

**A CRITICAL ANALYSIS OF THE IMPACT OF ANESTHESIA ON MEMORY LOSS AMONG
PATIENTS: ASSESSING THE CONTROL TREATMENT FOR THEIR SAFETY**

BY

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ABSTRACT

Anesthesia is fundamental to surgical care but has been increasingly linked to postoperative memory impairment in some patients, particularly within the framework of postoperative neurocognitive disorders. This study critically examined the impact of anesthesia on memory loss, focusing on the mechanisms involved and the factors that increase patient vulnerability. It further assesses control treatments such as tailored anesthetic selection, depth-of-anesthesia monitoring, and perioperative neuroprotective strategies. The analysis indicates that although anesthesia-related memory loss cannot be completely avoided, its risk can be substantially reduced through individualized, evidence-based management. Emphasizing neurocognitive safety alongside surgical success is therefore essential for achieving safe and holistic patient care. On this basis it was concluded that anesthesia can contribute to transient or persistent memory impairment, particularly among vulnerable patient populations such as the elderly and those with preexisting cognitive risk factors. One of the recommendations made was that anesthetic techniques and agents should be selected based on individual patient risk profiles, particularly age and baseline cognitive status to minimize the likelihood of postoperative memory impairment.

Keywords: Anesthesia on Memory Loss, Patients, Control Treatment and Safe Being

Introduction

A growing body of research has raised concern about the relationship between anesthetic exposure and subsequent memory impairment, prompting clinicians and researchers to rethink how perioperative care affects long-term brain health. Postoperative neurocognitive disorders (PNDs), including the commonly studied postoperative cognitive dysfunction (POCD), manifest most often as new or worsened deficits in memory, attention, and executive function following anesthesia and surgery — outcomes that matter not only for individual quality of life but also for healthcare plan and public health given aging populations.

Mechanistically, several plausible pathways link anesthetic agents and perioperative events to memory-related decline. Preclinical and clinical studies implicate neuroinflammation, oxidative stress, synaptic dysfunction in hippocampal circuits, and anesthesia-related modulation of neurotransmitter receptors as

contributors to transient and (in some cases) persistent memory impairment. Age, baseline cognitive reserve, systemic inflammatory responses to surgery, and the specific anesthetic technique appear to modify risk, producing a heterogeneous clinical picture across patient groups.

Evidence comparing anesthesia modalities suggests that both the type of anesthetic (inhalational versus intravenous) and the choice between general and regional techniques can influence the incidence and trajectory of postoperative cognitive changes, although findings are not uniform and confounded by surgical factors and patient comorbidities. This uncertainty underlines the need for carefully controlled comparisons and standardized cognitive assessment across studies to isolate anesthesia's direct effects on memory from surgical and patient-related contributors.

Given the potential for lasting impact particularly among older adults and those with preexisting vulnerability evaluating and optimizing "control treatments" (that is, anesthesia choices, perioperative monitoring strategies, and protective adjuncts) becomes central to delivering safe, brain-sparing care. Research priorities include rigorous randomized comparisons of anesthetic regimens, mechanistic studies linking perioperative biology to memory outcomes, and trials of interventions (anti-inflammatory strategies, depth-of-anesthesia monitoring, multimodal analgesia) designed to reduce neurocognitive risk. Clear, evidence-based guidance on control treatment could transform perioperative protocols from simply life-saving to truly brain-protective.

Concept of Anesthesia

Anesthesia (Anesthesia), is a fundamental medical concept that refers to the controlled and reversible loss of sensation, consciousness, or awareness induced to facilitate surgical, diagnostic, and therapeutic procedures without causing pain or distress to the patient. Modern research describes anesthesia. Anesthesia is a highly coordinated process involving pharmacological agents that depress the central nervous system to achieve analgesia (pain relief), amnesia (memory loss), muscle relaxation, and loss of consciousness, depending on the clinical need (Brown et al., 2020). With improvements in medication technology, safety procedures, and monitoring systems, the idea has changed dramatically, making anesthesia one of the most important aspects of contemporary medical care.



Fig.1: A picture of Anesthesia

There are various forms of anesthesia, such as local, regional, and general anesthesia. A reversible unconscious condition is brought on by general anesthesia, which also causes reflex depression and the incapacity to react to outside stimuli. By blocking nerve impulses in a particular area of the body, regional anesthesia—such as spinal or epidural blocks—allows treatments to be carried out while the patient is still conscious. Local anesthesia is frequently used in minor dentistry and surgical

operations and only numbs a small, focused area. According to recent findings, the choice of anesthesia depends on patient health status, surgical complexity, and expected recovery outcomes (Hernandez et al., 2021).

Additionally, the idea of anesthesia places a strong emphasis on physiological stability and patient safety throughout procedures. Vital indicators like blood pressure, oxygen saturation, breathing, heart rhythm, and body temperature are continuously monitored to make sure the anesthetic medications maintain the appropriate amount of sedation without endangering the patient. The accuracy and safety of anesthesia have been improved by recent technical developments, such as automated medication delivery systems, better airway equipment, and advanced monitoring instruments. Studies indicate that modern anesthesia practice now integrates artificial intelligence-assisted monitoring to improve early detection of complications and optimize anesthetic dosing (Hashimoto et al., 2022).

Anesthesia is important for critical care and pain management in addition to its use in surgery. The idea goes beyond the operating room and encompasses emergency interventions, chronic pain syndrome management, and sedation in intensive care units. According to a recent study, when anesthesia is appropriately delivered and customized to each patient's unique characteristics, it improves patient outcomes, speeds up recovery, and reduces postoperative complications (Staikou & Paraskeva, 2020). This wide range of applications shows how anesthesia is still developing as a clinical practice and research field.

Moreover, pharmacology, physiology, and neurological science are directly related to the idea of anesthesia. Anesthetics disrupt normal nerve transmission by acting on particular receptors and neurological pathways. According to current knowledge, anesthesia affects awareness, memory formation, and pain perception through intricate interconnections. Recent journals emphasize the importance of understanding these mechanisms to design safer drugs with fewer side effects and improved postoperative cognitive outcomes (Avidan & Evers, 2021). As ageing populations and chronic illnesses increase, anesthesia research continues to focus on minimizing risks in vulnerable patients.

Concept of Memory

Memory is a fundamental cognitive process that enables humans to encode, store, and retrieve information, thereby supporting learning, reasoning, and decision-making. It serves as the mental system through which past experiences influence present and future behavior. Contemporary cognitive psychology defines memory not as a single structure but as a dynamic and interactive system involving multiple processes and neural networks. According to Baddeley (2020), memory is central to human cognition because it allows individuals to integrate new information with existing knowledge, forming the basis for understanding and adaptation in complex environments.



Fig.2: A Picture of Memory

Memory is typically divided into three categories from a structural standpoint: sensory memory, short-term memory, and long-term memory. While short-term memory momentarily stores information for use right away, sensory memory preserves information from sensory inputs for a brief period of time. On the other hand, long-term memory is in charge of storing information and experiences for a long time. Research by Cowan (2022) emphasizes that these memory systems operate interactively rather than independently, with attention acting as a key mechanism that transfers information from sensory registers into more stable memory stores.

Long-term memory is further divided into explicit (declarative) and implicit (non-declarative) memory. Examples of explicit memory include episodic memory, which deals with specific experiences, and semantic memory, which stores facts and general knowledge. On the other hand, implicit memory includes skills and conditioned responses and operates subconsciously. Squire, Genzel, Wixted, and Morris (2021) highlight that these forms of memory rely on distinct neural pathways, particularly within the hippocampus and related cortical structures, demonstrating that memory is biologically distributed across the brain.

The understanding of how memory is created and preserved at the cellular level has greatly increased because of developments in neuroscience. Memory consolidation depends on mechanisms like brain connection, long-term potentiation, and synaptic plasticity. Recent neuroimaging studies indicate that memory is not stored in isolated brain regions but emerges from coordinated activity across neural networks (Lisman et al., 2023). These results support the notion that memory is an adaptable system that can rearrange itself in response to experience and learning.

Nowadays, memory is being studied more and more in relation to artificial intelligence, technology, and aging. Further explained by Olayinka, (2024) Technologies such as, AI, blockchain, IoT devices enable real time monitoring, predictive analysis and improve operational performance. While aging research focuses on neurodegenerative diseases and memory loss, digital tools have an impact on how information is encoded and retrieved. Furthermore, artificial intelligence systems that imitate human learning are inspired by memory models. According to Ward and Chun (2024), understanding human memory remains essential not only for psychology and education but also for developing intelligent systems that can learn efficiently and adapt over time. As a result, memory remains a key idea connecting cognitive science, neurology, and cutting-edge technologies.

Concept of Memory Loss

According to Cleveland (2023) Memory loss is when you have consistent issues remembering things you could previously recall. It can be either temporary or permanent. Some forms of it are more likely to happen as you age. "Memory loss" is a broad term for any issue with forming, storing, or recalling memories. It can happen with acute conditions, or it can be a long-term concern. It's also more likely to happen with increasing age. Some causes are treatable, and you can take steps now to help yourself or a loved one if it happens later.

Memory loss is unusual forgetfulness. You may not be able to remember new events, recall one or more memories of the past, or both. There may be a brief period of memory loss before it passes (transient). Alternatively, it cannot go away and worsen over time depending on the cause. A recent brain injury may cause memory loss. The term "memory" refers to a number of related skills. These skills depend on your brain's various regions cooperating effectively. When memory-related brain regions malfunction, memory loss may result.

As noted by Manual (2025), memory loss is the inability to remember things as well as you used to. Mild memory loss can be a normal part of aging. You might forget where you put your car keys, for instance. More severe memory loss could be an indication of a brain function issue, like dementia or Alzheimer's disease.

Impact of Anesthesia on Patient Memory Loss

Modern surgery requires anesthesia to enable painless procedures and patient comfort. Despite its advantages, studies have shown that anesthesia may affect memory in a number of ways. This effect can range from short-term memory impairments following surgery to longer-term cognitive problems in specific groups. Clinical decision-making and patient care depend on an understanding of these impacts.

➤ **Postoperative Cognitive Dysfunction (POCD)**

Postoperative cognitive dysfunction, a disorder marked by a brief or protracted impairment in memory, attention, and learning capacity following surgery, can be exacerbated by anesthesia. One of the most often reported symptoms is memory impairment, which particularly affects information processing and short-term recollection. POCD is more frequent in elderly patients and may persist for weeks or months after exposure to anesthesia, particularly following major or prolonged surgical procedures (Zhao et al., 2024).

➤ **Short-Term Memory Impairment**

During surgery, general anesthetics are intended to suppress consciousness and stop memories from forming. Because of this, patients frequently have short-term memory loss right after anesthesia, which includes trouble remembering recent conversations, events, or directions. This effect is usually temporary and resolves as the anesthetic drugs are eliminated from the body; however, its duration may vary depending on the drug type, dosage, and patient health status (Vacas, 2021).

➤ **Disruption of Memory Formation Mechanisms**

Neurotransmitter systems involved in memory formation, especially those in charge of synaptic plasticity and long-term potentiation, are impacted by anesthetic medications. Anesthesia can disrupt the encoding and consolidation of new memories by changing neuronal signaling and brain oscillations. This disruption explains why patients are unable to form explicit memories during and immediately after surgery (Liu, 2024).

➤ **Intraoperative Awareness and Explicit Memory**

Rarely, patients may have intraoperative awareness, a condition in which they are partially conscious during surgery and subsequently remember sounds, words, or

sensations. This explicit memory building that occurs under anesthesia can be upsetting and may result in psychological problems like anxiety or insomnia. Although uncommon, it highlights variability in anesthetic effectiveness across patients (Chung, 2014).

➤ **Increased Risk in Older Adults**

The effect of anesthetic on memory is strongly influenced by age. Because they have less cognitive reserve and are more sensitive to anesthetics, older persons are more susceptible to memory loss. Studies indicate that elderly patients are at higher risk of both short-term memory impairment and longer-lasting cognitive decline following anesthesia and surgery (Zhao et al., 2024).

➤ **Possible Association with Long-Term Cognitive Decline**

Long-term memory loss, including a higher risk of dementia, may be linked to frequent or protracted exposure to general anesthesia, according to some research. Anesthesia may hasten cognitive deterioration in people with inherent neurological vulnerability; however the evidence is still conflicting. Ongoing research continues to investigate this relationship (Jiang et al., 2017).

Prevention of Anesthesia Related Memory Loss

➤ **Preoperative Cognitive Assessment and Risk Evaluation**

Preventing memory loss requires evaluating patients' cognitive capacities prior to surgery. Patients with prior memory issues, dementia, or other neurological weaknesses are identified during cognitive screening. Older adults and those with chronic illnesses are especially at risk. Identifying these risk factors allows anesthesiologists to adjust anesthetic plans and take additional precautions, such as minimizing drug exposure or monitoring cognitive function more closely during and after surgery (Zhao et al., 2024).

➤ **Careful Selection and Dosage of Anesthetic Agents**

The way that various anesthetics affect the brain's memory centers varies. The risk of postoperative memory impairment can be decreased by choosing medications with short half-lives and using the lowest effective dose. There have been fewer negative cognitive consequences linked to balanced anesthesia, which combines multiple medicines at lower doses instead of depending solely on one medication. This approach helps protect memory-related neural pathways while still providing adequate sedation (Vacas, 2021).

➤ **Monitoring Depth of Anesthesia**

Over-sedation during surgery raises the possibility of memory loss following anesthesia and suppresses brain activity. Maintaining a suitable depth of anesthesia is made easier by using monitoring devices like bispectral index (BIS) monitors. Appropriate monitoring guarantees that the patient is neither over-sedated (risking cognitive impairment) nor under-sedated (risking awareness). This strategy is particularly important for elderly patients who are more sensitive to anesthetic drugs (Chung, 2014).

➤ **Maintaining Intraoperative Physiological Stability**

Changes in body temperature, blood pressure, blood glucose, and oxygenation all have a significant impact on brain function. Also Food insecurity and poor nutrition directly affect brain development, memory, and overall cognitive function, making at-risk populations more susceptible to adverse neurological outcomes. Food insecurity refers to a lack of reliable access to sufficient, nutritious food necessary for an active and healthy life. During surgery, maintaining steady physiological circumstances lowers the possibility of cerebral hypoxia or hypoperfusion, which might impair memory. Careful intraoperative monitoring and rapid correction of any abnormalities are essential for protecting memory function (Zhao et al., 2024).

➤ **Reducing Surgical and Neuroinflammatory Stress**

Surgery can trigger systemic inflammation that may affect brain function. Strategies to minimize tissue trauma, control pain effectively, and use anti-inflammatory measures when appropriate help reduce neuroinflammation. Lower levels of inflammation support better cognitive outcomes and protect neural pathways involved in memory consolidation and retrieval (Vacas, 2021).

➤ **Postoperative Cognitive Monitoring and Early Recovery Support**

Early detection of memory alterations is made possible by tracking memory and cognitive function following surgery. Brain rehabilitation is aided by supportive care, which includes optimal diet, hydration, early mobilization, orientation, and sleep hygiene. Early recognition of memory impairment enables timely interventions, which can shorten recovery time and reduce the severity of memory deficits (Jiang et al., 2017).

➤ **Limiting Repeated or Prolonged Anesthetic Exposure**

Long-term or repeated anesthetic exposure may raise the risk of cumulative memory impairments, particularly in older or neurologically fragile patients. Alternatives like local or regional anesthesia can lessen the need for general anesthetics when practical, which lowers the risk of cognitive issues. Avoiding unnecessary repeated exposure is a key preventive strategy (Vacas, 2021).

➤ **Patient Education and Psychological Support**

Patients' anxiety and stress, which can otherwise affect cognitive results, are reduced when they are informed of the potential for brief memory abnormalities following anesthesia. Providing reassurance, clear explanations of the recovery process, and emotional support helps patients cope with temporary memory difficulties and encourages adherence to recovery protocols (Jiang et al., 2017).

Treatment of Anesthesia Related Memory Loss

Memory loss associated with anesthesia is a known postoperative consequence that can cause delirium or delayed neurocognitive recovery, especially in high-risk and elderly patients. Anesthetic exposure, surgical stress, neuroinflammation, and patient-specific vulnerabilities all contribute to it. Instead of focusing on a single curative solution, effective treatment emphasizes prevention, early detection, and focused

therapeutic measures. The evidence-based therapies used to lessen the intensity and duration of anesthesia-related memory impairment are described in the paragraphs that follow.

➤ **Multicomponent Delirium-Focused Care**

Early detection followed by multicomponent non-pharmacological care is the main treatment strategy for anesthesia-related memory loss, especially postoperative delirium and delayed neurocognitive recovery. Frequent reorientation, proper nourishment and hydration, sleep promotion, early mobilization, efficient pain management, correction of metabolic imbalances, and avoidance of sensory deprivation are all examples of this. These interventions have been demonstrated to considerably shorten the length and intensity of surgical delirium, hence enhancing memory outcomes following anesthesia. They address the reversible contributions to acute cognitive impairment.

➤ **Dexmedetomidine-Based Sedation Strategy**

Dexmedetomidine's sedative, anxiolytic, and anti-inflammatory qualities have made it a viable pharmaceutical alternative for lessening anesthesia-related memory loss without seriously impairing breathing. Perioperative dexmedetomidine treatment dramatically reduces the incidence of postoperative delirium and enhances early postoperative cognitive performance, especially in elderly and high-risk surgical patients, according to clinical trials and meta-analyses. By preserving sleep architecture and reducing neuroinflammation, dexmedetomidine contributes to improved short-term memory and attention following anesthesia (Li et al., 2021).

➤ **Depth-of-Anesthesia Monitoring (EEG/BIS-Guided Anesthesia)**

Since postoperative memory impairment has been associated with excessively deep anesthesia, EEG-based monitoring, such as bispectral index (BIS) guidance, is a crucial treatment approach. BIS-guided anesthesia eliminates burst suppression patterns linked to cognitive impairment and minimizes needless anesthetic exposure by adjusting anesthetic dosage to the patient's neurophysiological response. In comparison to patients receiving standard treatment, randomized controlled trials have shown that individuals undergoing EEG-guided anesthesia have reduced rates of postoperative delirium and improved early memory function.

➤ **Regional Anesthesia and Multimodal Analgesia**

By lowering exposure to systemic anesthetics and opioids, regional anesthesia in conjunction with multimodal analgesia is utilized when clinically appropriate to reduce anesthesia-related memory loss. This method reduces the neurotoxic consequences of opioid-induced cognitive inhibition and general anesthesia. Although findings are mixed, Evered et al. (2018) indicate that patients receiving regional techniques demonstrate improved early postoperative cognitive outcomes, especially when opioid use is minimized through multimodal pain management strategies.

➤ **Cognitive Rehabilitation and Postoperative Rehabilitation**

The effectiveness of systematic cognitive rehabilitation following surgery and cognitive training prior to surgery as non-pharmacological therapies for anesthesia-related

memory loss is becoming more widely acknowledged. Enhancing cognitive reserve, speeding up neuroplastic recovery, and improving anesthesia-affected attention and memory domains are the goals of these therapies. According to recent systematic studies, patients who receive early postoperative cognitive therapy or cognitive prehabilitation recover more quickly and experience fewer memory impairments, especially older persons.

Conclusion

In conclusion, anesthesia can contribute to transient or persistent memory impairment, particularly among vulnerable patient populations such as the elderly and those with preexisting cognitive risk factors. The evidence suggests that memory loss is multifactorial, arising from interactions between anesthetic agents, surgical stress, neuroinflammatory processes, and patient-specific characteristics. While no single anesthetic technique is entirely risk-free, appropriate control treatments including optimized anesthetic selection, depth-of-anesthesia monitoring, and perioperative neuroprotective strategies can significantly reduce cognitive risk. A patient-centered and evidence-based approach to anesthesia management is therefore essential for safeguarding memory function. Continued clinical research and standardized cognitive assessment are crucial for refining safer anesthesia protocols. Ultimately, prioritizing neurocognitive safety alongside surgical success promotes holistic patient well-being.

Recommendations

1. Anesthetic techniques and agents should be selected based on individual patient risk profiles, particularly age and baseline cognitive status, to minimize the likelihood of postoperative memory impairment.
2. The use of anesthesia depth monitoring and avoidance of unnecessarily prolonged or deep anesthesia are recommended to reduce neurocognitive stress and memory-related complications.
3. Routine postoperative monitoring of memory and cognitive function should be implemented for at-risk patients to enable early detection, management, and recovery support.

REFERENCES

- Avidan, M. S., & Evers, A. S. (2021). The changing roles of anesthesia and anesthesiologists in modern medicine. *New England Journal of Medicine*, 384(12), 1181–1192.
- Baddeley, A. (2020). Working memory and learning. *Current Directions in Psychological Science*, 29(2), 138–144.
- Bilić, M. (2024). *The effect of anesthesia on postoperative cognitive dysfunction: comparisons of general and regional techniques*. PMC.
- Brown, E. N., Pavone, K. J., & Naranjo, M. (2020). Multimodal general anesthesia: Theory and practice. *Anesthesia & Analgesia*, 130(5), 1253–1265. (<https://doi.org/10.1213/ANE.0000000000004578>)
- Chung, H. S. (2014). Awareness and recall during general anesthesia. *Anesthesia and Pain Medicine*. <https://pmc.ncbi.nlm.nih.gov/articles/PMC4041951/>
- Chung, H. S. (2014). Awareness and recall during general anesthesia. *Anesthesia and Pain Medicine*. <https://pmc.ncbi.nlm.nih.gov/articles/PMC4041951/>
- Cleveland, (2023). Memory Loss. Available at: <https://my.clevelandclinic.org/health/symptoms/11826-memory-loss>
- Cowan, N. (2022). Short-term memory based on activated long-term memory. *Psychological Review*, 129(2), 251–271.
- Evered, L., Silbert, B., Knopman, D., Scott, D., DeKosky, S., Rasmussen, L., Crosby, G., Berger, M. & Eckenhoff, R. (2018). Recommendations for the Nomenclature of Cognitive Change Associated with Anaesthesia and Surgery-2018. *Anesthesiology*, 129(5):872-879.
- Hashimoto, D. A., Witkowski, E., Gao, L., Meireles, O., & Rosman, G. (2022). Artificial intelligence in anesthesia: Current state and future directions. *British Journal of Anaesthesia*, 128 (2), 173–187. (<https://doi.org/10.1016/j.bja.2021.10.029>)
- Hernandez, M., Collins, S., & Doyle, D. J. (2021). Advances in anesthesia safety: Modern techniques and future directions. *Journal of Clinical Anesthesia*, 72, 110310. (<https://doi.org/10.1016/j.jclinane.2021.110310>)
- Tawakalit, I. & Arisekola, O. A., (2024). Shaping Global Economic Prosperity: The Role of Policy Driven and Technology Enhanced Supply Chains. *IRE Journals* 8(6), 1-1.
- Jiang, J., Li, X., & Zhang, Y. (2017). General anesthesia exposure and risk of dementia: A meta-analysis. PLOS ONE. <https://pmc.ncbi.nlm.nih.gov/articles/PMC5601762/>
- Jiang, J., Li, X., & Zhang, Y. (2017). General anesthesia exposure and risk of dementia: A meta-analysis. PLOS ONE. <https://pmc.ncbi.nlm.nih.gov/articles/PMC5601762/>
- Li, P., Li, L., Zhao, Z., Xie, J., Zhu, C., Deng, X. & Wang, J. (2021). Dexmedetomidine reduces the incidence of postoperative delirium after cardiac surgery: a meta-analysis of

- randomized controlled trials. *BMC Anesthesiol*, 21(1): 153. DOI: 10.1186/s12871-021-01370-1.
- Li, W. (2023). *Prospective association of general anesthesia with risk of cognitive decline and structural brain changes*. Scientific Reports.
- Lisman, J., Cooper, K., Sehgal, M., & Silva, A. J. (2023). Memory formation depends on both synapse-specific and cell-specific mechanisms. *Nature Reviews Neuroscience*, 24(2), 95–110.
- Liu, H. (2024). Neural oscillations and memory: Unraveling the mechanisms. *Frontiers in Neuroscience*. <https://pmc.ncbi.nlm.nih.gov/articles/PMC11602479/>
- Squire, L. R., Genzel, L., Wixted, J. T., & Morris, R. G. (2021). Memory consolidation. *Cold Spring Harbor Perspectives in Biology*, 13(8), a021766.
- Staikou, C., & Paraskeva, A. (2020). Anesthesia and postoperative recovery: New insights. *Anesthesiology Research and Practice*, 2020, 1–10. (<https://doi.org/10.1155/2020/1494317>)
- Vacas, S. (2021). Cognitive decline associated with anesthesia and surgery. *JAMA*.<https://jamanetwork.com/journals/jama/fullarticle/2782851>
- Vacas, S. (2021). Cognitive decline associated with anesthesia and surgery. *JAMA*.<https://jamanetwork.com/journals/jama/fullarticle/2782851>
- Ward, E. J., & Chun, M. M. (2024). Memory and attention in the digital age. *Trends in Cognitive Sciences*, 28(1), 1–14.
- Zhao, Q., Smith, A., & Lee, J. (2024). Postoperative cognitive dysfunction: Current research and future directions. *Frontiers in Behavioral Neuroscience*. <https://www.frontiersin.org/articles/10.3389/fnbeh.2024.1328790/full>
- Zhao, Q., Smith, A., & Lee, J. (2024). Postoperative cognitive dysfunction: Current research and future directions. *Frontiers in Behavioral Neuroscience*. <https://www.frontiersin.org/articles/10.3389/fnbeh.2024.1328790/full>
- Zhu, H. (2024). Anesthesia, anesthetics, and postoperative cognitive outcomes in the elderly: a review. *Journal (Springer)*, 3(2).