SPECIAL ARTICLE

Effect of Inadequate Sleep on Clinician Performance

CME

Haleh Saadat, MD

The negative impacts of sleep deprivation and fatigue have long been recognized. Numerous studies have documented the ill effects of impaired alertness associated with the disruption of the sleep-wake cycle; these include an increased incidence of human error–related accidents, increased morbidity and mortality, and an overall decrement in social, financial, and human productivity. While there are multiple studies on the impact of sleep deprivation and fatigue in resident physicians, far fewer have examined the effects on attending physicians, and only a handful addresses the accumulated effects of chronic sleep disturbances on acute sleep loss during a night call-shift. Moreover, the rapid and unprecedented spread of coronavirus disease 2019 (COVID-19) pandemic significantly increased the level of anxiety and stress on the physical, psychological, and the economic well-being of the entire world, with heightened effect on frontline clinicians. Additional studies are necessary to evaluate the emotional and physical toll of the pandemic in clinicians, and its impact on sleep health, general well-being, and performance. (Anesth Analg 2021;132:1338–43)

GLOSSARY

ACGME = Accreditation Council for Graduate Medical Education; **COVID-19** = coronavirus disease 2019; **DOES** = disorders of excessive somnolence; **EEG** = electroencephalography; **EF** = executive function; **FIRST** = Flexibility in Duty Hour Requirements for Surgical Trainees; **ICU** = intensive care unit; **NREM** = nonrapid eye movement; **POMS** = profile of mood status; **PSD** = partial sleep deprivation; **PVT** = Psychomotor Vigilance Test; **REM** = rapid eye movement; **RT** = reaction time; **SD** = sleep deprivation; **SEM** = structural equation modeling; **TMD** = total mood disturbance; **TMS** = total mood status; **TSD** = total sleep deprivation

SLEEP PHYSIOLOGY

Sleep is an active state, characterized by reduced alertness and responsiveness, that is rapidly reversible.[1] The homeostatic regulation of sleep interacts with our circadian rhythm to regulate the sleep-wake cycle; this usually coincides with the hormonal response (melatonin) to initiate the nocturnal sleep period.[2,3] Sleep consists of nonrapid eye movement (NREM) and rapid eye movement (REM) periods. An individual transitions from relaxed wakefulness (alpha activity) to a slower theta rhythm in stage 1 of NREM. K complexes and sleep spindles start to superimpose theta activity in NREM stage 2. It is not until NREM stages 3 and 4 that mental and physical processes slow down to delta activity where physical and mental restoration take place. REM sleep occurs approximately 90 minutes afterward. It is an active stage where most dreaming occurs. The electroencephalography (EEG) pattern of REM sleep is similar to that of an awake state, except for REM in the right and left oculogram channels. Individuals cycle through these phases every 90–120 minutes.

The need for sleep changes with age; it also varies widely among individuals of the same age. There is no set number of sleep hours. Infants sleep as much as 16–18 hours per day, which boosts their growth and development. On average, school-age children and teens need 9 sleep hours per night, and most adults need 7–9 sleep hours per night. After age 60, nighttime sleep tends to be shorter, lighter, and interrupted by multiple awakenings. Older adults tend to take medications that can interfere with sleep.[4]

THE EFFECTS OF SLEEP DISTURBANCES

Sleep disturbances include disorders of initiating and maintaining sleep (insomnias), disorders of excessive somnolence (DOES), disorders of sleep-wake schedule, and dysfunctions associated with sleep, sleep stages, or partial arousals (parasomnias).[5] They consist of a broad range of clinical presentations that involve a variety of physiologic, emotional, and behavioral abnormalities. Consistent with the 24-hour day-night cycle, these abnormalities often do not confine themselves to the sleep period and frequently manifest themselves primarily during the waking hours. Sleep

From the Department of Anesthesiology, Frank H Netter School of Medicine, Quinnipiac University, Hartford Health Care, St. Vincent's Medical Center, Bridgeport, Connecticut.

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Address correspondence to Haleh Saadat, MD, FAAP, Department of Anesthesiology, Frank H. Netter School of Medicine, Quinnipiac University, 370 Bassett Rd, North Haven, CT. Address e-mail to haleh.saadat@quinnipiac.edu.

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disturbances associated with elevated inflammatory markers such as high-sensitivity C-reactive spectrum of diseases, such as atherosclerosis,[6,7] hypertension,[8] obesity,[9] type 2 diabetes,[10] which contributes to a higher all-cause mortality.[11–13]

Disruption of the sleep-wake cycle also affects a wide range of cognitive functions, such as decision making, memory, attention, and learning.[14–17] Sleep deprivation (SD) is a major contributing factor in motor vehicle accidents, which is the fifth leading cause of death in the United States with an estimated annual socioeconomic impact of over 60 billion dollars.[18–20] Driver fatigue after a night of total SD has been shown to produce psychomotor impairments similar to those seen in subjects with blood alcohol content of 0.07%.[21] Some of the most devastating health and environmental disasters (the nuclear reactor meltdowns at 3 Mile Island and Chernobyl; the grounding of the Star Princess cruise ship and the Exxon Valdez oil tanker) have been partially attributed to night shift work–related performance failure.[22–26]

The first study on the effects of SD on cognitive performance in humans was reported in 1896, where 3 volunteers were subjected to a 90-hour total sleep deprivation (TSD) during which 1 individual experienced hallucination.[28] Since then, 3 general types of SD have been studied regarding its impact on behavioral changes: (1) long-term SD (>45 hours), (2) short-term SD (≤45 hours), and (3) partial SD (<7 h/24 h). Partial sleep deprivation (PSD) can be due to stress, changes in lifestyle (eg, the birth of a baby), medications (eg, central stimulants), medical conditions (eg, acute or chronic pain, obstructive sleep apnea), suboptimal sleep environment as well as professional night call duties (eg, health care providers, pilots, military, drivers).The circadian system is also highly sensitive to external light, particularly short-wavelength light of approximately 460 nm, or "blue light." This type of light emits from electronic screens and has been shown to suppress melatonin.[27]

SD IN CLINICIANS

SD impacts neurocognition and behavior ranging from simple measures of cognition (eg, attention and reaction time [RT]) to far more complex errors in judgment and decision. The most prominent theory is based on the prefrontal vulnerability hypothesis.[28] It suggests that SD impairs cognitive performances that are dependent on the prefrontal cortex, such as language, executive functions (EFs), divergent thinking, and creativity. Cognitive performance increasingly worsens when time on task is prolonged and the fatigue exacerbated by SD sets in.

Previous studies have shown that resident trainees working frequent shifts of 24 or more consecutive hours made 36% more serious medical errors than those working night shifts that were limited to <16 consecutive hours.[29–30] Following those results, The National Academy of Medicine recommended that resident physicians work no more than 16 consecutive hours without sleep.[31] In 2011, the Accreditation Council for Graduate Medical Education (ACGME) prohibited work shifts exceeding 16 consecutive hours for first-year resident physicians.[32] However, the 2016 Flexibility in Duty Hour Requirements for Surgical Trainees (FIRST) trial showed that flexible duty-hour policies were not associated with higher patient deaths or serious complications. As a result, the ACGME overturned its work shift hour limit and once again permitted work shifts of 24 consecutive hours for residents.[33] A recent multicenter, cluster-randomized, crossover trial compared the incidence of serious medical errors among pediatric intensive care unit (ICU) residents between those who worked 24 hours or more (control group) and those who rotated through different shifts (day or night) of 16 hours or less (intervention group). This study showed that residents in the intervention group had a higher incidence of harmful medical errors despite the improvement in their sleep and neurobehavioral performances, compared to the control group. The investigators concluded that this unexpected finding was likely related to poor handoffs stemming from the lack of infrastructure, excessive workload, and inadequate staffing.[34]

A European survey on fatigue in more than 3500 attending anesthesiologists and pediatric intensivists in the United Kingdom and Ireland shows similarities with the North American experience. The analysis of the data showed that only 15% of participants can consistently achieve the 11-hour rest between their call and their next clinical duty that is mandated by the European Working Time Directive.[35] More than 90% of participants reported work-related fatigue, and over half experienced significant negative impact on their well-being, health, and work-life balance. More importantly, the survey demonstrated that the night call was not the only source of fatigue. Many other contributing factors at work such as long days, unmanageable workload, weekend shifts, staffing shortage, no ability to take breaks, stress of potential or actual legal litigations added significantly to work-related fatigue.

The pandemic has undoubtedly contributed to work level stress. The combination of the clinicians' concern regarding the patient care, personal safety, fear of transmission of the virus to family members, home confinement, and self-isolation have created an unrestful sleep with a negative impact on well-being. Anesthesiologists have been particularly affected due to direct involvement with aerosol-generating procedures, reassignments to off-floor locations such as intensive care units and emergency departments, and the emotional and physical toll of dealing with the overwhelming number of suffering and dying patients.

Some studies already started to evaluate the effect of the pandemic on health care workers. A 1-month cross-sectional observational study on 180 medical staff who treated patients with coronavirus disease 2019 (COVID-19) infection used a structural equation modeling (SEM), a multivariate analysis method to determine the structural relationship between measured variables. This observational study aimed to use SEM to determine the effects of social support on sleep quality and function of medical staff between January and February 2020 in Wuhan, China. Measuring various methods concluded that having social support for medical staff was positively associated with self-efficacy and sleep quality and negatively associated with the degree of anxiety and stress.[36]

Future research on the specific effect of COVID-19 pandemic on the frontline workers, such as anesthesiologists, is needed to capture the unique concepts that emerged during this period, with potential suggestions for protective measures.

INDIVIDUAL DIFFERENCES IN PSD VULNERABILITY

It is important to acknowledge the 2 confounding factors of intersubject and intrasubject variability on the effects of SD on cognitive tasks.[38,39] Timing, length, and the structure of sleep vary among individuals which creates significant individual vulnerability to the impact of PSD. Studies found that some people are more vulnerable to SD than others.[40] For example, 1 subject's poorest performance during SD may still be superior to the performance of a non–sleep-deprived individual (intersubject confounder). This is particularly problematic since individuals may not be fully aware of their susceptibility to impairment. Similarly, a person may be cognitively diminished by sleep loss, but can improve on a repeated task due to the effects of learning (learning is an intrasubject confounder). Incorporating contributing factors in individual differences (eg, history of insomnia, chronic exposure to psychological stress and allostatic load, age, work-home conflict, burnout) may more accurately predict the impact of SD in research studies.[40]

COGNITIVE TASKS AND SD

The degree of impairment varies widely not only within and between individuals but also among cognitive tasks.[41–43] The effects of SD are more apparent for tasks requiring vigilant attention, compared to tasks based on working memory, decision making, and EF.[44,45]

Attention refers to the process of focusing mental resources on specific parts of a stimulus or allocating resources between several responses; it does not require any working memory.[46,47] EF is a higher-level cognitive process responsible for more complex and goal-directed behaviors such as planning, initiation, sequencing, and monitoring. Working memory, behavioral inhibition, multitasking, and task shifting are all under the EF domain.[48,49] Therefore, the variable selected for measurement is critical since less sensitive metrics can miss the effects of SD on different cognitive outcomes.[50] Effective performance depends on prefrontal cortical cognitive functions of memory and tracking capacity to create mental models and to evaluate risks in the face of rapidly changing information. These processes can significantly stress and impair other prefrontal cortex functions (eg, EF, mood regulation, communication) that have vital importance in health care team models.[51]

Interestingly, some complex tasks that are intriguing in nature and that require critical reasoning show less sleep-related degradation compared to dynamic, naturalistic decision making. Therefore, it is possible for individuals to compensate for cognitive impairment when dealing with more stimulating scenarios (eg, performing medical procedures), but are less compensatory when tasks are repetitive and rely primarily on attention and vigilance (eg, monitoring vital signs, ordering medications).[52]

A wide range of medical skills, as well as effective communication and collaborative teamwork with other health care professionals, are required in dealing with challenging emergency situations among physicians. Our research team conducted a series of studies on the impact of SD during 17-hour night shifts (3 PM–7 AM) in attending anesthesiologists working in an academic, tertiary care children's hospital. In these studies, we evaluated the impact of PSD on the RT, the cognitive skills, and the total mood status (TMS) and its relationship with individual coping strategies in a typical clinical hospital setting as compared to regular working hours. RT and TMS have been found to be reliable metrics of performance. Specifically, they are accurate measures of attention, vigilance, and declarative memory.

For RT, we used the Psychomotor Vigilance Test (PVT). PVT is among the most widely used tools to assess behavioral alertness and sustained performance.[54,55] The task is a standard laboratory tool based on a simple visual response time test apparatus for the assessment of sustained performance in a variety of experimental conditions.[53] The measure is obtained using a 10-minute PVT (Ambulatory Monitoring Inc, New York, NY) device. The PVT-192 monitor is a handheld, self-contained system used for assessing repetitive reactions by measuring the speed with which subjects respond to a visual stimulus. Participants press a button on the handheld unit in response to numbers scrolling on the liquid crystal display screen with a 2- to 10-second interstimulus interval. The primary dependent variable is mean RT,

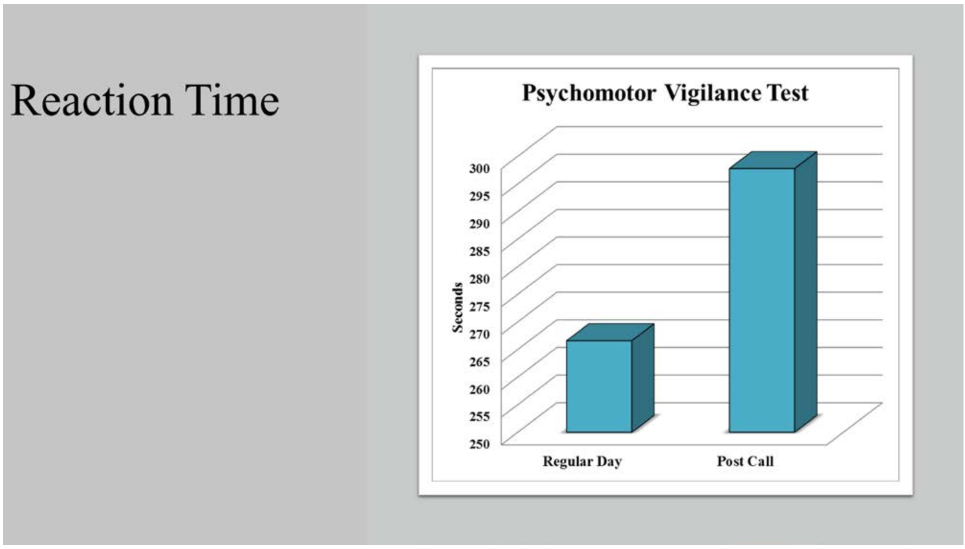

Figure. Reaction time.

with higher scores indicating increased RT or worse performance. PVT is minimally affected by aptitude and learning and responds to a variety of sleep loss conditions. Our study found that all subjects experienced a definite decline in motor task performance (PVT) at their postcall assessments (Figure).

For TMS, we used profile of mood status (POMS), a widely used quality-of-life measure with good psychometric properties.[54] It is a self-administered instrument comprising 65 adjective rating scales that assess transient mood states. Scores are obtained for 6 mood or affective states: (1) tension-anxiety, (2) depression-dejection, (3) anger-hostility, (4) vigor-activity, (5) fatigue-inertia, and (6) confusion-bewilderment. A total mood disturbance (TMD) score is obtained as the sum of all 6 factors scored after weighting vigor negatively. The total score provides a global estimate of affective state.

Coping Strategy Indicator

This is a relatively brief and practical instrument measuring modes of coping that has demonstrated considerable psychometric strength.[55] This instrument instructs responders to choose from a list of 33 coping behaviors in response to a recent stressful event, indicating the extent to which each was used to deal with the problem. It is a self-report instrument measuring 3 fundamental modes of coping (1. problem solving, 2. seeking support, and 3. avoidance).

TMD was significantly higher on a post call day with significant increase in tension; anger; fatigue; confusion; irritability, and significant decrease in vigor; energy; and confidence as compared to that observed on a regular noncall day. The first regression model identified a statistically significant positive correlation between change in avoidance coping strategy and change in PVT.[56,57]

COUNTERMEASURES

With all the controversies regarding the impact of work hours on medical errors, more evidence is needed to determine the most effective methods for fatigue mitigation. Health care organizations are exploring a variety of strategies and are implementing policies to ensure patient safety and to prevent medical errors. Examples of such strategies include risk assessment; standardized handoff practices; staff involvement in design of work schedules; fatigue management such as strategic use of caffeine and naps; staff education on sleep hygiene; and sleep breaks in suitable locations. Bright ambient illumination has also been shown to have a substantial impact on maintaining an optimal level of alertness and cognitive performance during nighttime work hours.[58] "Power nap," as coined by the military to lessen its potential negative connotation, has been shown to improve alertness and behavioral performance. It is particularly beneficial in performing tasks, such as addition, logical reasoning, RT, and symbol recognition.[59,61] Studies compared 5-, 10-, 20-, and 30-minute nap time, to determine if brief naps were as effective as longer naps. The 10-, 20-, and 30-minute naps led to improvement in cognitive performance and alertness, while the 5-minute nap and no nap conditions did not. Moreover, the 10-minute nap showed immediate benefits, while the 20- and 30-minute naps led at least initially to some sleep inertia, which is a transitional state of lowered arousal occurring immediately after awakening from sleep with temporary decrement in subsequent performance.[62] These strategies have already been implemented in other industries such as aviation, trucking, and rail transportation.[63]

Exposure to chronic psychological stress produces cumulative dysregulation of several major physiological systems, a concept referred to as allostatic load.[64] Working in an exhausting system can result in increased allostatic load and, ultimately, physician burnout. To realize the benefits of the aforementioned measures, organizational problems and systemic issues such as unmanageable workload, inadequate infrastructure, unhealthy workload demand, lack of role clarity and communication has to be addressed.

CONCLUSIONS

There is little doubt on the negative effects of SD on human performance. Nevertheless, the evidence on SD in resident physicians and rate of medical error is mixed; the topic is almost entirely ignored in attending (or staff) physicians.

The increased anxiety and unique concepts that clinicians confront during COVID-19 pandemic intensified sleep health and well-being problems. Robust research with strong methodologies that address the specific notions that emerged during this period, as well as the critical accumulated effect of individual differences, is urgently needed to guide improvement in current practices and policies that embrace the physical and mental well-being of practicing physicians, trainees, and patients.

DISCLOSURES

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