimally invasive gynecological surgery. Rom J Morphol Embryol. 2021;62(4):961-9. DOI: 10.47162/RJME.62.4.08.

17. Lisowska B, Jakubiak J, Siewruk K, Sady M, Kosson D. Which idea is better with regard to immune response? Opioid anesthesia or opioid free anesthesia. J Inflamm Res. 2020;13:859-69. DOI: 10.2147/JIR.S275986.

18. Relland LM, Hall M, Martin DP, Nateri J, Hanson-Huber L, Beebe A, et al. Immune function following major spinal surgery and general anesthesia. J Pediatr Intensive Care. 2021;10:248-55. DOI: 10.1055/s-0040-1716668.

19. Zhou M, Liu W, Peng J, Wang Y. Impact of propofol epidural anesthesia on immune function and inflammatory factors in patients undergoing gastric cancer surgery. Am J Transl Res. 2021;13(4):3064-73.

20. Vrbanović Mijatović V, Gatin L, Tonković D, Bandić Pavlović D, Smuđ Orehovec S, Miklić Bublić M, et al. The effect of regional vs. general anesthesia on the immune response in breast cancer surgery: A narrative review of the literature. Acta Clin Croat. 2022;61(Suppl 2):115-20. DOI: 10.20471/acc.2022.61.s2.15.

21. Chalkias A, Barreto EF, Laou E, Kolonia K, Scheetz MH, Gourgoulianis K, et al. A critical appraisal of the effects of anesthetics on immune-system modulation in critically ill patients with COVID-19. Clin Ther. 2021;43:e57-e70. DOI: 10.1016/j.clinthera.2021.01.004.

22. Ackerman RS, Luddy KA, Icard BE, Fernández JP, Gatenby RA, Muncey AR. The effects of anesthetics and perioperative medications on immune function: A narrative review. Anesth Analg. 2021;133:676-89. DOI: 10.1213/ANE.0000000000005607.

23. Jafarzadeh A, Hadavi M, Hassanshahi G, Rezaeian M, Vazirinejad R. General anesthetics on immune system cytokines: A narrative review. Anesth Pain Med. 2020;10(4):e103033. DOI: 10.5812/aapm.103033.

24. Oh TK, Jo H, Song IA. Propofol-based Intravenous Anesthesia is Associated with Improved Survival Outcomes after Major Cancer Surgery: A Nationwide Cohort Study in South Korea. Korean J Anesthesiol. 2023;76(5):461-70. DOI: 10.4097/kja.22747.

25. Yi S, Tao X, Wang Y, Cao Q, Zhou Z, Wang S. Effects of propofol on macrophage activation and function in diseases. Front Pharmacol. 2022;13:964771.

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CONFLICT OF INTEREST

None.

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