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Review Article

Post-Anesthesia Sleep Disturbances: A Review Article

Masoomeh Tabari[1], Ali Moradi[2], Afsaneh Attari Jahed[3]*

[1]*Department of Anesthesiology, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.*

[2]*Clinical Research Development Unit, Ghaem Hospital, Mashhad University of Medical Sciences, Mashhad, Iran.*

[3]*Department of Anesthesiology, Mashhad University of Medical Sciences, Mashhad, Iran.*

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ABSTRACT

General anesthesia is used in modern surgical practice to achieve low-reactivity consciousness, involving analgesia, hypnosis, amnesia, and immobility. Recently, studies have revealed a complex correlation between general anesthesia and postoperative sleep disturbances. In the days following surgery, patients who have undergone anesthesia may experience an increased level of Rapid Eye Movement (REM) sleep due to the suppression of REM sleep during anesthesia. Postoperative complications, such as delirium, may be caused by these disturbances. In particular, anesthesia can exacerbate sleep disorders among vulnerable populations, including those with preexisting disabilities. Insomnia, somnolence, appetite loss, and social withdrawal can be symptoms of preexisting sleep disorders that can worsen postoperative outcomes. There is still considerable uncertainty surrounding the relationship between general anesthesia and sleep disturbances. This scoping review aims to shed light on the incidence of sleep disturbances following surgical and dental anesthesia procedures and investigate the intricate connection between postoperative sleep and general anesthesia. A pioneering study in the field of anesthesia and perioperative care is embarked upon by exploring this critically important topic.

Introduction

General anesthesia , a fundamental component of modern surgical practice, is a medically induced state of reduced consciousness in patients. It encompasses various clinical endpoints, including hypnosis (a disconnection from surroundings), analgesia (pain reduction), amnesia (memory loss), and immobility after surgical stimulation [1-2]. However, beyond the carefully managed clinical aspects, there exists a relatively unexplored dimension the profound impact of general anesthesia on sleep [3-5].

Recent scientific investigations have started to uncover the intricate relationship between general anesthesia and sleep, revealing postoperative sleep disturbances [3, 6-9]. Patients who undergo surgical or dental procedures under general anesthesia may experience disruptions in their sleep cycles, characterized by a significant increase in rapid eye movement (REM) sleep in the days following the procedure. This surge in REM sleep is a result of the suppression of REM sleep during the anesthesia itself [1, 10-12].

The consequences of these postoperative sleep disturbances go beyond mere discomfort or inconvenience [13-14]. They extend into the realm of postoperative brain dysfunction, a complex condition where sleep disturbances are just one of its many manifestations [15-16]. These disturbances have the potential to induce postoperative fatigue, contribute to metabolic disorders, elevate blood pressure to hypertensive levels, and even increase the risk of cerebrovascular and cardiovascular diseases. Alarmingly, they have also emerged as a significant and unsettling risk factor for the development of delirium, a condition known for its harmful effects on patient outcomes [17-22]. The complexity of this issue is further

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*Corresponding author.
E-mail address: attari991@mums.ac.ir

heightened when considering individuals with preexisting disabilities. For these vulnerable populations, the impact of general anesthesia-induced sleep disturbances can be significantly amplified [23-25]. In such cases, the frequency of anesthesia exposure directly correlates with a decline in sleep quality [26-28]. Interestingly, it is not only the anesthesia itself, but also the interaction with preexisting sleep disorders that can contribute to severe postoperative consequences [29-31]. Noteworthy examples include patients with autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD), who may experience ongoing insomnia, loss of appetite, daytime sleepiness, and withdrawal from social interactions following exposure to anesthesia [32-33]. This underscored association between preexisting conditions and anesthesia-induced sleep disturbances casts a spotlight on the multifaceted nature of this phenomenon [34-35].

However, amid the significance of these revelations, the influence of general anesthesia on sleep disturbances remains a contentious and enigmatic territory, underscored by the scarcity of rigorous randomized clinical trials and empirical research [36-37]. As the complexity of this interplay unfolds, this scoping review endeavors to illuminate the intricate relationship between general anesthesia and postoperative sleep cycles and disturbances, drawing from the corpus of existing literature.

In the current discourse surrounding the prevalence of sleep disturbances after general anesthesia in the context of elective surgery and dental procedures, clarity remains elusive. Thus, this study aspires to contribute to the resolution of this debate, undertaking a meticulous comparison of the incidence of sleep disturbance between patients undergoing general anesthesia and those subjected to procedures without this anesthesia modality. In doing so, it embarks on a pioneering journey: the first comprehensive scoping review of this pivotal subject, one that holds profound implications for the field of anesthesiology and perioperative care.

Anesthesia and Sleep

Anesthesia Types and Mechanisms:

Anesthesia is a medical practice that encompasses a range of agents and techniques used to induce a reversible state of unconsciousness and insensitivity to pain in patients undergoing surgical or medical procedures [38-39]. The choice of anesthesia type depends on the nature and duration of the procedure, patient characteristics, and medical considerations. There are several primary types of anesthesia, including:

General Anesthesia: This form induces a deep state of unconsciousness and is typically administered intravenously or via inhalation [40]. It involves a combination of drugs to produce hypnosis (unawareness), analgesia (pain relief), amnesia (memory loss), and muscle relaxation to prevent movement during surgery [41-42].

Regional Anesthesia: Regional anesthesia involves the administration of anesthetic agents to a specific region of the body, blocking sensation in that area while allowing the patient to remain conscious. Types of regional anesthesia include spinal, epidural, and nerve blocks [43-44].

Local Anesthesia: Local anesthesia is used to numb a specific area of the body, typically through the injection of anesthetic agents near the targeted site [45-46]. It is commonly employed for minor surgical procedures or to manage pain in a localized region.

Each type of anesthesia has its own unique mechanisms of action and applications, contributing to the patient's overall experience during surgery.

Sleep Architecture and Stages

Sleep is a vital physiological function essential for promoting overall health and ensuring a state of well-being [47]. Understanding the intricate architecture and stages of sleep is pivotal in comprehending the profound impact of sleep on various facets of human physiology and psychology. Sleep architecture refers the structural organization of sleep cycles, while sleep stages represent distinct phases of sleep characterized by specific physiological and neurophysiological features [48-49]. Sleep is not a monolithic state but rather an orchestrated sequence of sleep cycles that repeat throughout the night [50]. These sleep cycles typically follow a consistent pattern, with each cycle lasting approximately 90 to 120 minutes [51-52]. During a typical night's sleep, individuals undergo multiple cycles, usually four to six cycles, although this can vary [53].

Sleep is conventionally divided into two main categories: Non-Rapid Eye Movement (NREM) sleep and Rapid Eye Movement (REM) sleep [54-55]. Each of these categories comprises distinct stages characterized by specific physiological markers and patterns of brain activity [56-57].

Non-Rapid Eye Movement (NREM) Sleep

NREM sleep is often described as the "quiet" or "restorative" phase of sleep. It can be further divided into three stages [58-59]:

N1 (Stage 1): This is the transitional stage between wakefulness and sleep [60]. During N1, individuals may experience drowsiness and a slowing of brain activity. Muscle tone decreases, and eye movements are slow. This stage typically lasts for a few minutes [61].

N2 (Stage 2): N2 represents a deeper stage of NREM sleep [62]. It is characterized by a reduction in muscle activity, heart rate and body temperature regulation.

Sleep spindles (brief bursts of rapid brain activity) and K-complexes (sharp waveforms) are observed during this stage [63].

N3 (Stage 3): N3 is the deepest stage of NREM sleep, often referred to as slow-wave sleep (SWS) [64]. Brain activity slows significantly, and this is the stage where restorative processes such as tissue repair, muscle growth, and immune system maintenance occur. Awakening individuals from N3 sleep poses a significant challenge, and upon being roused, they might experience a feeling of drowsiness [65-67].

Rapid Eye Movement (REM) Sleep

Rapid Eye Movement (REM) sleep stands as one of the most intriguing and enigmatic phases in the complex landscape of human slumber [68]. Characterized by its namesake rapid eye movements, heightened cerebral activity, and remarkably vivid dreams, REM sleep is often regarded as the "paradoxical" stage of sleep [69-70]. It earns this label because, despite the brain's heightened activity during this phase, the body's muscles are predominantly immobilized, preventing individuals from physically enacting the vivid scenarios that unfold within their dreams [71]. During REM sleep, the brain awakens, embarking on a journey of intense mental activity [72]. Dreaming takes center stage, with experiences in this stage often proving the most vivid and memorable. It is during these moments that fantastical narratives, surreal landscapes, and profound emotions come to life within the mind's eye [73]. As the brain navigates these dreamscapes, the eyes engage in rapid, darting movements, a distinctive hallmark of this sleep stage [74]. Physiologically, REM sleep is accompanied by irregularities in key vital signs [75]. Heart rate and respiration become notably erratic, fluctuating in response to the dreamer's internal experiences [76]. It is within this cognitive whirlwind that crucial mental processes take place. REM sleep is intimately linked to memory consolidation, contributing to the organization and storage of newly acquired information [77]. Additionally, it serves as an arena for emotional processing, helping individuals grapple with and understand the emotional content of their waking lives. Furthermore, REM sleep plays a pivotal role in cognitive function, aiding in tasks that require creative thinking, problem-solving, and learning [78]. The complexities of REM sleep continue to captivate researchers and sleep scientists, as its role in shaping our cognitive and emotional landscapes remains a subject of ongoing investigation.

Sleep Cycle and Clinical Significance

The sleep cycle encompasses a progression from N1 to N2, reaching N3, and eventually entering REM sleep, with this cycle repeating multiple times throughout the night [79-80]. Circadian rhythms, the body's internal biological clocks governing various physiological processes over a 24-hour cycle, significantly influence sleep architecture and stages, dictating the timing and quality of sleep and determining periods of alertness and natural sleep onset [81]. This comprehension of sleep architecture and stages holds paramount importance in the diagnosis and treatment of sleep disorders. Sleep studies, such as polysomnography, employ techniques like electroencephalography (EEG), electromyography (EMG), and electrooculography (EOG) to monitor brain activity, muscle tone, and eye movements during sleep, facilitating healthcare professionals in assessing sleep quality and identifying underlying sleep disorders [82-83]. In summary, sleep architecture and stages represent the intricate organization of sleep cycles, with NREM and REM sleep stages playing distinct roles in maintaining physical and cognitive health. The understanding of these stages is indispensable for researchers, clinicians, and individuals alike, as it sheds light on the essential functions of sleep and its impact on overall well-being.

Interaction between Anesthesia and Sleep

Anesthesia, particularly general anesthesia, is administered to induce a state of temporary unconsciousness during medical procedures [84]. During this period of unconsciousness, anesthesia significantly disrupts the normal sleep-wake cycle and sleep architecture [85]. Key aspects of this interaction include the suppression of sleep stages, where anesthesia-induced unconsciousness typically resembles a non-physiological sleep state, leading to disturbances in the natural sleep cycle [86]. Additionally, anesthesia can disrupt circadian rhythms, the body's internal biological clocks regulating sleep-wake patterns, resulting in changes in the timing and quality of sleep in the postoperative period [87]. Furthermore, anesthesia may impact sleep architecture, potentially leading to fragmented sleep, reduced SWS, and changes in REM sleep patterns during the recovery phase [88].

Conversely, an individual's preoperative sleep quality can significantly influence their response to anesthesia and the recovery process [89]. Poor preoperative sleep quality may render individuals more sensitive to anesthetic agents, potentially necessitating adjustments in dosage and anesthesia management to achieve the desired level of unconsciousness [90]. Sleep disturbances following surgery under anesthesia can have implications for the postoperative recovery period, contributing to increased fatigue, slower healing, and heightened pain perception [91-92]. Inadequate sleep before surgery may even increase the risk of postoperative delirium, a condition characterized by confusion and altered mental states, which can prolong hospital stays and impact overall patient well-being [93].

Recognizing the interplay between anesthesia and sleep, researchers and medical professionals are exploring techniques and strategies to minimize the disruption of sleep patterns during medical procedures. This includes balancing the depth of anesthesia to the specific procedure and the patient's sleep patterns to minimize disruption to sleep architecture. Optimizing recovery conditions by creating postoperative environments that promote restorative sleep, including reducing noise and disturbances in hospital settings, is crucial [94]. Additionally, patient education plays a role, as informing patients about the potential impact of anesthesia on sleep and providing guidance on strategies to improve sleep quality in the postoperative period contributes to a more holistic approach to patient care.

In conclusion, the interaction between anesthesia and sleep is a multifaceted phenomenon with implications for both the administration of anesthesia and patient outcomes. Recognizing this intricate relationship and its effects on sleep patterns and recovery is essential for healthcare professionals striving to optimize patient care and surgical outcomes within the context of anesthesia administration. Further research in this field continues to refine our understanding of this complex and important interplay.

Anesthetics and Analgesics

The realm of anesthetics and analgesics within the context of sleep interaction is marked by a diverse array of pharmacological agents, each exerting unique effects on sleep architecture and patterns [95]. Notably, intravenous anesthetics such as sodium thiopental and propofol have demonstrated the propensity to enhance the activity of GABAergic neurons within the ventrolateral preoptic nucleus (VLPO) of the hypothalamus [95]. This enhancement of GABAergic activity results in sedative and hypnotic effects, paralleling the mechanisms underlying the induction of natural sleep [96]. Propofol, in particular, is acknowledged for its rapid onset of action and is widely employed for its sleep-promoting properties [97]. However, it is noteworthy that even within this category, variations exist in their impact on sleep quality, with the potential for differences in SWS preservation and REM sleep patterns.

Conversely, the administration of opioids as analgesics presents a contrasting facet of anesthetics and analgesics, characterized by the propensity to disrupt sleep [98]. Opioids are renowned for their pain-relieving properties but are concurrently linked to alterations in sleep architecture [99]. These alterations manifest as reductions in SWS, REM sleep suppression, and frequent sleep cycle interruptions [100]. Such disturbances in sleep can lead to diminished sleep quality and heightened postoperative fatigue. Additionally, volatile general anesthetics, including Sevoflurane and isoflurane, have been associated with transient sleep disturbances and fragmented sleep patterns [9, 101]. Understanding the distinctive effects of these pharmacological agents on sleep architecture is instrumental in optimizing anesthesia regimens, ensuring postoperative sleep quality, and ameliorating the potential consequences on patient recovery, fatigue mitigation, and the management of postoperative delirium risk [102].

Postoperative Sleep Disruptions and Primary Factors

Knill et al. report that there is a risk of sleep disturbance following general anesthesia, which is characterized by an increase in rebound REM sleep. It has also been observed that the percentage of REM sleep tends to increase after abdominal surgery [103-104]. Furthermore, Chung et al. have noted changes in the sleep cycle within the first day after general anesthesia in patients with obstructive sleep apnea [105]. To counteract these disturbances, various measures can be taken, including reducing postoperative stress, managing pain appropriately, and promoting early return to daily activities at home by allowing patients to be discharged from the hospital earlier. Studies show that individuals undergoing surgery under general anesthesia experience reduced sleep efficiency on the initial night following the procedure [106-107].

The initial night following general anesthesia for pediatric patients undergoing tonsillectomy is characterized by decreased sleep efficiency and REM sleep [108]. Additionally, on the third night after surgery, there is a rebound in REM sleep due to the significant inhibition of REM sleep phases [109]. The choice of anesthetic agent used during general anesthesia can also impact sleep patterns. In this case, total intravenous anesthesia with propofol and remifentanil was utilized. While propofol has been found to eliminate REM sleep, it does not appear to cause an increased rebound during the REM phase. Opioids, on the other hand, can suppress slow-wave and REM sleep through the μ receptor [110-111]. Various factors, such as inflammation, environmental factors, and psychological factors, contribute to sleep disturbances after general anesthesia [112]. Severe pain perception resulting from regional wounds, particularly after tooth extraction, is a major risk factor for sleep disturbance [113]. However, in tooth extraction cases, the impact of pain on sleep disturbance is minimal due to the administration of acetaminophen during general anesthesia. Insomnia is another factor that can decrease sleep efficiency and REM sleep after surgery [107]. There is a hypothesis that general anesthesia may disrupt postoperative sleep patterns and/or circadian rhythm [114], but the underlying mechanisms and potential behavioral changes are not fully understood. To understand the clinical relevance of postoperative sleep disturbances in individuals with Autism Spectrum Disorder (ASD), it may be necessary to investigate cognitive function and behavioral science. Additionally, there is a need to establish a preventative pharmacological protocol for postoperative sleep disturbances following general anesthesia.

Ayuse et al. have proposed that general anesthesia can lead to sleep disturbances in the postoperative period among patients with disabilities. They discovered that the percentage of deep sleep significantly decreased on the first day after surgery, while the percentage of light sleep increased. Additionally, they observed that sleep cycles were noticeably longer on the first day after surgery. These findings suggest that the sleep cycle may be affected in patients with disabilities within the initial 24 hours following general anesthesia [5]. In another study, Song et al. found that patients undergoing hip fracture surgery experienced greater disruption in their circadian rhythm when receiving general anesthesia compared to those receiving subarachnoid anesthesia [115]. Wang et al. stated that children who underwent multiple plastic surgeries between the ages of 6 and 15 years with repeated exposure to general anesthesia may experience poorer sleep quality and a higher likelihood of sleep disorders [6]. Additionally, van Zuylen et al. concluded that general anesthesia disrupts the circadian timing system, as evidenced by a perioperative phase advance at the midpoint of sleep [116]. However, some studies have opposing results and suggest that general anesthesia does not significantly affect sleep quality. In fact, Selvadural et al. reported that general anesthesia did not lead to disrupted sleep or negative behavioral changes in otherwise healthy children undergoing elective low complexity surgeries [117]. Tran et al. also indicated that no notable variance in sleep disturbance was observed in any of the surveys conducted following general anesthesia. This conclusion was drawn after analyzing anesthesia records and conducting interviews with patients [118].

Cerebellar malfunction and postoperative sleep disturbance

The cerebellum, traditionally synonymous with motor coordination, has increasingly come under scrutiny for its involvement in non-motor functions, particularly the regulation of sleep-wake cycles [119]. Cerebellar dysfunction has the capacity to disrupt these cycles, resulting in a spectrum of sleep disturbances, and emerging evidence suggests its relevance in the realm of postoperative sleep quality after general anesthesia [120]. Extensive research has delineated the role of the cerebellum in motor processes, procedural memory formation, and the temporal prediction of motor actions, all of which exhibit intimate connections with the sleep-wake cycle [121]. Notably, postoperative sleep deprivation has been shown to impact the functional link between cerebellar nuclei and neocortical regions, particularly following tasks involving motor learning [121-122]. Sleep patterns undergo significant perturbations immediately after surgery, marked by reductions in total sleep time, slow-wave sleep (SWS), and rapid eye movement (REM) sleep, accompanied by heightened sleep arousal times [123]. These disruptions can persist for several nights or even weeks post-surgery. Moreover, the sustained diminishment of REM sleep has been linked to the emergence of REM sleep behavior disorder, a condition characterized by the enactment of dreams during sleep [124].

Conversely, cerebellar dysfunction stemming from various conditions, including spinocerebellar ataxia and cerebellar stroke, has been associated with a litany of sleep disturbances, encompassing insomnia, excessive daytime sleepiness, and REM behavioral disorders [125]. Research has unveiled alterations in sleep architecture, including changes in non-rapid eye movement (NREM) and REM sleep in patients grappling with cerebellar impairments [126]. Plausible mechanisms underpinning these effects may involve the influence of cerebellar projections on neural circuits governing the sleep-wake cycle, the cerebellar cortex, and anterior cerebellar nuclei's role in motor control, and potential interactions with brainstem systems and intracranial inflammatory responses [127]. To sum up, there is substantial evidence indicating a high occurrence of sleep disturbances after surgery in individuals with cerebellar dysfunction. Impaired sleep quality post-surgery significantly affects their overall well-being [128]. Consequently, forthcoming clinical investigations aim to pinpoint the root cause of cerebellar dysfunction prior to surgery to prevent sleep disturbances, devise innovative treatment approaches for addressing sleep issues, and ultimately enhance the quality of life for individuals with cerebellar dysfunction.

Alzheimer's disease (AD) is a leading cause of dementia in both old and middle-aged individuals, manifesting as memory loss, decreased cognitive ability, and loss of fine motor skills [129]. The cerebellum is an essential component of neural networks involved not only in motor functions, but also in autonomic nervous system regulation, emotional processing, and cognitive behaviors [130]. Damage to the motor cerebellum can result in movement disorders, while lesions in the posterior lobe can lead to intellectual and emotional sensory disturbances [131]. Furthermore, cerebellar dysfunction and sleep disruptions can exacerbate neurodegenerative and neuropsychiatric disorders, making them significant factors in the progression of AD

[132]. Studies have suggested that general anesthesia, which induces loss of consciousness, may have neurotoxic effects and potentially lead to long-term behavioral issues [133]. However, there remains limited clinical knowledge regarding the interplay between AD, general anesthesia's impact on the cerebellum, and sleep quality. Thus, large-scale, multicenter trials are necessary to enable early identification and intervention for improved postoperative recovery in patients.

A report indicated that individuals with ASD suffer from sleep disorders even in normal living conditions, and there is a strong correlation between these sleep disorders and self-harming behaviors [134]. We hypothesized that the symptoms of daytime insomnia, caused by a decrease in overall sleep duration commonly experienced by those with ASD, may contribute significantly to the disruption of sleep patterns [135]. Additionally, sleep efficiency decreases with age [136]. Therefore, when working with older ASD patients, it is important to consider potential changes in their sleep architecture before planning for general anesthesia [137]. Previous studies have suggested that minimizing agitation and excitement during the recovery period from local anesthesia using sedative agents may help reduce sleep disturbances after general anesthesia in individuals with ASD. It is worth noting that sleep disturbances can interact with oral medications such as antiepileptic and/or antipsychotic drugs in individuals with ASD. An increased risk of sleep disorders associated with elevated orexin levels after general anesthesia has also been reported [138]. Alongside insomnia treatment, future strategies for managing sleep disturbances in ASD patients could involve proactive measures to normalize orexin levels through the administration of an orexin antagonist, such as Suvorexant. Furthermore, comprehensive perioperative management, including preoperative instructions, hospitalization, and post-operative follow-up, is essential for ASD patients.

How to improve sleep disturbance after general anesthesia?

Pharmacological measures

A recent systematic review found inadequate evidence to support the use of pharmacotherapy for improving sleep in hospitalized patients [139]. However, certain drugs are currently being utilized to enhance sleep in postoperative patients. Zolpidem, a short-acting nonbenzodiazepine compound of the imidazopyridine class, enhances the activity of GABA, an inhibitory neurotransmitter, by binding to GABAA receptors at the same location as benzodiazepines [139]. In a study with a small sample size, Zolpidem given one night before and one night after surgery in patients undergoing hip or knee replacement improved perceptions of sleep quality and fatigue but did not impact sleep architecture [140].

Melatonin, which is secreted by the pineal gland and regulates circadian rhythms and sleep, has decreased levels in surgical and hospitalized patients [141]. A meta-analysis demonstrated that preoperative melatonin reduces anxiety before surgery and performs just as effectively as midazolam [142]. In a small study of patients undergoing prostatectomy, preoperative melatonin improved sleep quality, reduced pain scores and tramadol use, but caused sedation during the early postoperative period [143]. In patients recovering from breast cancer surgery, melatonin administration improved sleep quality without significant side effects [144].

Dexmedetomidine, a selective $\alpha 2$ adrenoceptor agonist with sedative and analgesic properties [145], exerts its sedative effects through a sleep-promoting pathway and induces a state similar to N2 sleep [146]. Nighttime infusion of a sedative dose of dexmedetomidine in mechanically ventilated ICU patients maintained the day-night sleep cycle and enhanced sleep architecture by increasing sleep efficiency and N2 stage [147-148]. In non-mechanically ventilated elderly patients admitted to the ICU after surgery, a low dose of dexmedetomidine infusion during the night (0.1mg/kg/h) extended total sleep time, increased N2 sleep (and decreased N1 sleep), and improved subjective sleep quality [149].

Nonpharmacological measures

Some strategies that can be implemented to improve the sleep quality of patients in the ICU after surgery are as follows: utilizing regional anesthesia whenever possible, minimizing surgical trauma by opting for laparoscopic surgery instead of open abdominal surgery, providing multiple forms of pain relief to reduce the need for opioids, and eliminating disruptive factors during nighttime. According to sleep care guidelines, creating a serene and dim setting while minimizing disturbances from medical procedures can enhance the quality and efficiency of sleep in these patients. Furthermore, a meta-analysis demonstrated that using ear plugs and eye masks can also facilitate better sleep among ICU patients [150-152].

Electroacupuncture has emerged as a promising approach in clinical practice. This innovative technology has gained popularity in recent years due to its potential to regulate neurotransmitter levels within the brain, particularly reducing norepinephrine and dopamine concentrations, which are known to influence sleep patterns [153]. By modulating these neurotransmitters, electroacupuncture aims to enhance sleep quality in the postoperative period. Additionally, this technique plays a role in managing surgical pain, a factor that can significantly impact sleep quality after general anesthesia

[154]. It achieves pain relief by downregulating immune activity through the suppression of substances such as substance P (SP), neurokinin-1 (NK-1), and cyclooxygenase-1 (COX-1). Simultaneously, it upregulates serotonin receptor expression (particularly 5-HT1AR and 5-HT2AR) and enhances endocannabinoid levels, further contributing to improved sleep outcomes [155]. While electroacupuncture shows promise in mitigating the adverse effects of general anesthesia on postoperative sleep, further research is warranted. To optimize the effectiveness of electroacupuncture in improving sleep quality and managing pain during the post-anesthesia recovery phase, it is crucial to conduct extensive and multicenter research studies. These studies should focus on identifying the most suitable duration, frequency, and timing for the application of electroacupuncture. This ongoing exploration of electroacupuncture's potential underscores the importance of innovative approaches in addressing the intricate relationship between anesthesia and sleep disturbances.

Conclusions

Sleep disruptions often occur following surgery, particularly major procedures. Factors such as advanced age, existing health conditions before surgery, the type of anesthesia used, the severity of the surgical trauma, postoperative pain, environmental stress, and other factors that cause discomfort in patients contribute to these disruptions. The development of sleep disturbances has negative consequences for postoperative patients, including an increased risk of delirium, heightened sensitivity to pain, a higher likelihood of experiencing cardiovascular events, and a diminished rate of recovery.

Both non-pharmacological and pharmacological approaches can be employed to enhance postoperative sleep and may prove beneficial for patients with impaired cerebellar or cognitive function, as well as intellectually disabled individuals with autism spectrum disorder or attention-deficit/hyperactivity disorder. Further research is needed to fully understand the long-term effects of sleep promotion therapy.

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