SciMedCentral

Journal of Sleep Medicine & Disorders

Review Article

# Systematic Review of Perioperative Sleep Management in Elderly Patients and its Relationship with Postoperative Delirium

Xiaochen Ji[1]*, Yabo Wang[2], Zhiqiang Niu[1] and BoYa Zhang[2]

[1]Hebei Medical University, Shijiazhuang, Hebei Province, China

[2]Chengde Medical University, Shuangqiao, Chengde, Hebei, China

***Corresponding author**

Xiaochen Ji, Hebei Medical University, Shijiazhuang, Hebei Province, China

**Submitted:** 21 August, 2025

**Accepted:** 15 September, 2025

**Published:** 19 September, 2025

**ISSN:** 2379-0822



**Keywords**

• Elderly Patients; Perioperative; Sleep Management; Postoperative Delirium; Neuropsychiatric Disorders; Sleep Disorders; Sleep Interventions; Cognitive Function

**Abstract**

Perioperative Sleep Disorders (PSD) are prevalent among elderly patients and have been confirmed as independent risk factors for Postoperative Delirium (POD) and other Perioperative Neuropsychiatric impairments (PND). With the intensifying population aging, effective management of perioperative sleep issues in this group has become particularly crucial. This systematic review synthesizes recent literature on the epidemiological characteristics, pathophysiological mechanisms, clinical manifestations, and correlations with postoperative delirium in elderly patients. We focus on analyzing the impact of pharmacological and non-pharmacological sleep intervention strategies on postoperative delirium incidence. By integrating current clinical trials and basic research findings, this review aims to explore optimized perioperative sleep management strategies and their potential effects in reducing postoperative delirium, providing theoretical foundations and practical recommendations for clinical practice.

## INTRODUCTION

Postoperative Delirium (POD) is a significant complication affecting elderly patients, particularly common after surgery. This acute cognitive impairment manifests as disorientation, altered consciousness levels, and disordered thinking, leading to increased morbidity and mortality rates. Studies indicate that the prevalence of POD may be alarmingly high reaching up to 80% among elderly patients undergoing specific surgeries like hip fracture repair or cardiac procedures [1]. The impact of POD extends far beyond the postoperative recovery phase, contributing to prolonged hospital stays, increased healthcare costs, and long-term cognitive decline. Consequently, it has become a critical focus in geriatric surgical care [2]. To improve treatment outcomes for this vulnerable population, comprehensive understanding of POD's multidimensional characteristics encompassing its risk factors and potential prevention strategies is essential.

Among various identified risk factors, perioperative sleep disorders have emerged as a significant independent predictor of Postoperative Cognitive Dysfunction (POD) in elderly patients. Sleep disturbances are prevalent among older adults and are exacerbated by factors such as anxiety, pain, and hospitalization stress [3]. Recent studies indicate that significant postoperative sleep quality deterioration may trigger cognitive impairment and increase the likelihood of POD development [4]. The complex interplay between sleep disorders and cognitive health underscores the critical need to prioritize sleep management during perioperative care. Furthermore, research demonstrates that interventions to improve sleep quality could reduce POD risks and enhance overall rehabilitation outcomes [5].

Epidemiological studies indicate that preoperative sleep disorders in elderly surgical patients may occur at rates as low as 0% or as high as 91%, while postoperative sleep disturbances range from 6.7% to 93% [6]. These sleep issues are often associated with increased pain sensitivity, heightened anxiety and depression, and impaired cognitive function. These factors not only prolong recovery time but also significantly elevate the risk of postoperative delirium. Therefore, timely identification and proper management of sleep disorders are crucial for improving surgical outcomes and reducing delirium incidence. The causes of perioperative sleep disorders are complex and multifaceted, including surgical environment, medication effects, and the patient's pre-existing psychological state [7].

The underlying mechanisms linking sleep disorders and Postoperative Cognitive Decline (POD) involve multiple biological pathways. Disrupted sleep patterns may trigger neuroinflammation and oxidative stress, factors that have been proven to impair cognitive function [4]. Furthermore, the glial lymphatic system – responsible for clearing brain metabolic waste – becomes most active during sleep. This suggests that poor sleep quality could hinder this process, ultimately leading to cognitive deterioration [8]. These findings underscore the necessity of implementing targeted interventions for elderly surgical patients- as improved sleep quality may play a crucial role in reducing the incidence of postoperative cognitive decline and maintaining cognitive health after surgery.

While there is a clear correlation between sleep disorders and Postoperative Cognitive Dysfunction (POD), current perioperative care practices often overlook the critical importance of sleep management. To address perioperative sleep disorders, establishing standardized assessment tools and evidence-based interventions has become imperative. Strategies such as optimizing pain management, reducing environmental stressors, and implementing pharmacological or non-pharmacological sleep aids may yield positive outcomes. As our understanding of the relationship between sleep and cognitive health in elderly patients deepens, incorporating sleep management into perioperative protocols could provide a significant breakthrough for improving prognosis in this vulnerable population.

## PRIMARY COVERAGE

### Epidemiology and Clinical Characteristics of Perioperative Sleep Disorders in Elderly Patients

**Definition and classification of perioperative sleep disorders:** Perioperative sleep disorders encompass various conditions that may significantly impact postoperative sleep quality. These disorders manifest as decreased sleep quality, shortened sleep duration, and disrupted sleep architecture, specifically including difficulty falling asleep, frequent awakenings, and altered sleep phases. Elderly patients exhibit particularly pronounced sleep quality declines, being more susceptible to multiple factors that exacerbate perioperative sleep disturbances. These factors include pre-existing sleep disorders, psychological stressors, anesthetic effects, postoperative pain management, and environmental changes during hospitalization. Research indicates that elderly patients frequently experience sleep disorders such as insomnia and obstructive sleep apnea, which not only prolong recovery time but also increase postoperative complication risks [9,10]. These disorders can be broadly categorized into primary sleep disorders (e.g., insomnia and sleep apnea) and secondary sleep disorders, the latter potentially caused by medical conditions, medication use, or surgical procedures themselves. Accurately identifying common perioperative sleep disorder types is crucial for developing targeted interventions to improve sleep quality and ultimately enhance patient outcomes.

The prevalence of sleep disorders among elderly surgical patients reveals concerning patterns. Research indicates that insomnia, one of the most common sleep disturbances affecting this population, is often exacerbated by anxiety stemming from surgical procedures and postoperative recovery [11]. Furthermore, Obstructive Sleep Apnea (OSA) frequently remains undiagnosed in elderly patients undergoing surgery, leading to postoperative complications such as delirium and cognitive impairment [12]. The high incidence of these conditions necessitates comprehensive perioperative care strategies, including preoperative sleep disorder screening and personalized management plans to mitigate their impact. Effective interventions like cognitive behavioral therapy for insomnia, pharmacological treatments such as melatonin, and non-pharmacological measures like environmental adjustments have all demonstrated efficacy in improving perioperative sleep quality [13,14]. Notably, sleep disorders as significant risk factors for adverse surgical outcomes underscore the importance of multidisciplinary collaboration involving anesthesiologists, surgeons, and sleep specialists to optimize perioperative care and promote rehabilitation.

In conclusion, defining and classifying perioperative sleep disorders is essential for understanding their impact on elderly surgical patients. The complex interplay between various sleep disorders and their contributing factors underscores the importance of proactive management strategies during this critical period——These strategies aim to improve sleep quality, ultimately enhancing postoperative recovery outcomes.

**Perioperative sleep disorders in elderly patients and their influencing factors:** The prevalence of perioperative sleep disorders in elderly patients is significantly higher, closely related to multiple factors including surgical type, anesthesia methods, and perioperative environmental conditions. Studies indicate that prolonged or invasive procedures notably impair sleep quality in older adults. For instance, both procedure duration and anesthesia administration significantly influence postoperative sleep outcomes. Compared to regional anesthesia, general anesthesia demonstrates a higher incidence of

sleep disturbances due to its longer recovery period and increased risk of postoperative delirium [15]. Additionally, common perioperative elements like noise, bright lights, and frequent medical interventions exacerbate sleep challenges for this vulnerable population. These factors compound age-related physiological changes which alter sleep patterns and worsen existing sleep disorders. Therefore, comprehensive understanding of these contributing factors is crucial for developing targeted interventions to improve sleep quality in elderly patients, thereby enhancing postoperative recovery outcomes.

Furthermore, age-related physiological changes and comorbidities significantly impact perioperative sleep disorders in elderly patients. With advancing age, individuals often experience altered sleep patterns characterized by reduced total sleep duration and increased sleep fragmentation. These changes may be exacerbated by common age-related conditions such as heart disease, diabetes, and cognitive impairment [16]. Additionally, psychological factors including chronic pain, anxiety, and depression further impair postoperative sleep quality in older adults, increasing risks of complications like delirium and cognitive dysfunction [17].The interaction between these physiological changes and comorbidities underscores the importance of comprehensive preoperative evaluations which should assess both sleep quality and address existing sleep issues. Such proactive preventive measures not only reduce the risk of postoperative sleep disorders but also facilitate overall rehabilitation in elderly patients.

In summary, the incidence of perioperative sleep disorders in elderly patients is influenced by multiple factors, including surgical type, anesthesia methods, perioperative environmental stressors, and physiological changes associated with aging and comorbidities. Implementing targeted interventions and comprehensive preoperative evaluations to address these factors are crucial for improving sleep quality and reducing postoperative complication risks in this vulnerable population.

**Influence of sleep disorders on postoperative recovery in elderly patients:** Sleep disorders in elderly patients significantly impair postoperative recovery through multiple physiological and psychological mechanisms. The most immediate impact is reduced immune function which critically affects rehabilitation outcomes. Research indicates that sleep deprivation decreases the secretion of immune mediators like cytokines, weakening the body's ability to cope with surgical stress and increasing infection risks [17]. This immune dysregulation may lead to postoperative complications such as infections and delayed wound healing, prolonging hospital stays and compromising overall recovery. Additionally, sleep disorders exacerbate pain perception, creating additional challenges in postoperative management. Poor sleep quality interacts with central nervous system pain pathways, causing patients with suboptimal sleep to develop hypersensitive pain responses [15], forming a vicious cycle: intensified pain triggers sleep disturbances, which worsen the condition and delay recovery.

Notably, sleep disorder patients often exhibit mental health changes including cognitive decline and mood swings. Postoperative delirium, characterized by disorientation and altered consciousness, is prevalent among these patients and closely associated with poor sleep quality [18]. Cognitive impairment in these patients hinders their participation in rehabilitation activities, further delaying recovery. The relationship between sleep disorders and neurocognitive functions is complex, as poor sleep quality induces neuroinflammation and leads to accumulation of neurotoxic proteins—substances closely linked to cognitive decline [19]. Therefore, preoperative intervention for sleep disorders may be a key strategy to enhance postoperative recovery outcomes in elderly patients. Medications such as dexmedetomidine and dexamethasone have been proven to effectively improve sleep quality, thereby promoting postoperative recovery [20,21]. By enhancing sleep quality, these interventions can boost immune function, reduce pain perception, and stabilize psychological states, ultimately helping elderly patients undergoing surgery achieve better rehabilitation outcomes. Therefore, implementing comprehensive strategies for managing sleep disorders during the perioperative period is crucial for optimizing postoperative recovery and improving quality of life in elderly surgical patients.

## Pathophysiological Mechanism of Postoperative Delirium and Its Relationship with Sleep Disorders

**Definition and clinical manifestations of postoperative delirium:** Postoperative Delirium (POD) is a significant neurocognitive complication frequently observed in elderly patients following surgery. This condition manifests as acute confusion characterized by fluctuations in attention, cognitive function, and consciousness levels. Specific clinical symptoms include: acute cognitive fluctuations, changes in consciousness levels, and attention deficits. Acute cognitive fluctuations may present as disorientation, memory impairment, and information processing difficulties, causing substantial

distress to both patients and caregivers. The spectrum of consciousness level variations ranges from hyperactive states (manifesting as restlessness) to sluggish responses (presenting as apathy and delayed reactions) [22]. Particularly prominent are attention deficits, where patients struggle to maintain focus, resulting in impaired participation in conversations or execution of simple instructions. These multidimensional manifestations complicate diagnosis and treatment, as symptoms may be misdiagnosed as dementia or depression—particularly prevalent among elderly individuals with pre-existing cognitive impairments [23].

The incidence of Postoperative Delirium (POD) varies significantly, influenced by multiple factors including surgical type, patient age, and pre-existing conditions. Studies indicate that elderly patients undergoing major surgeries such as cardiac or orthopedic procedures face substantially increased risks of POD [24,25]. This condition carries substantial clinical implications, not only prolonging hospital stays and driving up medical costs but also potentially triggering severe complications like cognitive decline and mortality [26,27]. Its complex pathogenesis may involve a combination of neuroinflammatory responses, metabolic disorders, and the effects of anesthetic medications [28]. Furthermore, postoperative anemia, dehydration, and specific medication use can all exacerbate the risk of delirium [29,30].

In clinical practice, Postoperative Delirium (POD) requires heightened vigilance, particularly among high-risk populations. Currently, commonly used screening tools include the Consciousness Assessment Method (CAM) and Nursing Delirium Screening Scale (Nu-DESC), which effectively help detect delirium symptoms in surgical patients [31]. Early detection is crucial as it enables timely interventions to reduce both the severity and duration of delirium. Management strategies typically involve optimizing patient environments, ensuring adequate hydration and nutritional support, and minimizing the use of sedatives that may induce cognitive impairment [32]. In summary, postoperative delirium represents a common and severe complication in elderly surgical patients, characterized by acute cognitive disturbances. Therefore, close monitoring and proactive interventions are essential to improve patient outcomes.

**Central nervous system inflammation and blood-brain barrier damage:** The correlation between sleep disorders and neuroinflammation is increasingly recognized as a key factor in the pathogenesis of various neurological diseases, particularly in elderly patients with postoperative delirium. Sleep disturbances activate neuroinflammatory pathways that compromise the integrity of the Blood-Brain Barrier (BBB). As the central nervous system's natural defense against harmful substances in the bloodstream, the BBB consists of tightly packed endothelial cells that regulate the passage of molecules and immune cells. When sleep deprivation occurs, inflammatory mediators such as cytokines and chemokines are released, disrupting this protective barrier and increasing BBB permeability [33,34]. This enhanced permeability allows peripheral immune cells and pro-inflammatory cytokines to infiltrate the central nervous system, exacerbating neuroinflammatory responses and potentially leading to cognitive dysfunction and delirium [35,36].

Neuroinflammation is characterized by the activation of glial cells (particularly microglia), which play a critical role in immune responses within the central nervous system. When activated, microglia release various inflammatory mediators that lead to neuronal damage and functional impairment [37,38]. The interaction between sleep disorders and neuroinflammation is particularly pronounced in elderly populations. Due to age-related circadian rhythm changes, comorbidities, and medication effects, they often experience disrupted sleep patterns [39,40]. Sleep deprivation elevates levels of pro-inflammatory cytokines such as Interleukin-6 (IL-6), and Tumor Necrosis Factor-α (TNF-α), which have been proven closely associated with the pathogenesis of postoperative delirium [41,42].

Furthermore, the activation of NLRP3 inflammasomes—a key component of innate immune responses has been shown to be closely associated with sleep deprivation and neuroinflammation. These inflammatory bodies promote the release of IL-1β and IL-18, which further exacerbate the inflammatory response and lead to compromised Blood-Brain Barrier (BBB) integrity [43,44]. This neuroinflammatory cascade creates a vicious cycle: increased BBB permeability allows more inflammatory mediators to infiltrate the central nervous system, not only sustaining the inflammatory response but also potentially accelerating cognitive decline [45,46].

In summary, the relationship between sleep disorders, neuroinflammation, and Blood-Brain Barrier (BBB) disruption is complex and multidimensional. Sleep disturbances activate neuroinflammatory pathways that compromise BBB integrity, increasing its permeability and allowing inflammatory mediators to infiltrate the central nervous system. This process warrants particular attention in elderly patients, who are more susceptible to cognitive impairment caused by inflammation. Understanding

these mechanisms is crucial for developing targeted interventions aimed at improving sleep quality and reducing postoperative delirium and other neurocognitive impairments in this vulnerable population. Future research should focus on elucidating specific pathways within this association and exploring potential therapeutic strategies to enhance sleep quality and mitigate neuroinflammation, thereby assisting high-risk patients [47,48].

**Circadian rhythm disorders and neurotransmitter imbalance:** The circadian rhythm plays a crucial role in regulating various physiological processes, including sleep-wake cycles, hormone release, and neurotransmitter activity. Disruptions in these rhythms can lead to severe cognitive impairment, particularly evident in elderly populations already predisposed to neurocognitive disorders. The interaction between circadian rhythms and the neurotransmitter system is highly complex, involving multiple neurochemical pathways that influence cognitive function. For instance, Dopamine (DA), a neurotransmitter closely associated with circadian rhythms, is regulated by the suprachiasmatic nucleus (the brain's primary circadian clock——). Studies have shown that circadian rhythm disorders cause imbalances in dopamine levels, exacerbating conditions like Parkinson's disease and mood disorders, ultimately impairing cognitive abilities [49]. Additionally, research indicates that sleep disturbances may elevate pro-inflammatory cytokine levels, potentially triggering neuroinflammation and subsequent cognitive decline [50]. The relationship between sleep quality and memory function is particularly pronounced among older adults: poor sleep quality correlates with declining performance on memory tests, demonstrating that disrupted sleep directly damages cognitive processes [51].

Furthermore, the impact of circadian rhythm disruption on neurotransmitter imbalances extends far beyond dopamine. For instance, changes in serotonin and norepinephrine levels are closely associated with sleep disorders, which further complicate the neurochemical environment supporting cognitive functions [12]. The cumulative effects of these neurotransmitter imbalances may create a vicious cycle: declining cognitive abilities exacerbate sleep disturbances, forming a feedback mechanism particularly detrimental to elderly individuals. Compounding this issue, anesthetics used during surgery disrupt circadian rhythms, leading to Postoperative Cognitive Dysfunction (POCD) [52]. The timing and type of anesthetic administration influence circadian rhythm recovery, thereby affecting the progression of postoperative cognitive function restoration [53].

In addition to neurotransmitter imbalances, circadian rhythm disorders can disrupt the expression of circadian rhythm genes which are crucial for maintaining the body's internal biological clock. For instance, studies have found that general anesthesia can cause acute suppression of circadian rhythm gene expression, potentially having profound long-term impacts on cognitive health in elderly patients [54]. This disruption interferes with the normal cyclical release of neurotransmitters, thereby impairing cognitive abilities such as memory, attention, and executive functions.

Furthermore, melatonin – a hormone closely associated with sleep regulation – plays an indispensable role. Its secretion follows circadian rhythms, and disruptions to these patterns have been shown to correlate with increased rates of postoperative delirium and cognitive impairment in elderly patients [55]. The application of exogenous melatonin has demonstrated potential in alleviating certain cognitive impairments, highlighting the feasibility of therapeutic interventions that improve cognitive outcomes through circadian rhythm restoration [56].

In summary, the mechanisms by which circadian rhythm disorders impair cognitive function exhibit multidimensional characteristics, involving complex interactions between circadian rhythms, neurotransmitter systems, and inflammatory responses. Optimizing sleep quality and strategically timing anesthetic administration may prove crucial for improving cognitive performance in elderly surgical patients. To fully elucidate these mechanisms and develop effective countermeasures, sustained research efforts remain essential.

**Impaired brain metabolic waste removal function and abnormal neural network:** Sleep deprivation has been shown to significantly impair the brain's ability to clear metabolic waste, leading to the accumulation of neurotoxic substances and impaired neural connectivity. The glial lymphatic system, a critical network for brain waste removal, primarily functions during sleep to eliminate harmful metabolites closely associated with neurodegenerative diseases like Alzheimer's disease, such as β amyloid plaques and tau proteins [57]. Studies indicate that sleep deprivation damages glial lymphatic function, resulting in elevated levels of metabolic waste in Cerebrospinal Fluid (CSF) and interstitial fluid [58]. For instance, research demonstrates that even a single night of sleep deprivation causes significant increases in CSF metabolic waste levels, suggesting that chronic sleep disorders may progressively worsen neurotoxic substance accumulation over time [59]. This impaired waste clearance capacity poses particular concerns for elderly patients, as

age-related changes in the glial lymphatic system already increase their risk of cognitive decline and delirium [60].

Furthermore, multiple studies have confirmed the correlation between sleep deprivation and neural network dysfunction. Research indicates that sleep disruption alters functional connectivity in critical brain networks, including the Default Mode Network (DMN)which plays a pivotal role in memory and cognitive processes [61]. This impairment not only reduces cognitive performance but also exacerbates symptoms of delirium and other neurocognitive disorders [12]. When sleep is insufficient, the efficiency of the glial lymphatic system significantly declines, triggering a series of neurophysiological changes that ultimately compromise the integrity and connectivity of the nervous system [62]. Beyond directly impairing waste removal, sleep deprivation disrupts the expression and polarization of Aquaporin 4 (AQP4) – a protein essential for Cerebrospinal Fluid (CSF) system function. When this critical protein becomes dysfunctional, it exacerbates the brain's impaired waste clearance, creating a vicious cycle that elevates risks of cognitive impairment and neurodegenerative diseases. These findings carry profound implications, particularly for elderly patients undergoing surgery. Their pre-existing sleep disorders and compromised CSF functions significantly increase postoperative delirium risks [60].

Existing evidence strongly demonstrates that sleep plays a vital role in maintaining brain health, with particularly significant effects observed in older adults. Strategies to improve sleep quality not only enhance cognitive function but also boost the brain's natural waste removal mechanisms, thereby reducing risks of neurodegenerative diseases and postoperative complications. As our understanding of the cerebrospinal fluid system and its relationship with sleep deepens, it becomes increasingly evident that addressing sleep disorders should be a top priority in geriatric care management, especially for surgical patients undergoing procedures.

**Gut microbiota dysbiosis and neurocognitive function:** The Gut-Brain Axis (GBA) is a complex communication network connecting the gastrointestinal tract and central nervous system, regulating physiological and psychological processes such as sleep regulation and cognitive functions. Recent studies reveal that gut microbiota plays a pivotal role in these interactions, particularly in the treatment of sleep disorders and postoperative delirium in elderly patients. Gut microbiota dysbiosis, characterized by microbial imbalance, has been shown to correlate with various neurocognitive impairments including delirium, a condition particularly prevalent during perioperative periods. Research indicates that changes in gut microbiota affect the production of neuroactive substances like Short-Chain Fatty Acids (SCFAs), which are crucial for regulating neuroinflammation and synaptic plasticity, both key factors in maintaining cognitive function and sleep quality [64]. Additionally, gut microbiota influences the synthesis of neurotransmitters such as serotonin and dopamine, which play critical roles in emotional regulation and cognitive activities. When microbial dysbiosis disrupts these metabolic pathways, it may exacerbate neuroinflammation and impair cognitive function, thereby becoming a significant contributing factor to surgical patients developing delirium [65].

The interaction between sleep disorders and gut microbiota holds particular significance in postoperative delirium, as sleep disturbances are prevalent among this population. Research indicates that sleep deprivation exacerbates gut microbiota imbalance, triggering inflammatory cascade reactions that impair cognitive function [66]. For instance, sleep deprivation alters gut microbiota composition, which subsequently activates inflammatory pathways detrimental to brain function. This bidirectional correlation suggests that restoring gut microbiota balance through probiotic supplementation or dietary adjustments may help alleviate sleep disorders and cognitive decline associated with delirium [67]. Furthermore, a deeper understanding of how gut microbiota influences sleep and cognitive functions could pave the way for developing novel therapies targeting the gut-brain axis, thereby improving prognostic outcomes for elderly surgical patients.

In conclusion, the gut-brain axis plays a pivotal role in the interplay between gut microbiota dysbiosis, sleep disorders, and cognitive decline, particularly in the context of postoperative delirium. As scientific understanding of gut health's critical impact on neurocognitive functions deepens, future research should focus on elucidating specific microbial communities involved and their mechanisms of action. These findings are expected to drive the development of precision interventions that not only improve sleep quality but also reduce delirium incidence while enhancing overall cognitive function in vulnerable populations such as elderly surgical patients.

## Perioperative Sleep Management Strategies and their Effects on Postoperative Delirium

**Pharmacological interventions:** Current management of Postoperative Delirium (POD) in elderly patients increasingly emphasizes pharmacological interventions, particularly their effects on sleep quality and

inflammatory responses. A noteworthy study investigated the use of dexamethasone during robot-assisted radical prostatectomy. The results demonstrated that this corticosteroid alleviates postoperative inflammation, thereby improving sleep quality and potentially reducing the risk of delirium [15]. Dexamethasone works by inhibiting the hypothalamic-pituitary-adrenal axis, a neural network frequently activated during surgical stress. By suppressing inflammatory responses, patients may experience improved sleep patterns after surgery, a critical factor given the established link between sleep disorders and increased delirium risks [68]. Additionally, the study highlighted that intravenous dexamethasone not only enhances sleep quality but also accelerates postoperative recovery, indicating its potential as an essential component of perioperative care for elderly patients undergoing major surgeries.

In addition to dexamethasone, other medications such as benzodiazepines, melatonin receptor agonists, and dexmedetomidine have also been used to evaluate their therapeutic effects on postoperative sleep disorders and delirium. While benzodiazepines are widely used due to their sedative properties, studies have found that these drugs increase the risk of delirium, particularly in elderly patients [69]. In contrast, melatonin receptor agonists show promising potential for improving sleep quality without the associated risks of benzodiazepines. Research indicates that melatonin helps regulate circadian rhythm disruption caused by surgery, potentially reducing the incidence of Postoperative Daytime Sleepiness (POD) [70]. As a α-2 adrenergic receptor agonist, dexmedetomidine has garnered attention, for its sedative effects and ability to maintain natural sleep architecture. By alleviating surgical stress responses, this characteristic may effectively prevent delirium [48].

However, the use of these medications is not without risks. Sedatives (particularly in elderly patients) may cause adverse reactions such as respiratory depression and prolonged sedation duration, which can impair postoperative recovery [71]. Therefore, when weighing the benefits of improved sleep quality against potential risks of pharmacological interventions, careful evaluation is essential. Studies indicate that while medications like dexmedetomidine and melatonin receptor agonists can improve sleep quality and reduce delirium risk, they should be used cautiously and personalized adjustments should be made based on individual patient characteristics to optimize treatment outcomes [72].

In elderly patients undergoing perioperative care, integrating pharmacological interventions requires a comprehensive evaluation of their potential benefits in improving sleep quality versus associated risks. Ongoing research on these medications will be crucial for developing evidence-based guidelines that promote postoperative recovery while minimizing complications such as delirium. As our understanding of the mechanisms linking sleep and delirium deepens, establishing clear clinical protocols has become imperative. This not only ensures patient safety but also guarantees effective treatment for this vulnerable population.

**Non-pharmacological interventions:** Non-pharmacological interventions have become essential strategies for managing Postoperative Delirium (POD) in elderly patients, particularly during perioperative care. Environmental regulation plays a crucial role in enhancing patient comfort and reducing delirium risks. Simple measures like earplugs and eye masks can effectively alleviate sensory overload commonly encountered in hospital environments. Research indicates that using blackout curtains at night to control lighting while ensuring adequate daylight exposure during daytime helps restore circadian rhythms, thereby improving sleep quality and decreasing postoperative delirium incidence [73]. Additionally, creating a calming environment through noise reduction and soothing ambiance promotes better sleep and accelerates recovery. This environmental management is especially vital for elderly patients who are more sensitive to external disturbances and prone to delirium. By implementing these simple yet effective strategies, healthcare providers can create rehabilitation-friendly environments, ultimately achieving superior surgical outcomes.

Cognitive Behavioral Therapy (CBT) and sleep hygiene education, as key non-pharmacological interventions, have demonstrated significant efficacy in preventing postoperative delirium. CBT helps patients develop strategies to manage anxiety and stress, known risk factors for delirium. By guiding patients to maintain regular sleep patterns, avoid stimulating activities before bedtime, and create a quiet sleep environment, these interventions effectively help patients regulate their sleep cycles [12]. Such measures not only improve sleep quality but also alleviate preoperative anxiety that may lead to postoperative complications. Studies show that patients who consistently follow CBT and sleep hygiene guidelines exhibit enhanced sleep quality with reduced delirium incidence, highlighting the crucial role of psychological support in perioperative care for elderly patients [74]. Integrating cognitive education strategies into routine clinical practice allows healthcare providers to simultaneously address patients' physical and mental rehabilitation needs.

Physical exercise and non-invasive brain stimulation techniques (such as repetitive transcranial magnetic stimulation, rTMS), have gained significant attention as non-pharmacological interventions in preventing postoperative delirium. Tailoring light exercise regimens to individual patient needs can enhance blood circulation, improve emotional well-being, and elevate overall health status, all crucial factors for reducing delirium risks [75]. Research demonstrates that regular physical activity effectively improves cognitive function and decreases postoperative delirium incidence, with systematic training during the recovery phase showing particularly strong efficacy. Moreover, rTMS has been validated as an innovative therapy for cognitive enhancement, with this non-invasive technology demonstrating notable improvements in cognitive function and reduced delirium rates among elderly patients [76].

The application of rTMS in perioperative care offers new approaches to strengthen cognitive resilience in vulnerable populations. Collectively, these non-pharmacological interventions establish a multidimensional delirium prevention framework, underscoring the necessity to balance physical function and cognitive health in geriatric surgical patients. By integrating these strategies into clinical practice, healthcare providers can not only significantly improve patient outcomes but also effectively alleviate the distress caused by postoperative delirium.

**Multimodal sleep management strategies:** The integration of pharmacological and non-pharmacological interventions in multimodal sleep management has emerged as an effective approach to improve sleep quality in elderly surgical patients. Given the high prevalence of Perioperative Sleep Disorders (PSD) among this population, the synergistic effects of these combined interventions are particularly crucial, as such disorders significantly increase the risk of Postoperative Delirium (POD) and cognitive impairment. Pharmacological interventions such as dexmedetomidine and melatonin receptor agonists have been proven to improve sleep quality and reduce POD incidence [6], working through mechanisms that regulate sleep architecture and promote sleep onset, thereby mitigating the negative impact of surgical stress on sleep. Non-pharmacological strategies like cognitive behavioral therapy for insomnia, environmental optimization (such as noise reduction and light intensity control), and cultivation of sleep hygiene habits have also demonstrated benefits in enhancing sleep quality. Research indicates that these non-invasive methods effectively alleviate anxiety and promote relaxation, key elements for achieving restorative sleep [12].

The combined application of these strategies not only improves immediate sleep quality but also facilitates overall postoperative recovery, as good sleep is closely associated with reduced pain sensitivity and improved emotional well-being [6]. However, implementing multimodal sleep management presents challenges. Individual patient variations, including existing sleep disorders, comorbidities, and anesthesia effects, complicate personalized intervention approaches. Additionally, the lack of standardized protocols for perioperative sleep disorder assessment and management may hinder the effective implementation of multimodal interventions [77]. Developing personalized care plans is crucial, requiring thorough consideration of each patient's specific circumstances to maximize the effectiveness of combined interventions. Future research should focus on establishing evidence-based guidelines to promote the integration of multimodal sleep management into routine perioperative care protocols. This ensures elderly patients receive comprehensive support during this critical phase, meeting their sleep needs effectively.

The implementation of perioperative individualized sleep management presents both opportunities and challenges. As the academic community increasingly recognizes the impact of sleep disorders on postoperative outcomes particularly in elderly patients personalized interventions for this population have become crucial. This management model requires comprehensive evaluation of each patient's sleep history, underlying conditions, and potential effects of surgical procedures and anesthesia on sleep patterns. Such personalized strategies can identify modifiable risk factors (such as anxiety, pain, and environmental stressors), and manage them through a combination of pharmacological and non-pharmacological interventions [6]. However, practical implementation of individualized sleep management still faces multiple challenges.

The primary obstacle lies in the lack of standardized assessment tools and perioperative sleep quality monitoring protocols. Differences between subjective questionnaires and polysomnography-based evaluations make it difficult to establish a unified intervention framework [78]. Moreover, the multifactorial nature of sleep disorders in elderly patients, influenced by comorbidities such as dementia, depression, and obstructive sleep apnea, necessitates multidisciplinary approaches that may not always be feasible in current clinical settings [79]. Additionally, concerns about potential side effects and drug interactions often lead physicians to avoid medication interventions, resulting in inadequate sleep disorder treatment [80]. Therefore, establishing a

collaborative medical team involving anesthesiologists, geriatric specialists, and nursing staff is essential for developing and implementing effective personalized sleep management plans. By promoting a collaborative team model, healthcare professionals can share expertise and experience, thereby improving the overall quality of care for elderly surgical patients. In conclusion, while perioperative individualized sleep management holds significant potential, overcoming related challenges requires coordinated efforts from multiple stakeholders: standardizing assessment protocols, strengthening interdisciplinary collaboration, and integrating sleep management into routine perioperative care systems.

## Relationship between Intraoperative Pain Management, Sleep and Delirium

**Mechanism of pain's effect on sleep quality:** Acute pain is a significant disruptor of sleep quality, not only affecting duration but also altering sleep architecture. The relationship between pain and sleep is complex and bidirectional: pain can cause sleep disturbances, while poor sleep quality may exacerbate pain perception. Acute pain typically manifests as sudden onset with intense intensity, triggering physiological and psychological responses that severely disrupt sleep patterns. For instance, patients may struggle to fall asleep or maintain sleep due to pain. This disruption is evident in multiple aspects, including difficulty falling asleep, frequent awakenings, and reduced total sleep time [81,82]. Additionally, sleep architecture undergoes changes with decreased proportions of restorative deep sleep and Rapid Eye Movement (REM) sleep, both crucial for physical and mental recovery [83,84].

Research indicates that acute pain increases the frequency of arousal during sleep, leading to fragmented sleep patterns. These disruptions not only reduce overall sleep quality but also weaken its restorative effects, creating a vicious cycle where pain and sleep disorders reinforce each other [85,86]. The neurobiological mechanism involves activating the body's stress response system (including the hypothalamic-pituitary-adrenal axis), which triggers elevated levels of stress hormones like cortisol, further impairing sleep quality [87,88].

Furthermore, psychological and emotional factors associated with pain management may contribute to sleep disorders. Pain-related anxiety and stress can create a state of heightened alertness, making it harder for patients to relax and fall asleep [89,90]. This emotional distress forms a vicious cycle: poor sleep quality increases pain sensitivity, which in turn intensifies pain perception, leading to more sleep issues [91,92].

In clinical practice, improving sleep quality is crucial for acute pain management, as enhanced sleep quality significantly promotes pain control and overall recovery. Interventions such as Insomnia Cognitive Behavioral Therapy (CBT-I) or pharmacological approaches to improve sleep quality may positively impact both pain relief and sleep disorders [93,94]. Furthermore, a deeper understanding of the complex relationship between pain and sleep enables healthcare providers to develop integrated treatment plans addressing both issues simultaneously, thereby effectively improving patient outcomes and quality of life [95,96].

In summary, acute pain profoundly impacts sleep quality by disrupting sleep architecture and significantly reducing overall restorative efficiency. Addressing these challenges is crucial for effective pain management and improving the quality of life for patients with acute pain. Future research should continue to explore the mechanisms linking pain and sleep, while developing evidence-based interventions to mitigate these adverse effects.

**Pain control strategies and their effects on sleep and cognition:** Perioperative pain management is crucial, particularly for elderly patients, as it significantly impacts postoperative recovery, sleep quality, and cognitive function. Recent studies have compared regional anesthesia techniques such as Psoas Muscle Block (PCB) with traditional methods in terms of analgesic efficacy and subsequent effects on sleep and cognition. Research indicates that PCB technology provides effective pain relief, potentially reduces opioid dosage, and decreases systemic opioid-related side effects like drowsiness and cognitive impairment [97]. In contrast, conventional anesthesia often over-reliance on opioids may exacerbate postoperative sleep disorders and induce delirium, a phenomenon more pronounced in older adults [94]. Clinical evidence shows that PCB technology improves pain management and enhances postoperative sleep quality patients receiving this block experience fewer awakenings and higher sleep efficiency compared to traditional anesthesia groups [94-98]. Furthermore, improved sleep quality profoundly affects cognitive function: multiple studies demonstrate that good sleep correlates closely with cognitive improvement, suggesting that effective analgesic strategies like PCB can reduce the risk of postoperative cognitive impairment [97]. Therefore, the choice of anesthesia not only impacts immediate pain control but also has lasting effects on patients' overall recovery trajectory, underscoring the necessity of tailoring anesthesia approaches for elderly populations.

Pain medications play a crucial role in postoperative pain

management, but their impact on sleep quality and the risk of postoperative delirium requires careful consideration, especially in elderly patients. While opioids effectively relieve pain, they disrupt sleep architecture, leading to increased sleep fragmentation and reduced sleep quality [94]. This disruption may accelerate cognitive decline and increase the risk of delirium, a common postoperative complication in older patients [98]. In contrast, non-opioid analgesics such as acetaminophen and Nonsteroidal Anti-Inflammatory Drugs (NSAIDs) can adequately control pain while minimizing adverse effects on sleep and cognition [97]. Additionally, multimodal analgesia (integrating different types of analgesic agents) has been proven to reduce opioid use while enhancing pain relief, thereby maintaining sleep quality and lowering delirium incidence [94-98]. The interaction between pain control and sleep is particularly critical: sleep deprivation exacerbates pain perception, creating a vicious cycle that impacts recovery progress and cognitive function [97]. Therefore, clinicians must strike a balance between effective pain management and potential cognitive/sleep-related issues caused by analgesics, advocating personalized treatment plans that prioritize sleep quality and cognitive health while providing pain relief for elderly postoperative patients.

**Early postoperative activity and its relationship with sleep recovery:** The relationship between early postoperative activity and sleep recovery remains a key focus of current research, particularly for elderly patients who face higher risks of postoperative complications such as sleep disorders and cognitive decline. Studies demonstrate that early mobilization significantly enhances recovery outcomes, with improved sleep quality being crucial for cognitive rehabilitation. For instance, a survey of liver resection patients using the Pittsburgh Sleep Quality Index (PSQI) revealed that those who actively engaged in early activities showed markedly better sleep quality than inactive groups [99]. This improvement in sleep quality is particularly significant. As sleep deprivation not only exacerbates postoperative pain and increases delirium risk but also prolongs hospital stays, thereby delaying recovery. Moreover, early postoperative activity facilitates rapid gastrointestinal recovery, which not only improves overall health status but also effectively reduces the incidence of postoperative complications [69].

The physiological mechanisms behind these benefits are multifaceted. Postoperative physical activity enhances blood circulation and triggers endorphin release, which helps alleviate pain, improve mood, and consequently promote better sleep quality [100]. Moreover, early mobilization aids in restoring circadian rhythm disruptions caused by surgery and anesthesia, thereby optimizing sleep patterns. For instance, patients undergoing total knee replacement who participated in early rehabilitation training not only reported reduced pain levels but also demonstrated positive outcomes including improved sleep quality and accelerated functional recovery [101].

Furthermore, the psychological dimension of early rehabilitation activities should not be overlooked. Research indicates that patients who engage in light exercise tend to better manage their recovery process, effectively alleviating common postoperative anxiety and depressive symptoms [102]. This psychological empowerment is crucial, as mental health is closely linked to sleep quality and cognitive function. Studies show that patients with preoperative sleep disorders face higher risks of cognitive impairment after surgery, highlighting the importance of considering both physiological and psychological factors when developing rehabilitation plans [17].

In conclusion, existing evidence demonstrates a significant correlation between early postoperative activity and improved sleep quality, which in turn promotes cognitive function recovery. Implementing structured early rehabilitation programs during postoperative care, particularly for elderly patients, can effectively enhance the effectiveness of rehabilitation. This approach not only reduces postoperative complication rates but also creates a holistic recovery environment that addresses both physical and mental health needs, ultimately improving patients' quality of life. Future research should continue exploring optimal early activity types and intensities tailored to different surgical populations, aiming to achieve optimal sleep quality and cognitive function recovery outcomes.

## Effects of Perioperative Inflammatory Response on Sleep and Cognitive Function

**Surgical stress and systemic inflammatory response:** Surgical stress represents a significant physiological challenge that triggers systemic inflammatory responses, which may profoundly impact the Central Nervous System (CNS). Characterized by the release of various inflammatory mediators including cytokines, chemokines, and acute phase proteins, this stress response affects neuronal function and contributes to postoperative complications such as delirium and cognitive impairment. For instance, Interleukin-6 (IL-6) and C-Reactive Protein (CRP), key inflammatory markers, have been shown to correlate with cognitive deficits in surgical patients [103,104]. During surgical stress, activation of the Hypothalamic-Pituitary-Adrenal (HPA) axis elevates cortisol levels, exacerbating inflammation and impairing neuroplasticity – factors that collectively increase the risk of postoperative neuropsychiatric

disorders [105]. Furthermore, the inflammatory environment damages the Blood-Brain Barrier (BBB), allowing pro-inflammatory cytokines to infiltrate the CNS and intensify neuroinflammation, potentially leading to long-term cognitive deficits [106,107].

Furthermore, inflammatory mediators exert their effects through modulation of neuroimmune interactions. Activated microglia and astrocytes release increased inflammatory cytokines, creating a vicious cycle of neuroinflammation [108]. This neuroinflammatory response may lead to synaptic dysfunction and neuronal apoptosis, subsequently causing Postoperative Cognitive Impairment (POCD) and delirium – particularly prevalent among vulnerable populations such as the elderly [109,110]. The regulation of these inflammatory responses through anesthetic techniques (e.g., regional anesthesia or anti-inflammatory medications) has been proposed as an effective strategy to mitigate these adverse effects [111,112].

In conclusion, the systemic inflammatory response triggered by surgical stress plays a critical role in central nervous system function and may lead to severe postoperative complications. A thorough understanding of the complex relationship between surgical stress, inflammatory mediators, and central nervous system prognosis is essential for developing effective strategies to reduce cognitive impairment and promote patient recovery. Future research should focus on identifying biomarkers that predict postoperative cognitive outcomes and implementing targeted interventions to regulate perioperative inflammatory responses [113,114].

**Mechanism of action of anti-inflammatory drugs such as dexamethasone:** Dexamethasone and other anti-inflammatory drugs play multiple roles in managing inflammatory responses and improving sleep quality during perioperative care for elderly patients. As a synthetic glucocorticoid, dexamethasone primarily exerts its effects by inhibiting the Hypothalamic-Pituitary-Adrenal (HPA) axis, which serves as the key mechanism for stress response and inflammation regulation. By suppressing this axis, dexamethasone effectively reduces ACTH secretion, thereby lowering cortisol levels and helping alleviate the inflammatory responses commonly associated with surgical stress. This reduction in inflammation is crucial because elevated inflammatory markers are closely linked to postoperative complications such as delirium and decreased sleep quality, particularly in elderly patients who are already vulnerable to these conditions [15].

Furthermore, studies have demonstrated that dexamethasone inhibits the production of pro-inflammatory cytokines such as Interleukin-6 (IL-6) and Tumor Necrosis Factor-α (TNF-α). These inflammatory mediators not only exacerbate inflammation but also contribute to sleep disturbances [115]. By regulating these inflammatory pathways, dexamethasone effectively alleviates inflammation while improving postoperative sleep quality. The interplay between inflammation and sleep has been well-documented: elevated levels of inflammatory cytokines disrupt sleep patterns, whereas adequate rest is crucial for recovery and cognitive function, a finding particularly evident in elderly populations [116].

Dexamethasone not only provides anti-inflammatory benefits but also enhances sleep quality by promoting postoperative recovery. Studies indicate that patients receiving dexamethasone therapy demonstrate better pain management after surgery, which significantly improves sleep quality [115]. Given that pain is a major contributor to postoperative sleep disorders, effective pain relief through dexamethasone helps create a more conducive environment for restful sleep.Furthermore, the timing and dosage of dexamethasone administration are crucial for maximizing its therapeutic benefits while minimizing potential side effects such as hyperglycemia and immunosuppression. These adverse effects may complicate postoperative recovery in elderly patients [117]. By carefully considering these factors, we can effectively enhance dexamethasone's therapeutic efficacy in reducing inflammation and improving sleep quality, ultimately achieving better surgical rehabilitation outcomes.

Overall, the anti-inflammatory mechanism of dexamethasone highlights its crucial value in perioperative management of elderly patients. By effectively suppressing the hypothalamic-pituitary-adrenal axis and reducing inflammatory cytokine levels, this medication not only alleviates surgery-related inflammatory responses but also significantly improves sleep quality, thereby facilitating better postoperative recovery outcomes for this vulnerable population. Future research should continue exploring optimized strategies for using dexamethasone and other anti-inflammatory drugs in elderly patients' sleep management and postoperative delirium prevention.

**Interaction between inflammation, sleep disorders and delirium:** Chronic inflammation has been increasingly recognized as a significant factor influencing sleep disorders and cognitive decline, particularly evident in elderly populations. The interaction between these two factors is complex: chronic inflammatory states can induce sleep disturbances, which in turn exacerbate cognitive

impairment and increase postoperative delirium risks. Studies indicate that systemic inflammation disrupts normal sleep patterns, leading to common conditions like insomnia and obstructive sleep apnea, symptoms that are especially prevalent among older adults [118]. Inflammation also alters neurotransmitter systems involved in sleep regulation (such as serotonin and norepinephrine), thereby reducing both sleep quality and duration [119]. Notably, sleep deprivation itself triggers inflammatory responses, creating a vicious cycle: poor sleep quality worsens inflammation, which subsequently damages cognitive function and elevates postoperative delirium risks [12].

Clinical studies have confirmed that elevated levels of inflammatory markers such as Interleukin-6 (IL-6) and C-Reactive Protein (CRP) are closely associated with sleep disorders and cognitive decline [120]. In chronic sleep-deprived patients, for instance, neuroinflammatory responses are significantly intensified, a condition directly linked to memory impairment and attention deficits [121]. This correlation warrants particular attention in postoperative care. As surgical stress exacerbates existing inflammatory states, it substantially increases the incidence of postoperative delirium [122].

Furthermore, these interactions involve mechanisms such as Blood-Brain Barrier (BBB) disruption and alterations in neuroinflammatory pathways. Chronic inflammation increases BBB permeability, allowing inflammatory cytokines to enter the central nervous system and impair neuronal function [123]. This process proves particularly detrimental for elderly individuals, as aging brains are inherently more susceptible to inflammatory damage. The cumulative effects of chronic inflammation and sleep disorders may lead to neurodegenerative changes, including the accumulation of βamyloid and tau proteins which are closely associated with Alzheimer's disease and other forms of dementia [118].

Therefore, interventions targeting inflammation and sleep quality may be crucial for delaying cognitive decline and reducing the risk of delirium in older adults. Strategies such as cognitive behavioral therapy for insomnia, pharmacological treatments for sleep disorders, and anti-inflammatory therapies could help break the vicious cycle between inflammation and cognitive impairment [124]. Moreover, lifestyle changes like regular exercise and dietary adjustments have been proven to effectively reduce inflammatory levels and improve sleep quality, further supporting efforts to maintain cognitive health [119].

In summary, the interplay between chronic inflammation, sleep disorders, and cognitive impairment represents a pivotal research focus. This highlights the critical need for comprehensive management strategies in elderly populations, particularly during perioperative care. Understanding these connections enables healthcare providers to develop targeted interventions that enhance surgical outcomes for older patients undergoing procedures.

## Assessment and Prediction of Perioperative Sleep Disorders and Delirium Risk in Elderly Patients

**Existing risk assessment tools and their applicability:** In perioperative care for elderly patients, sleep quality assessment and Postoperative Delirium (POD) prediction are critical factors influencing patient outcomes. Multiple evaluation tools have been developed, with the Pittsburgh Sleep Quality Index (PSQI) being the most widely used. This scale assesses subjective sleep quality, time to fall asleep, duration of sleep, sleep efficiency, sleep disorders, use of sedatives, and daytime functional impairment. Studies indicate that surgical patients with poor sleep quality show significantly increased risks of postoperative delirium, particularly in older populations [125]. For instance, a meta-analysis demonstrates a strong correlation between preoperative sleep disturbances and postoperative delirium incidence, underscoring the importance of routine sleep assessments for elderly patients [126].

In addition to sleep quality assessment tools, researchers have developed various delirium prediction models to identify high-risk patients for Postoperative Delirium (POD). These models typically integrate multiple risk factors such as age, cognitive impairment, and pre-existing conditions. For instance, the Duke Anesthesia Resistance Scale (DARS) and Delirium Risk Assessment Tool (DRAT) have undergone predictive validity validation in surgical settings. Studies show that DARS demonstrates significant predictive efficacy in predicting postoperative delirium among elderly patients with hip fractures, where higher scores correlate with greater delirium risks [127]. Similarly, validation of DRAT across different surgical populations has demonstrated its effectiveness in identifying patient groups suitable for targeted preventive measures [128].

Furthermore, machine learning approaches have emerged as a game-changing solution for predicting operative time (POD), leveraging electronic health record data to optimize risk stratification. Cutting-edge research demonstrates that machine learning models

outperform traditional logistic regression in surgical timing predictions, signalling a clinical shift toward more precise forecasting methods [129]. These advancements highlight the transformative potential of integrating machine learning algorithms with existing diagnostic tools, enabling more accurate identification of high-risk patient populations.

While existing evaluation tools and predictive models are now ready for clinical use, their practical implementation in medical practice remains significantly limited. Challenges such as insufficient awareness among healthcare professionals, inadequate training programs, and the inherent complexity of risk factors have hindered widespread adoption. More critically, current models face persistent issues including high bias risks and inadequate external validation, raising questions about their applicability across diverse patient populations [130]. Therefore, it is imperative to conduct ongoing research to refine these tools' performance, validate their effectiveness in various surgical scenarios, and establish standardized perioperative care protocols.

In conclusion, integrating sleep quality assessment scales with delirium prediction models is crucial for improving perioperative management of elderly patients. By identifying high-risk groups for postoperative complications (POD), healthcare providers can implement targeted interventions to enhance patient outcomes and reduce the burden of postoperative complications. Future research should focus on validating these tools' applicability across different surgical scenarios and exploring the potential advantages of combining traditional assessment methods with advanced predictive analytics.

**Biomarkers and neuroimaging to aid prediction:** The correlation between biomarkers and neuroimaging techniques in predicting postoperative delirium (POD) in elderly patients has garnered increasing attention, particularly as inflammatory factors have been identified as potential mediators. Recent studies indicate that the Systemic Inflammatory Index (SII) serves as a significant predictor of postoperative sleep disorders, which are closely associated with delirium. A prospective cohort study involving 500 elderly patients undergoing total joint replacement revealed that those with SII values ≥500.3 showed a significantly increased risk of postoperative sleep disorders, with a odds ratio of 3.26 observed in univariate analysis, a strong association persisting even in multivariate models [131].

This demonstrates that SII, obtained through routine blood tests, not only serves as an easily accessible biomarker but also acts as an economically effective tool for assessing POD risks, highlighting the importance of perioperative inflammatory processes. Additionally, the Neutrophil/Lymphocyte Ratio (NLR) has emerged as a relevant biomarker, especially in Obstructive Sleep Apnea (OSA), a known risk factor for perioperative complications. Research indicates that NLR levels are markedly elevated in high-risk OSA patients, further confirming the link between systemic inflammatory responses and surgical sleep-related complications [132].

Beyond inflammatory biomarkers, neuroimaging techniques such as functional Magnetic Resonance Imaging (fMRI) and Electroencephalography (EEG) are crucial for elucidating the neurobiological mechanisms underlying Postoperative Delirium (POD). For instance, a study of surgical aortic valve replacement patients revealed that specific infarction sites and altered brain connectivity were associated with increased postoperative delirium incidence. Notably, patients developing delirium exhibited larger lesions in critical brain regions like the right cerebellum and temporal lobe white matter, suggesting that occult brain damage may significantly contribute to delirium onset [133]. This underscores the importance of advanced neuroimaging technologies in detecting subtle brain changes unobservable through conventional assessments. Additionally, Non-Dissemination Diffusion Imaging (NODDI) has been validated for identifying microstructural brain damage linked to cognitive impairment and delirium risk. A preoperative diffusion MRI analysis demonstrated significant differences in microscopic structural metrics among patients who later developed postoperative delirium, indicating that preoperative brain abnormalities may predispose patients to postoperative cognitive dysfunction [134].

The integration of inflammatory biomarkers with neuroimaging findings enables a comprehensive understanding of Postoperative Delirium (POD) mechanisms in elderly patients. By identifying high-risk groups through these predictive indicators, targeted interventions can be implemented to reduce delirium incidence. For instance, personalized anesthesia protocols and proactive postoperative care strategies can be developed by combining individual risk profiles with inflammatory status and neuroimaging results. Furthermore, recent studies suggest that neuroprotective agents may mitigate anesthesia-related neurotoxicity, underscoring the necessity for longitudinal research integrating biomarkers and imaging technologies to improve patient outcomes [135]. Ultimately, collaboration between clinical practice and scientific research in applying biomarkers and neuroimaging will pave new pathways for

optimizing predictive models and therapeutic strategies for postoperative delirium in elderly patients.

**Personalized risk management strategies:** Given the high incidence of Postoperative Delirium (POD) in geriatric surgical patients, developing personalized sleep management and delirium prevention strategies is crucial. By comprehensively evaluating multidimensional risk factors such as preoperative cognitive function, comorbidities, and sleep quality, tailored intervention plans can be formulated for each patient. Studies indicate that preoperative cognitive impairment significantly increases POD risk, with up to 70% of elderly patients experiencing POD [1]. Therefore, incorporating cognitive function assessment into preoperative evaluations helps identify high-risk groups and enable early intervention. Notably, sleep disorders have been proven to be a major contributor to POD, and preoperative interventions can effectively reduce delirium risks [15].

Non-pharmacological interventions like optimizing sleep hygiene habits and environmental adjustments serve as vital components of the delirium prevention system. For instance, ensuring adequate daylight exposure and minimizing nighttime disturbances not only improves sleep quality but also reduces POD incidence [73]. Additionally, predictive models (such as the Duke Anesthesia Resistance Scale-DARS) can stratify patients based on their POD risk, allowing healthcare providers to allocate resources efficiently and implement targeted preventive measures [127]. Through interdisciplinary collaboration involving geriatric medicine specialists, anesthesiologists, and nursing teams, we can create customized plans combining pharmacological treatments and non-pharmacological interventions for each patient. This precision medicine approach not only enhances care quality but also optimizes postoperative recovery outcomes, thereby alleviating the dual pressures of delirium on both patients and healthcare systems.

## Future Research Direction and Clinical Practice Outlook

**Development and application of new sleep management techniques:** In elderly patients, particularly in perioperative care management, significant progress has been made in treating sleep disorders through the development and application of new technologies. Novel medications like eszopiclone have demonstrated effectiveness in improving sleep quality and cognitive function in Alzheimer's disease patients with sleep disorders, indicating that pharmacological interventions may promote postoperative rehabilitation [136]. Additionally, brain stimulation techniques such as Transcranial Magnetic Stimulation (TMS) are emerging as novel options for treating sleep disorders. TMS can regulate sleep-regulating neural circuits to improve sleep architecture and alleviate insomnia symptoms in older adults [137]. Digital health tools, particularly smartphone apps and wearable devices are increasingly popular as convenient sleep monitoring solutions.

A systematic review highlights that multiple sleep-related apps assist in diagnosing and managing sleep disorders (including obstructive sleep apnea), with their role in personalized sleep management strategies becoming increasingly prominent [138]. These applications not only provide real-time sleep pattern data but also enhance patient engagement through self-monitoring and feedback mechanisms, which is crucial for ensuring treatment adherence. Furthermore, integrating telemedicine into sleep management allows remote consultations and follow-ups, enabling healthcare providers to monitor patient progress more easily and adjust treatment plans as needed [139]. The combination of these innovative approaches pharmacology, technology, and telemedicine promises to improve sleep quality, reduce postoperative delirium rates in elderly patients, thereby enhancing overall surgical outcomes and quality of life.

**Construction of multi-disciplinary collaboration mode:** The perioperative management of elderly patients requires establishing a multidisciplinary collaborative model that integrates the professional expertise of anesthesiology, neurology, psychiatry, and nursing teams. This coordinated mechanism is crucial for addressing the unique challenges faced by this population, particularly in managing sleep disorders and preventing postoperative delirium. Anesthesiologists play a pivotal role in developing personalized anesthesia plans, requiring comprehensive consideration of patients 'overall health status, comorbidities, and potential anesthesia-related risks. For instance, elderly patients are often more susceptible to the effects of anesthetic drugs, which may exacerbate cognitive decline and increase the risk of postoperative complications (such as delirium) [140]. Neurologists, through evaluating patients' baseline cognitive levels and identifying pre-existing neurological conditions that may impact postoperative recovery, provide critical guidance for optimizing anesthesia techniques and postoperative care protocols. This approach effectively reduces risks and promotes rehabilitation.

Psychiatrists play a vital role in this healthcare framework, particularly in addressing psychological challenges arising from surgical interventions. They can

identify patients at high risk of anxiety and depression – emotional factors that may hinder recovery. By conducting preoperative psychological assessments and implementing interventions, psychiatrists effectively alleviate anxiety, thereby enhancing overall treatment outcomes [141]. Furthermore, the nursing team plays a central role in monitoring patients' physical and mental health throughout the perioperative period. Nurses often serve as the first line of defense in recognizing postoperative delirium symptoms and developing strategies to improve sleep hygiene practices while reducing environmental stressors – the primary culprits behind sleep disorders. Specific measures include creating restorative environments, educating patients and families about postoperative recovery protocols, and ensuring proper pain management. All these efforts are crucial for successful rehabilitation.

Establishing structured communication frameworks among interdisciplinary teams is crucial to ensure alignment of objectives and interventions. Regular cross-disciplinary meetings facilitate the sharing of insights into patient progress and updates, enabling timely adjustments to care plans based on actual circumstances. Additionally, implementing training programs that emphasize teamwork can further enhance the effectiveness of this model. By fostering a work environment characterized by mutual respect and open communication, healthcare professionals can collaborate more efficiently in addressing the complex needs of geriatric surgical patients.

In conclusion, establishing a multidisciplinary collaborative model integrating anesthesiology, neurology, psychiatry, and nursing teams is crucial for optimizing perioperative management of elderly patients. This approach not only enhances surgical safety and effectiveness but also significantly improves patient experience by addressing both medical and psychological needs. With the intensifying population aging and increasing surgical demands, the importance of such collaborative models will grow increasingly prominent. This reality calls for continuous research and development efforts to refine clinical practices, ultimately delivering superior treatment outcomes for elderly patients undergoing surgery.

**Need for large-scale multicenter clinical trials:** The relationship between perioperative sleep management and Postoperative Delirium (POD) in elderly patients highlights the necessity of large-scale multicenter clinical trials to verify the effectiveness of sleep interventions. Postoperative delirium, a significant complication particularly prevalent among older adults, can lead to cognitive impairment, prolonged hospital stays, and increased healthcare costs [142]. Identifying effective strategies to alleviate postoperative delirium is crucial, as sleep disorders have been confirmed as independent risk factors for its development [15]. Recent studies suggest that medications like dexmedetomidine and dexamethasone may indirectly reduce postoperative delirium incidence by improving perioperative sleep quality [15-143]. However, due to limited sample sizes and single-center designs, small-scale research findings often lack generalizability and fail to adequately reflect the diversity of elderly surgical patients. Therefore, conducting multicenter trials is essential for establishing evidence-based interventions such as pharmacological treatments or cognitive behavioral therapies for insomnia, which can significantly reduce postoperative delirium rates and improve recovery outcomes.

Beyond verifying the efficacy of sleep interventions, these large-scale clinical trials will also help explore multiple factors influencing the relationship between sleep quality and cognitive outcomes. For instance, the interactions between preoperative sleep quality, surgical stress, and postoperative recovery demonstrate complexity and multifactorial nature. Developing personalized sleep intervention plans based on baseline characteristics such as patient age, comorbidities, and existing sleep disorders can enhance the precision of perioperative care [144]. Furthermore, multicenter studies provide a platform to evaluate how different surgical approaches affect sleep quality and cognitive function, thereby offering a more comprehensive understanding of how surgical stressors contribute to postoperative cognitive impairment (POD) across various scenarios.

Furthermore, implementing standardized treatment protocols across multiple medical centers can effectively collect high-quality data. This data is crucial for evaluating the actual effectiveness of sleep interventions on postoperative recovery days (POD) and other surgical outcomes. By adopting unified methods for sleep quality assessment, cognitive function testing, and delirium incidence statistics, researchers can obtain more reliable and comparable data results. Given the variations in perioperative care management and patient prognosis monitoring among different medical institutions [145], such standardized protocols become particularly vital.

Ultimately, the findings from these large-scale multicenter trials hold significant implications for clinical practice and healthcare policy. Developing evidence-based perioperative sleep management guidelines not only enhances postoperative recovery outcomes and reduces medical costs for elderly patients, but also

optimizes their rehabilitation protocols. Therefore, investing in multicenter trials to explore the impact of sleep interventions on Postoperative Delirium (POD) is not only essential but also a critical initiative to advance perioperative medicine and improve care quality for vulnerable populations [146]. In conclusion, conducting large-scale multicenter clinical trials is vital to validate the value of sleep interventions in reducing postoperative delirium and improving overall surgical outcomes among elderly patients. This will ultimately foster higher-quality medical practices and patient-centered care models.

**Development and promotion of perioperative sleep management guidelines:** Developing and promoting perioperative sleep management guidelines is crucial for addressing the high incidence of postoperative sleep disorders in elderly patients. These sleep disturbances may lead to adverse outcomes such as delirium, cognitive decline, and prolonged recovery periods. Recent studies have shown significant variations in perioperative sleep disorder prevalence among elderly surgical patients: 0-91% preoperatively versus 6.7-93% postoperatively [6]. Guidelines should be developed based on comprehensive understanding of perioperative sleep disorder epidemiology, integrating subjective assessments (e.g., Pittsburgh Sleep Quality Index) with objective monitoring methods (e.g., polysomnography) to achieve precise diagnosis and effective management [147]. Additionally, guidelines must emphasize the importance of establishing multidisciplinary collaboration mechanisms involving anesthesiologists, surgeons, nurses, and sleep specialists to ensure systematic implementation of sleep management throughout the perioperative period.

Standardized clinical protocols are essential for reducing sleep disorder-related risks, which are often exacerbated by adverse factors such as pain management, anesthesia administration, and hospital environments [148]. Clinical guidelines should promote multimodal interventions that combine pharmacological treatments (e.g., melatonin and dexmedetomidine) with non-pharmacological approaches (e.g., cognitive behavioral therapy), along with environmental adaptations to improve sleep quality [149]. Furthermore, implementing these guidelines requires establishing a sustained healthcare education system to ensure medical professionals consistently adhere to best practice standards in sleep management.

To promote the widespread adoption of these guidelines, it is crucial to involve all stakeholders including healthcare professionals, patients, and policymakers in the development process. This collaborative approach enables tailored guideline content that addresses the specific needs of different patient groups while ensuring practical applicability across various clinical scenarios [150]. Furthermore, implementing quality improvement programs and performance evaluation metrics can effectively monitor guideline implementation and their impact on patient outcomes, thereby fostering a culture of accountability and continuous improvement in perioperative care [6].

In conclusion, developing standardized perioperative sleep management guidelines is crucial for improving care quality in geriatric surgical patients. By implementing systematic clinical practices to address the multidimensional nature of sleep disorders, these guidelines can not only significantly enhance postoperative recovery and reduce complication rates, but ultimately elevate the overall nursing standards for this vulnerable population. Future research should focus on refining guideline content based on the latest evidence and exploring innovative strategies to optimize perioperative sleep management [151].

## BEAR

In conclusion, perioperative sleep disorders serve as a significant independent risk factor for postoperative delirium in elderly patients, highlighting the urgent need to optimize sleep management strategies to alleviate cognitive impairment following surgery. These sleep disturbances involve multifaceted factors including neuroinflammation, compromised blood-brain barrier function, and circadian rhythm disruptions, with their complex impact on postoperative delirium being self-evident. Such intricate causality demands a thorough understanding of underlying mechanisms to effectively address and manage perioperative sleep disorders.

Recent studies demonstrate that both pharmacological treatments and non-pharmacological interventions show significant efficacy in improving sleep quality and reducing delirium risks. Medications such as dexamethasone and dexmedetomidine, when combined with environmental adjustments and non-pharmacological therapies like repetitive Transcranial Magnetic Stimulation (rTMS), have been proven to yield notable results. The key challenge lies in balancing these diverse approaches to develop comprehensive management strategies tailored to the individual needs of elderly patients.

Pain management has emerged as a pivotal factor in improving sleep quality and preventing delirium. Extensive research confirms the interplay between pain and sleep patterns, demonstrating that optimized pain control significantly enhances sleep quality and reduces the risk of delirium. Therefore, developing personalized

multimodal sleep management strategies incorporating effective pain control is crucial for enhancing treatment outcomes in elderly surgical patients.

Looking ahead, there is an urgent need to conduct large-scale multicenter clinical studies to establish a scientifically rigorous risk assessment system and comprehensive sleep management guidelines. Such initiatives will not only improve perioperative sleep quality for elderly patients but also effectively reduce postoperative delirium incidence. Ultimately, enhancing perioperative sleep quality plays a crucial role in optimizing patient outcomes and ensuring surgical effectiveness.

In conclusion, while existing research has conclusively established the critical role of sleep disorders in postoperative delirium, developing effective intervention strategies still requires further exploration. By strengthening collaboration among researchers, clinicians, and stakeholders, we can not only deepen our understanding of this complex issue but also implement evidence-based approaches that prioritize the well-being of elderly surgical patients. Integrating diverse research perspectives and findings will be crucial for achieving balanced sleep management strategies, ultimately improving postoperative care quality and treatment outcomes for this vulnerable population.

## REFERENCES

1. Travers R, Gagliardi G, Ramseyer M. Delirium management in perioperative geriatric services: a narrative review of non-pharmaceutical strategies. Front Psychiatr. 2024; 15: 1394583.
2. Miao Q, Zhou R, Li X, Xiong L. Bibliometric Analysis of the Top-100 Cited Articles on Postoperative Delirium. J Multidiscip Health. 2024; 17: 2961-2972.
3. Liu Y, Shen W, Tian Z. Using Machine Learning Algorithms to Predict High-Risk Factors for Postoperative Delirium in Elderly Patients. Clin Interv Aging. 2023; 18: 157-168.
4. Ruel M, Boussat B, Boudissa M. Preoperative Pain Management in Elderly Patients with Moderate to Severe Cognitive Impairment and Hip Fractures: A Retrospective Single-Center Study from the Orthopedic Geriatrics Center. BMC Geriatrics. 2021; 21: 575.
5. Lim C, Roh YH, Park YG, Lee J, Nam KW. Is there a difference between preoperative and postoperative delirium in elderly hip fracture patients?: A retrospective case control study. Medicine (Baltimore). 2024; 103: e36584.
6. Guo H, Li LH, Xiao F, Xie YB. Perioperative sleep disturbances in older adults: a scoping review of epidemiology and treatment. Eur Geriatr Med. 2025.
7. Liu Y, Zhang X, Jiang M, Zhang Y, Wang C, Sun Y, et al. Impact of Preoperative Sleep Disturbances on Postoperative Delirium in Patients with Intracranial Tumors: A Prospective, Observational, Cohort Study. Nat Sci Sleep. 2023; 15: 1093-1105.
8. Li Y, Li Z, Lv Q, Gu Y, Qi Y, Li J, et al. Prevalence and risk factors of postoperative delirium in tumor patients after free flap reconstruction: A systematic review and meta-analysis of case-control studies. Surgery. 2024; 176: 906-917.
9. Lin D, Huang X, Sun Y, Wei C, Wu A. Perioperative Sleep Disorder: A Review. Front Med (Lausanne). 2021; 8: 640416.
10. Wang X, Hua D, Tang X. "The Role of Perioperative Sleep Disorders in Postoperative Neurocognitive Impairment". Nature Science Sleep. 2021; 13: 1395-1410.
11. Purcell KF, Scarcella N, Chun D, Holland C, Stauffer TP, Bolognesi M, et al. Treating Sleep Disorders After Total Hip and Total Knee Arthroplasty. Orthop Clin North Am. 2023; 54: 397-405.
12. Chen C, Zhai RX, Lan X. Sleep Disorders' Impact on Postoperative Neurocognitive Impairment in Elderly Patients: A Review. Ibrain J. 2024; 0: 197-216.
13. Gao Y, Chen X, Zhou Q, Song J, Zhang X, Sun Y, et al. Effects of Melatonin Treatment on Perioperative Sleep Quality: A Systematic Review and Meta-Analysis with Trial Sequential Analysis of Randomized Controlled Trials. Nat Sci Sleep. 2022; 14: 1721-1736.
14. Liu Y, Li Y, Liu M, Zhang M, Wang J, Li J. Effects of Acupuncture-Point Stimulation on Perioperative Sleep Disorders: A Systematic Review with Meta-Analysis and Trial Sequential Analysis. Int J Clin Pract. 2024; 2024: 6763996
15. Shi Y, Sun Q, Wang Y, Chen C, Jin J, Wang W, et al. Can dexamethasone improve postoperative sleep and postoperative delirium in elderly patients undergoing robot-assisted laparoscopic radical prostatectomy? Protocol for a prospective, randomized, double-blind, controlled study. Trials. 2023; 24: 505.
16. Ding X, Qi LX, Sun DY. Differences in Self-Rating Results of Insomnia Among Elderly Hospitalized Patients. World J Psychiatr. 2024; 14: 686-694.
17. Li R, Chen N, Wang E, Tang Z. Correlation between preoperative sleep disorders and postoperative delayed neurocognitive recovery in elderly patients. Zhong Nan Da Xue Xue Bao Yi Xue Ban. 2021; 46: 1251-1259.
18. Cai J, Chen Y, Hao X, Zhu X, Tang Y, Wang S, et al. Effect of Intraoperative Dexmedetomidine Dose on Postoperative First Night Sleep Quality in Elderly Surgery Patients: A Retrospective Study with Propensity Score-Matched Analysis. Front Med (Lausanne). 2020; 7: 528.
19. Gu Xu, Zhu Jie. The Role of Exosomes and Exosomal MicroRNAs in Postoperative Sleep Disorders. J Natural Sci Sleep. 2021; 13: 1363-1375
20. He J, Zhang X, Li C, Fu B, Huang Y, Li H. Dexmedetomidine nasal administration improves perioperative sleep quality and neurocognitive deficits in elderly patients undergoing general anesthesia. BMC Anesthesiol. 2024; 24: 42.
21. Starks SCE, Pohrt A, Halzl-Yürek F, Heinrich M, Müller A, Spies CD, et al. Long-term and pre-operative benzodiazepine use in older adults and risk for postoperative delirium: An additional analysis of the multicentre Biomarker Development for Postoperative Cognitive Impairment in the Elderly Study. Eur J Anaesthesiol. 2025; 42:704-713.
22. Hunt T, Payne T, Brophy JM. "Preoperative Right Trametomidine for Postoperative Delirium After Cardiac Surgery: A Systematic Review, Bayesian Meta-Analysis, and Bayesian Retrospective Analysis of the DECADE Trial." Bri J Anesthesiol. 2025; 134: 1671-1682.
23. Thedim M, Vacas S. Postoperative Delirium and the Older Adult: Untangling the Confusion. J Neurosurg Anesthesiol. 2024; 36: 184-189.
24. Dubiel C, Hiebert BM, Stammers AN. Dementia Definitions Affect Functional Survival of Patients One Year After Cardiovascular Surgery. J Thoracic Cardiovasc Surg. 2022; 163: 725-734.

25. Yoshimura M, Shiramoto H, Morimoto Y, Koga M. Comparison of total intravenous with inhalational anesthesia in terms of postoperative delirium and complications in older patients: a nationwide population-based study. J Anesth. 2022; 36: 698-706.

26. Yang Y, Zheng KJ, Guo YT. Relationship Between Postoperative Delirium and Plasma Amyloid β Oligomers. Scientific Rep. 2025; 15: 13147.

27. Weasley AJ, Johnson CA, Liu D, Kanakriyil PJ, Smith HAB, Bates KA. Correlation Between Hyperoxygenation During Circulatory Support and Postoperative Delirium in Pediatric Cardiac Intensive Care Unit Patients. Crit Care Med Res. 2024; 6: e1119.

28. Evered L, Atkins K, Silbert B, Scott DA. Acute peri-operative neurocognitive disorders: a narrative review. Anaesthesia. 2022; 77: 34-42.

29. Kunz JV, Spies CD, Bichmann A, Sieg M, Mueller A. Postoperative anaemia might be a risk factor for postoperative delirium and prolonged hospital stay: A secondary analysis of a prospective cohort study. PLoS One. 2020; 15: e0229325.

30. Irqsusi M, Loos D, Dielmann K, Ramzan R, Wulf H, Ghazy T, et al. Influence of cardioplegic solution on incidence of delirium after CABG surgery: Use of Calafiore blood cardioplegia versus HTK - Bretschneider - solution in a single-center retrospective analysis from 2017 to 2021. J Card Surg. 2022; 37: 4670-4678.

31. Lin CJ, Fick DM, Traynor V, Chen YC, Hsiang HF, Chiu HY. Comparative Diagnostic Accuracy of Nursing Delirium Screening Scale Versus Confusion Assessment Method for Postoperative Delirium: A Systematic Review and Meta-Analysis. J Clin Nurs. 2025; 34: 287-298.

32. Meng L, Zhao X, Sun Y, Cheng S, Bao L, Fang K, et al. Characteristics associated with effectiveness in postoperative delirium research: a systematic review of randomised controlled trials with meta-regression and meta-analysis. Br J Anaesth. 2024; 133: 565-583.

33. Wang Y, Wu J, Wang J, He L, Lai H, Zhang T, et al. Mitochondrial oxidative stress in brain microvascular endothelial cells: Triggering blood-brain barrier disruption. Mitochondrion. 2023; 69: 71-82.

34. Deng J, Chen C, Xue S, Su D, Poon WS, Hou H, et al. Microglia-mediated inflammatory destruction of neuro-cardiovascular dysfunction after stroke. Front Cell Neurosci. 2023; 17: 1117218.

35. Bode N CN, Watson JB, Higgins EK, Quan N, Bachstert AD. Inflammatory Regulation of the Central Nervous System Barrier Following Traumatic Brain Injury: A Leukocyte Interleukin-1-Dominant Regulatory Mechanism. Front Immunol. 2021; 12:688254.

36. Rustenhoven J, Tanumihardja C, Kipnis J. Cerebrovascular Anomalies: Perspectives from Immunology and Cerebrospinal Fluid Flow. Circ Res. 2021; 129: 174-194.

37. Shafqat A, Noor Eddin A, Adi G. Central Nervous System Pathology: The Role of Neutrophil Exocytic Traps: A Brief Review.Front Med (Lausanne). 2023; 10: 1083242.

38. Barasolo D, Matthews SG, Blois E. The Role of the Blood-Brain Barrier in Health and Disease: Focusing on Brain Protection. Veterinary J. 2025; 45: 12-32.

39. Hathcock SF, Mamana J, Keyzer TE, Vollmuth N, Shokri M-R, Mauser HD, et al. Transcriptomic analysis of coxsackievirus B3 infection in induced pluripotent stem cell-derived brain-like endothelial cells. J Virol. 2025; 99: e0182424.

40. Koh HJ, Joo J. The Role of Cytokines in Perioperative Neurocognitive Disorders: A Review in the Context of Anesthetic Care. Biomed. 2025; 13: 506.

41. Hu Y, Hu XD, He ZQ, Liu Y, Gui YK, Zhu SH, et al. Anesthesia/surgery activate MMP9 leading to blood-brain barrier disruption, triggering neuroinflammation and POD-like behavior in aged mice. Int Immunopharmacol. 2024; 135: 112290.

42. Alexander NG, Hathcock SF, Kim BJ. Studying Group B Streptococcus-Blood-Brain Barrier Interaction In Vitro Using an Induced Pluripotent Stem-Cell-Derived Brain-Like Endothelial Cell Model. Methods Mol Biol. 2025; 2950: 3-25.

43. Ma G, Sun P, Chen Y. NLRP3 inflammasome activation leads to cognitive decline after cardiac surgery. Front Surg. 2022; 9: 992769.

44. Lu J, Tao X, Dai H, Gao S, Zhou H. Peripheral and cerebral inflammation induced by repeated anesthesia and surgery do not cause impairment of learning and memory in middle-aged mice. Acta Neurobiol Exp (Wars). 2023; 83: 45-56.

45. Lu J, Liang F, Bai P. Serum tau protein-PT217 promotes anesthesia/surgery-induced delirium-like behavior in aged mice. Alzheimer's Dis J. 2023; 19: 4110-4126.

46. Cho I, Kim J, Jung S. The Impact of Persistent Noise Exposure on the Inflammatory State. Med Care (Basel). 2023; 11: 2067.

47. Yan F, Chen B, Ma Z. Exploring the Molecular Mechanisms of Postoperative Delirium in Plasma Exosomes Through Multimodal Strategies. Sci Rep. 2024; 24: 29466,

48. Wróbel M, Wołkowiecki M, Janocha A, Jabłońska Z. Majaczenia w okresie pooperacyjnym u osób starszych [Postoperative delirium in the elderly]. Med Pr. 2025.

49. Kim R, Witelski TP. Uncovering the dynamics of a circadian-dopamine model influenced by the light-dark cycle. Math Biosci. 2022; 344: 108764.

50. Yang Bo, Han Yu, Hu Si, Xie Xu, Zhu Xu, Yuan Lu. Polystyrene microplastics induce depression-like behaviors in zebrafish through neuroinflammation and circadian rhythm disruption. Science Total Environment. 2025; 959: 178085.

51. Cruz T, Garcia L, Alvarez MA, Manzanelo AL. Sleep Quality and Memory Function in Healthy Aging. Neurology (English Edition). 2022; 37: 31-37.

52. Luo R, Qiu M, Wu W. Effects of volatile and intravenous anesthetics on postoperative cognitive dysfunction: a mechanistic review. J Anesth. 2025.

53. Mori K, Komatsu T, Fujiwara Y, Fujita Y. Comparison of the Effects of Desflurane and Sevoflurane on Variations in Salivary Melatonin and Sleep Disturbance After Total Knee Arthroplasty: A Single-center, Prospective, Randomized, Controlled, Open-label Study. J Perianesth Nurs. 2024; 39:101-108.

54. Mizuno T, Higo S, Kamei N, Mori K, Sakamoto A, Ozawa H. Effects of general anesthesia on behavioral circadian rhythms and clock-gene expression in the suprachiasmatic nucleus in rats. Histochem Cell Biol. 2022; 158: 149-158.

55. Pérez-Alavéz JC, Castañeda-López JT, Nieto-Nino AG, Rojas-Granados A, Angeles-Castellanos M. Association Between Postoperative Delirium and Loss of Melatonin Rhythm After Hip Arthroplasty: A Pilot Study. Cureus. 2025; 17: e86728.

56. Guo R, Ye J, Liao B, Luo X, Rao P. The Relationship Between Anesthesia and Melatonin: A Review. Front Pharmacol. 2023; 14:1255752.

57. Salehpour F, Khademi M, Bragin DE, DiDuro JO. Photobiomodulation Therapy and the Glymphatic System: Promising Applications for Augmenting the Brain Lymphatic Drainage System. Int J Mol Sci. 2022; 23: 2975.

58. Deng S, Hu Y, Chen S, Xue Y, Yao D, Sun Q, et al. Chronic sleep fragmentation impairs brain interstitial clearance in young wildtype mice. J Cereb Blood Flow Metab. 2024; 44: 1515-1531.

59. Eide PK, Vinje V, Pripp AH, Mardal KA, Ringstad G. Sleep deprivation impairs the molecular clearance function of the human brain. Brain. 2021; 144: 863-874.

60. Chen K, Du X, Chao MA, Xie Z, Yang G. Surgery impairs glymphatic activity and cognitive function in aged mice. Mol Brain. 2025; 18: 7.

61. Iliam A, Maher AS, Choudary NN, Choudary NF, Jacobs EB. Acute Cognitive Deficits Following Traumatic Brain Injury Predict the Alzheimer's Disease-like Degeneration of the Human Default Mode Network. Aging Science. 2020; 42: 1411-1429.

62. Ghanizada H, Nedergaard M. The glymphatic system. Handb Clin Neurol. 2025; 209: 161-170.

63. Maloviscara M, Humenick F, Vikatovska Z et al. Cerebrospinal fluid metabolite clearance pathways. Physiological Res. 2022; 71: 199-208.

64. Dai W, Liu J, Qiu Y. Gut Microbiota Dysbiosis and Cognitive Impairment in Bipolar Disorder: Current Evidence. Front Pharmacol. 2022; 13: 893567.

65. Dahiya D, Nigam PS. Antibiotic-Therapy-Induced Gut Dysbiosis Affecting Gut Microbiota-Brain Axis and Cognition: Restoration by Intake of Probiotics and Synbiotics. Int J Mol Sci. 2023; 24: 3074.

66. Lv Y, Xian Y, Lei X, Xie S, Zhang B. The role of the microbiota-gut-brain axis and artificial intelligence in cognitive health of pediatric obstructive sleep apnea: A narrative review. Medicine (Baltimore). 2024;103: e40900.

67. Hu A, Zaongo SD, Harypursat V, Wang X, Ouyang J, Chen Y. HIV-associated neurocognitive disorder: key implications of the microbiota-gut-brain axis. Front Microbiol. 2024; 15: 1428239.

68. Chen SX, Qin FY, Yu XM, Huang YJ, Zhou SN, Gu WP, et al. Analysis of risk factors for delirium in elderly patients with head and neck cancer after free flap reconstruction surgery. Zhonghua Kou Qiang Yi Xue Za Zhi. 2025; 60: 54-60.

69. Wei W, Huang X, Zhu J. Effect of Acupoint Therapies on Postoperative Sleep Quality: A Narrative Review. Med Sci Monit. 2023; 29: e938920.

70. Sewart E, Barnes J, Armstrong RA, Pufulete M, Hinchliffe R, Gibbison B, et al. Melatonin for the prevention of postoperative delirium in older adults: a protocol for a systematic review and meta-analysis. BMJ Open. 2022; 12: e063405.

71. Brenna CTA, Goldstein BI, Zarate CA Jr, Orser BA. Repurposing General Anesthetic Drugs to Treat Depression: A New Frontier for Anesthesiologists in Neuropsychiatric Care. Anesthesiology. 2024; 141: 222-237.

72. Möllmann HL, Alhammadi E, Boulghoudan S, Kuhlmann J, Mevissen A, Olbrich P, et al. Assessment of Geriatric Problems and Risk Factors for Delirium in Surgical Medicine: Protocol for Multidisciplinary Prospective Clinical Study. JMIR Res Protoc. 2025; 14: e59203.

73. Li T, Feng Z, Hou Y, Li P. The clinical value of nonpharmacological interventions for preventing postoperative delirium: a narrative review. Minerva Anestesiol. 2024; 90: 785-796.

74. Weidner E, Hancke L, Nydahl P, Spies C, Lütz A. Nicht pharmakologisches Management des postoperativen Delirs [Non-pharmacological Management of Postoperative Delirium]. Anasthesiol Intensivmed Notfallmed Schmerzther. 2023; 58: 494-512.

75. Li J, Fan Y, Luo R, Yin N, Wang Y, Jing J, et al. The Impact of Non-Pharmacological Sleep Interventions on Delirium Prevention and Sleep Improvement in Postoperative ICU Patients: A Systematic Review and Network Meta-Analysis. Intensive Crit Care Nurs. 2025; 87: 103925.

76. Finne KF, Thorup T, Skovsen APG, Tolstrup MB. Outcomes of a delirium prevention program after major abdominal emergency surgery: An interventional study. World J Surg. 2025; 49: 219-229.

77. Li X, Wang Y, Liu J, Xiong Y, Chen S, Han J, et al. Effects of perioperative interventions for preventing postoperative delirium: A protocol for systematic review and meta-analysis of randomized controlled trials. Medicine (Baltimore). 2021; 100: e26662.

78. Li W, Shi Q, Bai R, Zeng J, Lin L, Dai X, et al. Advances in research on the pathogenesis and signaling pathways associated with postoperative delirium (Review). Mol Med Rep. 2025; 32: 220.

79. Titu IM, Vulturar DM, Chis AF, Oprea A, Manea A, Todea DA. Impact of obstructive sleep apnea in surgical patients: A Systematic Review. J Clin Med. 2025; 14: 5095.

80. O'Gara BP, Gao L, Marcantonio ER, Subramaniam B. Sleep, Pain, Cognition: Modifiable targets for optimal perioperative brain health. Anesthesiology. 2021; 135: 1132-1152.

81. Zambelli Z, Halstead EJ, Fidalgo AR, Dimitriou D. Good sleep quality improves the relationship between pain and depression among individuals with chronic pain. Front Psychol. 2021; 12: 668930.

82. Schlenz AM, Thomas SJ, Gloston G, Lebensburger J, Maxwell SL, Kanter J. Sleep quality and pain in adolescents and young adults with sickle cell disease. J Clin Sleep Med. 2022; 18: 2845-2853.

83. Lee MK, Oh J. The relationship between sleep quality, neck pain, shoulder pain and disability, physical activity, and health perception among middle-aged women: A cross-sectional study. BMC Womens Health. 2022; 22: 186.

84. Huber FA, Toledo TA, Newsom G, Rhudy JL. The relationship between sleep quality and emotional modulation of spinal, supraspinal, and perceptual measures of pain. Biol Psychol. 2022; 171: 108352.

85. Wilson M, Skeiky L, Muck RA, Honn KA, Williams RM, Jensen MP, et al. Pain catastrophizing mediates the relationship between pain intensity and sleep disturbances in U.S. Veterans with Chronic Pain. Mil Med. 2023; 188: e2639–e2645.

86. Sheffler JL, Saliga H, Pickett S. The role of physical activity on the relationships between pain, anxiety, and sleep quality in older age. J Gerontol A Biol Sci Med Sci. 2023; 78: 1881-1886.

87. Wang Y, Varghese J, Muhammed S, Lavigne G, Finan P, Colloca L. Clinical phenotypes supporting the relationship between sleep disturbance and impairment of placebo effects. J Pain. 2024; 25: 819-831.

88. Alhalal EA, Alhalal IA, Alaida AM, Alhweity SM, Alshojaa AY, Alfaori AT. Effects of chronic pain on sleep quality and depression: A cross-sectional study. Saudi Med J. 2021; 42: 315-323.

89. Joensen EDR, Frederiksen L, Frederiksen SV, Valeur ES, Giordano R, Hertel E, et al. Sex and Sleep Quality effects on the relationship between sleep disruption and pain sensitivity. Eur J Pain. 2025; 29: e70023.

90. Chen S, Xie Y, Liang Z, Lu Y, Wang J, Xing F, et al. A Narrative review of the reciprocal relationship between sleep deprivation and chronic pain: the role of oxidative stress. J Pain Res. 2024; 17: 1785-1792.

91. Tracy EL, So CJ, Shoemaker SD, Kanaley JA, Trull T, et al. Bidirectional links between sleep and pain among heavy-drinking veterans with insomnia. Sleep Adv. 2024; 5: zpae089.

92. Ault A, Wilkerson AK, McCauley JL, Muzzy W, Mappin GM, Yonce S, et al. Sleep, pain catastrophizing, and pain intensity in treatment seeking adults with opioid use disorder. Clin J Pain. 2025; 41: e1264.

93. Mu CX, Lee S. The moderating role of trait and state mindfulness between daily sleep and physical pain symptoms: An ecological

momentary assessment and actigraphy study. Psychol Health. 2024; 39: 91-108.

94. Bowen ME, Ji X, Griffioen MA. Poor sleep predicts increased pain perception among adults with mild cognitive impairment. Nurs Res. 2021; 70: 310-316.

95. Kim S, Zeitzer JM, Mackey S, Darnall BD. Revealing sleep and pain reciprocity with wearables and machine learning. Commun Med (Lond). 2025; 5: 160.

96. Colgan DD, Parman N. Interoceptive awareness mediates effects of sleep disturbance on pain outcomes in chronic pain patients. Integr Med Rep. 2024; 3: 59-66.

97. Bean DJ, Horne J, Lee AC, Johnson MH. Pre-sleep cognitive arousal exacerbates sleep disturbance in chronic pain: An exploratory daily diary and actigraphy study. Scand J Pain. 2021; 21: 724-731.

98. Arévalo-Martínez A, Barbosa-Torres C, García-Baamonde ME, Díaz-Muñoz CL, Moreno-Manso JM. Sleep quality and cognitive performance in chronic primary musculoskeletal pain: An observational study with healthy controls. Eur J Pain. 2025; 29: e70085.

99. Ni CY, Hou GJ, Tang YY, Wang JJ, Chen WJ, Yang Y, et al. Quantitative study of the effects of early standardized ambulation on sleep quality in patients after hepatectomy. Front Surg. 2022; 9: 941158.

100. Buehne KL, Winder M, Marietta J, et al. Qualitative needs assessment of early participants in accelerated rehabilitation programs for patients with Congenital Heart Disease. Cardiol Young. 2024; 34: 2323-2328.

101. Strickland LH, Rahman A, Jenkinson C, Pandit HG, Murray DW. Early recovery following total and unicompartmental knee arthroplasty assessed using novel patient-reported measures. J Arthroplasty. 2021; 36: 3413-3420.

102. Haslam-Larmer L, Vellani S. Postoperative delirium in geriatric orthopedic and trauma patients: Care begins preoperatively! Int J Orthop Trauma Nurs. 2025; 56: 101143.

103. Miyatani K, Sakano Y, Makinoya M, Miyauchi W, Shimizu S, Shishido Y, et al. A low cumulative perioperative prognostic nutritional index predicts poor long-term outcomes in patients with gastric cancer: A single-center retrospective study in Japan. Surg Today. 2023; 53: 1294-1304.

104. Gao Z, Xu Z. Postoperative sepsis-associated neurocognitive disorder: mechanisms, predictive strategies, and treatment approaches. Front Med (Lausanne). 2025; 12: 1513833.

105. Cheon SY, Cho MR, Kim SY, Koo BN. The immune-inflammatory responses on the hypothalamic-pituitary-adrenal axis and the neurovascular unit in perioperative neurocognitive disorder. Exp Neurol. 2025; 386: 115146.

106. Qiu Y, Mo C, Xu S, Chen L, Ye W, Kang Y, Chen G, Zhu T. Research progress on perioperative blood-brain barrier damage and its potential mechanism. Front Cell Dev Biol. 2023; 11: 1174043.

107. Chalalai T, Srinontong P, Aengwanich W, Srisila K, Promkrathok S, Sununta M, et al. Impact of Burdizzo and Surgical Castration on Immune and Oxidative Stress Markers in Cattle. Vet Sci. 2025; 12: 537.

108. Milone M, Desiderio A, Velotti N, Manigrasso M, Vertaldi S, Bracale U, et al. Surgical stress and metabolic response after totally laparoscopic right colectomy. Sci Rep. 2021; 11: 9652.

109. Banerjee D, Feng J, Sellke FW. Strategies to attenuate maladaptive inflammatory response associated with cardiopulmonary bypass. Front Surg. 2024; 11: 1224068.

110. Huh J, Hwang W. The role of anesthetic management in lung cancer recurrence and metastasis: A Comprehensive Review. J Clin Med. 2024; 13: 6681.

111. Li J, Yan J, Tu G, Jiang W, Qiu Y, Su Y, et al. NRF1 coordinates mitochondrial adaptations to dampen intracellular ROS and inflammatory responses during ischemia reperfusion. Cell Death Discov. 2025; 11: 236.

112. Cui H, Huang W. Anesthesia Methods and Their Impact on Cancer Recurrence and Metastasis: A Review. Cancer (Basel). 2024; 16.

113. Pan WT, Ji MH, Ma D, Yang JJ. Effect of perioperative autonomic nervous system imbalance on surgical outcomes: A systematic review. Br J Anaesth. 2025; 135: 608-622.

114. Handke J, Kummer L, Weigand MA, Larmann J. Modulation of Peripheral CD4+CD25+Foxp3+ Regulatory T Cells ameliorates surgical stress-induced atherosclerotic plaque progression in ApoE-Deficient Mice. Front Cardiovasc Med. 2021; 8: 682458.

115. Hwang S, Cho JM, Yoon YJ, Seo S, Hong Y, Lim JY. Retroductal dexamethasone administration promotes the recovery from obstructive and inflammatory salivary gland dysfunction. Front Immunol. 2024; 15: 1418703.

116. Bala R, Singh S, Sharma J, Kumawat M. Variations in levels of blood sugar and anti-inflammatory mediators following dexamethasone in neurosurgical patients. Ann Afr Med. 2025; 24: 649-655.

117. Terekhina OL, Kirova YI. Vliyanie etilmetilgidroksipiridina suktsinata na parametry khronicheskogo neirovospaleniya i plasticheskikh protsessov v mozge starykh krys pri kursovom vvedenii deksametazona [The effect of ethylmethylhydroxypyridine succinate on the parameters of chronic neuroinflammation and plastic processes in the brain of old rats during course of dexamethasone administration]. Zh Nevrol Psikhiatr Im S S Korsakova. 2024; 124: 115-121.

118. Mayer G, Frohnhofen H, Jokisch M, Hermann DM, Gronewold J. Associations of sleep disorders with all-cause MCI/dementia and different types of dementia - clinical evidence, potential pathomechanisms and treatment options: A narrative review. Front Neurosci. 2024; 18: 1372326.

119. Lim CR, Ogawa S, Kumari Y. Exploring β-caryophyllene: A non-psychotropic cannabinoid's potential in mitigating cognitive impairment induced by sleep deprivation. Arch Pharm Res. 2025; 48: 1-42.

120. Rice RR, Chidambaram AG, Nandalike K, Willen SM. The impact of sleep on neurologic and neurocognitive complications in children with sickle cell disease: A Scoping Review. Pediatr Blood Cancer. 2025; 72: e31793.

121. Bojarska W, Bury K, Januszczak R, Burda B, Pawęzka J. Role of Sleep-in depressive disorders and the potential therapeutic role of short-term sleep deprivation and light therapy: A Review. Med Sci Monit. 2024; 30: e945319.

122. Hua F, Zhu H, Yu W, Zheng Q, Zhang L, Liang W, et al. β-arrestin1 regulates astrocytic reactivity via Drp1-dependent mitochondrial fission: Implications in postoperative delirium. J Neuroinflammation. 2023; 20: 113.

123. He D, Chen J, Du X, Xu L. Summary of drug therapy to treat cognitive impairment-induced obstructive sleep apnea. Front Cell Neurosci. 2023; 17: 1222626.

124. Cheng J, Williams JP, Zhou L, Wang PC, Sun LN, Li RH, et al. Ozone rectal insufflation mitigates chronic rapid eye movement sleep deprivation-induced cognitive impairment through inflammation alleviation and gut microbiota regulation in mice. Med Gas Res. 2024; 14: 213-224.

125. Zheng X, Jin Q, Lu Q, Cai Q. Effect of comprehensive nursing intervention on perioperative anxiety and sleep quality in elderly patients with digestive tract malignancies. Am J Transl Res. 2022; 14: 7189-7198.

126. Wang H, Zhang L, Zhang Z, Li Y, Luo Q, Yuan S, et al. Perioperative sleep disturbances and postoperative delirium in adult patients: A systematic review and meta-analysis of clinical trials. Front Psychiatr. 2020; 11: 570362.

127. Lei Z, Zhang L, Yang J, Ye L, Xia L. Predictive value of the duke anesthesia resistance scale in postoperative delirium among elderly patients with hip fractures. Altern Ther Health Med. 2024; 30: 122-126.

128. Singh M, Sahhar M, Nassar JE, Farias MJ, Rasquinha R, Kim J, et al. Analysis of delirium risk assessment tools for prediction of postoperative delirium following lumbar spinal fusion. Spine (Phila Pa 1976). 2025; 30.

129. Zhou B, Wang A, Cao H. Risk prediction models for postoperative delirium in elderly patients with fragility hip fracture: A systematic review and critical appraisal. Int J Orthop Trauma Nurs. 2024; 52: 101077.

130. Cai S, Li J, Gao J, Pan W, Zhang Y. Prediction models for postoperative delirium after cardiac surgery: Systematic review and critical appraisal. Int J Nurs Stud. 2022; 136: 104340.

131. Guo H, Wang H, Xiao F, Xie YB. Systemic immune-inflammation index and postoperative sleep disturbance in elderly patients with total joint arthroplasty: A prospective cohort study. Sci Rep. 2025; 15: 27393.

132. Ka Maz HY, Akutay S, Kahraman H, Dal F, S Z Er E. Diagnostic value of neutrophil to lymphocyte ratio for assessing obstructive sleep apnea risk in surgical patients. J Perianesth Nurs. 2023; 38: e1-e6.

133. Browndyke JN, Tomalin LE, Erus G, Overbey JR, Kuceyeski A, Moskowitz AJ, et al. Infarct-related structural disconnection and delirium in surgical aortic valve replacement patients. Ann Clin Transl Neurol. 2024; 11: 263-277.

134. Reekes TH, Upadhya VR, Merenstein JL, Cooter-Wright M, Madden DJ, Reese MA, et al. Predilection for Perplexion: Preoperative microstructural damage is linked to postoperative delirium. medRxiv. 2025: 08: 24319243.

135. Maniaci A, Lentini M, Trombadore R, Gruppuso L, Milardi S, Scrofani R, et al. Neurological and Olfactory Disturbances After General Anesthesia. Life (Basel). 2025; 15: 344.

136. Huo S, Cheng L, Li S, Xu F. Effects of eszopiclone on sleep quality and cognitive function in elderly patients with Alzheimer's disease and sleep disorder: A randomized controlled trial. Brain Behav. 2022; 12: e2488.

137. Cheng H, Zhou W, Nasuhi VN, Zhu X, Yu C, Zhang H, et al. Effect of general anesthesia vs regional anesthesia on sleep disturbance in elderly patients after discharge from the hospital for 3 months. Nat Sci Sleep. 2024; 16: 1679-1686.

138. Baptista PM, Martin F, Ross H, O'Connor Reina C, Plaza G, Casale M. A systematic review of smartphone applications and devices for obstructive sleep apnea. Braz J Otorhinolaryngol. 2022; 88: S188-S197.

139. Zhu R, Peng L, Liu J, Jia X. Telemedicine for obstructive sleep apnea syndrome: An updated review. Digit Health. 2024; 10: 20552076241293928.

140. Sun Y, Liu Y, Liu P, Zhang M, Liu M, Wang Y. Anesthesia strategies for elderly patients with craniocerebral injury due to foreign-body penetration in the plateau region: a case report. Front Med (Lausanne). 2024; 11: 1385603.

141. Kim VC, Nepomnayshy D. Obesity: Surgical and Device Interventions. FP Essent. 2020; 492: 30-36.

142. Zhang X, Chen Y, Tang Y, Zhang Y, Zhang X, Su D. Efficiency of probiotics in elderly patients undergoing orthopedic surgery for postoperative cognitive dysfunction: a study protocol for a multicenter, randomized controlled trial. Trials. 2023; 24: 146.

143. Geng P, Shang Z, Cheng F, Zhang Y, Deng X, Chen X, et al. Preoperative low-dose dexmedetomidine reduces postoperative delirium in elderly patients with hip fracture under spinal anesthesia: A randomized, double blind, controlled clinical study. J Clin Anesth. 2025; 105: 111897.

144. Cheng Y, Gao Y, Liu GY, Xue FS, Jin M. Short-term inhalation of xenon during anesthesia for prevention of postoperative delirium in elderly patients undergoing laparoscopic radical colectomy: Study protocol for a randomized controlled clinical trial. Trials. 2024; 25: 434.

145. Wang J, Wang X, Li S, Yang J, Yan X, Gao J, et al. The effect of repetitive transcranial magnetic stimulation (rTMS) on perioperative neurocognitive disorders in patients after cardiac surgery: Study protocol for a randomized controlled trial. Trials. 2025; 26: 253.

146. Liu T, Tuo J, Wei Q, Sun X, Zhao H, Zhao X, et al. Effect of perioperative dexmedetomidine infusion on postoperative delirium in elderly patients undergoing oral and maxillofacial surgery: A randomized controlled clinical trial. Int J Gen Med. 2022; 15: 6105-6113.

147. Ertürk Çetin Ö, Totuk Ö, Güngör Doğan İ, Eryiğit Baran G, Taşdelen B, Darici D, et al. Current approach to perioperative evaluation of neurological diseases. Neurologist. 2025; 30: 310-328.

148. Berezin L, Chung F. Positive airway pressure in surgical patients with sleep apnea: What is the Supporting Evidence? Anesth Analg. 2024; 139: 107-113.

149. Sleep Respiratory Disorders Working Committee of the Respiratory Medicine Branch of the Chinese Medical Doctor Association; Chinese Society of Anesthesiology of Chinese Medical Association; National Clinical Research Center for Geriatric Diseases. [Expert consensus on perioperative management of adult patients combined with obstructive sleep apnea (2025 edition)]. Zhonghua Yi Xue Za Zhi. 2025; 105: 1045-1054.

150. Tracy E, Crandall C, Grajales A, Plunkett A. The perioperative implications of the patient with Obstructive Sleep Apnea (OSA) - a narrative review. Future Sci OA. 2025; 11: 2540744.

151. Pappu A, Singh M. Best perioperative practices in the management of obstructive sleep apnea patients undergoing ambulatory surgery. Curr Opin Anaesthesiol. 2024; 37: 644-650.