To Sleep, Perchance to Dream: Acute and Chronic Sleep Deprivation in Acute Care Surgeons

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BACKGROUND: Acute and chronic sleep deprivation are significantly associated with depressive symptoms and are thought to be contributors to the development of burnout. In-house call inherently includes frequent periods of disrupted sleep and is common among acute care surgeons. The relationship between in-house call and sleep deprivation among acute care surgeons has not been previously studied. The goal of this study was to determine prevalence and patterns of sleep deprivation in acute care surgeons.

STUDY DESIGN: A prospective study of acute care surgeons with in-house call responsibilities from 2 level I trauma centers was performed. Participants wore a sleep-tracking device continuously over a 3-month period. Data collected included age, sex, schedule of in-house call, hours and pattern of each sleep stage (light, slow wave, and rapid eye movement [REM]), and total hours of sleep. Sleep patterns were analyzed for each night, excluding in-house call, and categorized as normal, acute sleep deprivation, or chronic sleep deprivation.

RESULTS: There were 1,421 nights recorded among 17 acute care surgeons (35.3% female; ages 37 to 65 years, mean 45.5 years). Excluding in-house call, the average amount of sleep was 6.54 hours, with 64.8% of sleep patterns categorized as acute sleep deprivation or chronic sleep deprivation. Average amount of sleep was significantly higher on post-call day 1 (6.96 hours, $p = 0.0016$), but decreased significantly on post-call day 2 (6.33 hours, $p = 0.0006$). Sleep patterns with acute and chronic sleep deprivation peaked on post-call day 2, and returned to baseline on post-call day 3 ($p = 0.046$).

CONCLUSIONS: Sleep patterns consistent with acute and chronic sleep deprivation are common among acute care surgeons and worsen on post-call day 2. Baseline sleep patterns were not recovered until post-call day 3. Future study is needed to identify factors that affect physiologic recovery after in-house call and further elucidate the relationship between sleep deprivation and burnout. (J Am Coll Surg 2019;229:166−174. © 2019 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

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Sleep deprivation leads to a significant number of physical and emotional consequences including increased risk of stroke, obesity, colorectal cancer, breast cancer, suicide, depression, and low quality of life scores.[1-3] Mood alterations after periods of sleep deprivation specifically include exacerbation of negative emotions and a reduction in feelings of empathy, both of which are key components of burnout.[4-6] Burnout is a syndrome characterized by emotional exhaustion, a sense of depersonalization, and a decreased sense of accomplishment, particularly in relation to one's profession.[7-9] Burnout, which is one of the

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chief contributors to depression and suicide, is estimated to be as high as 50% among surgeons in the United States.[7] Studies since 2009 have shown that between 28% and 40% of surgeons surveyed experienced symptoms of burnout, with each subsequent study reporting higher rates than those before.[8-11]

In this context, it is not surprising that the number of hours worked and the number of nights on call per week have a strong association with development of burnout.[7,11,12] Compared with other surgical specialties, trauma surgeons reported the highest workload, with 1 study reporting 65% of trauma surgeons surveyed having worked more than 70 hours/week.[11] Trauma and acute care surgeons, along with cardiovascular, transplant, and urologic surgeons, report not only the longest hours, but the most nights on call.[12] Previous surveys, however, have not distinguished between nights of home call vs in-house call.[5,12] In-house call for attending surgeons, which is commonly required on trauma and acute care surgery services, inherently includes frequent periods of disrupted sleep.[13]

Sleep deprivation can occur as a result of either a lack of quality or quantity of sleep obtained. Acute sleep deprivation is defined by periods of wakefulness that extend beyond 16 to 18 hours; chronic sleep deprivation occurs when too little or poor quality sleep is achieved over multiple nights.[14] Sleep deprivation can also occur as a function of loss of either REM (rapid eye movement) or slow wave sleep—2 main stages of sleep.[15] Loss of REM sleep has been associated with a decreased ability of perceptual learning and memory consolidation; loss of slow wave sleep reduces the ability to perform simple tasks.[15] Sleep deprivation, burnout, and depression have clear negative side effects not only for the surgeon, but also for their patients. Acute and chronic sleep loss has been associated with an increase in medical errors, with 1 study reporting that burnout and depression were among the strongest contributors to major medical errors.[9,10,16]

There is a paucity of literature regarding the prevalence of sleep deprivation among surgeons, particularly those specializing in trauma and acute care. In addition, the physiologic impact of in-house call on sleep and the amount of time that is needed to recover after nights of in-house call have not been previously studied. The purpose of this study was to characterize patterns of sleep and recovery surrounding nights of in-house call and to determine the prevalence of sleep deprivation among trauma and acute care surgeons with in-house call responsibilities.

METHODS

After approval by the Institutional Review Board of Indiana University School of Medicine, a prospective observational study of acute care surgeons with in-house call responsibilities was performed at Indiana University Health Methodist Hospital and Sydney and Lois Eskenazi Hospital over a period of 3 months. These are both American College of Surgeons-verified Level I trauma centers in Indianapolis, IN. Attending trauma or acute care surgeons with in-house call responsibilities were eligible for enrollment. There were no exclusion criteria within this cohort. Acute care surgeons who volunteered to participate in the study were given a fitness and sleep tracking device called Whoop! (Whoop). The surgeons then downloaded the accompanying smart phone application and created a deidentified profile. The participants were instructed to wear the device either on the wrist or upper arm continuously for 3 months. They also were required to log into the smart phone application once daily to ensure noninterrupted data collection on call and noncall nights.

The Whoop! device is a trademarked, wearable biometric instrument, manufactured by a company that continuously measures physiologic stress and the body's response to that stress. It measures heart rate, heart rate variability, ambient temperature, skin conductivity, and movement via a 3-axis accelerometer 100 times per second on a continual basis. Through heart rate, heart rate variability, and movement detection, it automatically detects sleep and sleep stage. Whoop! has been internally validated in a laboratory setting by comparison against graded polysomnography conducted by a certified polysomnography technologist. Whoop! was shown to have 96% accuracy, 93% sensitivity, and 98% specificity. Data collected included age, sex, hours and pattern of each sleep stage, and total hours of sleep. Sleep stages were recorded as light, slow wave, or rapid eye movement (REM). Sleep patterns were also analyzed for each night excluding nights of in-house call. In-house call night patterns were unable to be analyzed secondary to either a complete lack of sleep or clearly disrupted sleep patterns.

Normal sleep is comprised of 2 different physiologic states: rapid eye movement (REM) sleep and non-REM sleep.[17] Non-REM sleep is then further divided into 4 stages, with stages 1 and 2 collectively referred to as light sleep and stages 3 and 4 as slow wave sleep.[17] Rapid eye movement sleep normally constitutes approximately 20% to 25% of total sleep time, with slow wave sleep occupying another 13% to 23%, and light sleep occupying the remainder.[17] A normal sleep pattern in a healthy, rested adult begins with non-REM sleep and includes progression to slow wave sleep for approximately 80 to 100 minutes before the first episode of REM sleep.[17] After this first cycle of REM sleep, non-REM and REM sleep then cycle throughout the sleep period, with slow wave sleep decreasing in duration and frequency and

REM sleep increasing in duration and frequency as the night progresses.[17] In people with 1 or 2 nights of decreased sleep, this normal pattern of sleep is characteristically altered.[17] Recovery from acute sleep deprivation is marked by a predominance of slow wave sleep and a delay in or the prevention of REM sleep.[14] In this study, nights of sleep with 2 or more cycles of slow wave sleep before a cycle of REM sleep were categorized as acute sleep deprivation. Chronic sleep restriction and irregular sleep schedules also show a characteristic sleep pattern, which consists of premature REM sleep.[14] Nights of sleep with 1 or more episodes of REM before the onset of slow wave sleep were therefore categorized as consistent with chronic sleep deprivation.

Descriptive analysis using the chi-square test followed by tests of proportions for sleep patterns (normal, acute, or chronic) was performed to compare differences in proportions between pre-call and post-calls consecutively on days 1 through 3. For circumstances in which participants took every other night call, data were recorded as post-call day 1 data, not pre-call data. Specifically, when a date was both post-call day 1 and pre-call due to the every other night schedule, the data were used and analyzed as post-call day 1 data only, not as pre-call. Within this study period, there were 23 instances of every other night call among 10 of the participants. Pairwise comparisons were made using Wald tests for the linear relationship after estimation of the proportion. For continuous variables, such as total sleep hours, REM sleep hours, and slow wave sleep hours, paired Student's *t*-tests were used to examine the mean differences between pre-call and post-calls consecutively at days 1 through 3. All tests were examined at 0.05 level of significance, and 95% confidence intervals were reported. Stata/SE 14.2[TLR1] (StataCorp) was used as software for the analysis.

RESULTS

There were 19 surgeons who met the inclusion criteria of in-house call responsibilities at either Indiana University Health Methodist Hospital or Sydney and Lois Eskenazi Hospital, and were approached to volunteer for the study. Eighteen surgeons consented to participate, with 1 surgeon terminating participation before conclusion of the trial, secondary to noncompliance of device wear. A total of 1,421 nights, including 227 nights of call, were recorded among the remaining 17 participants. The majority of participants were male ($n = 11$, 64.7%), with a mean age of 45.5 years (range 37 to 65 years). Average sleep latency (time it takes to fall asleep) across all nights included in the analysis was 4 minutes and 37 seconds.

The average number of in-house call nights per month during the study period was 2.5 to 6, with an overall average of 4.85 calls per surgeon. Excluding nights of in-house call, the average amount of sleep obtained by participants was 6.54 hours per night. Participants slept an average of 6.45 hours on the nights before call, and slept a significantly higher number of hours, 6.96, on post-call day 1 ($p < 0.001$). From post-call day 1, the number of sleep hours decreased significantly to an average of 6.33 ($p < 0.001$). Hours slept on post-call day 3 increased to 6.65; however, no significance was found in comparison to number of hours slept on nights before call or post-call day 2 (Fig. 1, Table 1).

Excluding nights of in-house call, sleep patterns were categorized as consistent with either normal, acute, or chronic sleep deprivation. Nights of sleep with 1 or more episodes of REM before the onset of slow wave sleep were categorized as chronic sleep deprivation. Acute sleep deprivation was defined by nights of sleep with 2 or more cycles of slow wave sleep before a cycle of REM sleep. Sleep patterns consistent with either acute or chronic sleep deprivation were recorded on 64.8% of nights. Nights of in-house call were not able to be analyzed due to the wide range of variability in the quality and pattern of sleep due to frequent disruptions and at times, complete lack of sleep.

Participants obtained an average of 1.12 hours of REM sleep and 1.24 hours of slow wave sleep on nights preceding in-house call. On post-call day 1, the number of REM sleep hours significantly increased, to 1.32 ($p = 0.02$), and there was an increase in the amount of slow wave sleep to 1.38 hours, but the difference did not reach statistical significance ($p = 0.07$). The amount of REM sleep decreased on post-call day 2 to 1.15 hours and then increased to 1.24 hours on post-call day 3, although statistical significance was not reached. Slow wave sleep significantly decreased on post-call day 2 to 1.11 hours ($p < 0.001$), then increased to 1.28 hours on post-call day 3; however, the increase on post-call day 3 did not reach statistical significance (Fig. 2, Table 2).

The percentage of nights with patterns consistent with acute sleep deprivation decreased from 44.0% on post-call day 2 to 40.3% on post-call day 3, but it did not reach significance. Sleep patterns categorized as chronic sleep deprivation decreased from 25.8% on post-call day 2 to 18.6% on post-call day 3, but also did not reach significance. Normal sleep patterns were recorded in 36.8% of pre-call nights and were not statistically different from post-call day 1 patterns, in which 37.0% were normal (Fig. 3, Table 3). The percentage of normal sleep patterns decreased to 29.8% on post-call day 2 and significantly increased to 41.1% on post-call day 3 ($p < 0.04$).

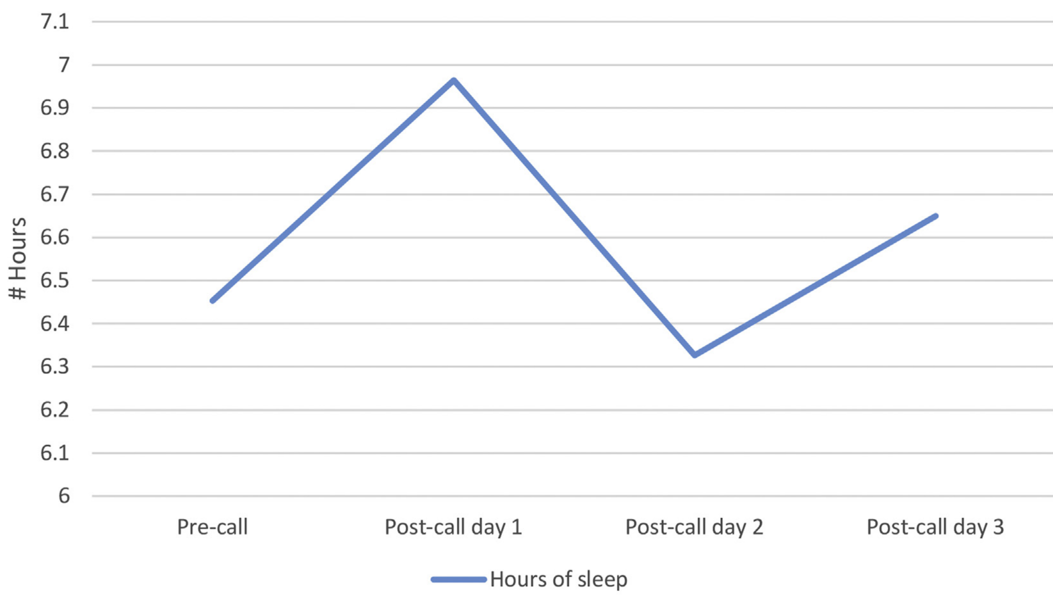

Figure 1. Overall trend of total hours of sleep, with significant decrease on post-call day 2 ($p = 0.0016$).

DISCUSSION

Work-related stress is a significant contributor to development of both burnout and depression. For surgeons in particular, there are unique physical and psychological components that contribute to stress in the workplace. The acts of performing surgery, participating in trauma activations, leading difficult conversations, and sleep deprivation have all been shown to produce physiologic changes in heart rate and heart rate variability that are consistent with moderate to high stress levels.[18-21] Given that information, it is not surprising that a career in surgery is associated with burnout rates reported in the range of 40% to 50%.[7,19,20,22] But a 2008 survey conducted by the American College of Surgeons examining the presence of distress and career satisfaction among 14 surgical specialties, revealed that not all surgeons and specialties experience burnout equally.[11] In fact, trauma surgeons reported the lowest mental quality of life and highest incidence of burnout among the 14 specialties surveyed.[11]

This study was therefore designed to physiologically track sleep patterns and determine the prevalence of sleep deprivation within trauma and acute care surgeons at 2 level I trauma centers to begin addressing the rapidly expanding rates of burnout and depression in this professional field. In this study of acute care surgeons with in-house call responsibilities, the average amount of sleep recorded on noncall nights, 6.54 hours, is significantly less than the recommended amount of sleep. Sleep patterns consistent with either acute or chronic sleep deprivation were common among participants. Chronic sleep deprivation patterns, as well as the lowest amounts of REM and slow wave sleep were most prevalent on post-call day 2, with normal sleep patterns occurring at the highest frequency on post-call day 3. These findings are similar to those discussed by Banks and colleagues,[14-23] which suggest that 2 to 3 nights of extended sleep may be needed to return to baseline neurobehavioral functions.

To achieve the full restorative effects of sleep, sleep must be adequate in duration, continuity, and type.[14,23] Therefore, the right amount of sleep and the right quality of sleep are imperative in achieving physiologic recovery. Within this small study population, restoration of

Table 1. Total Hours of Sleep

Night as related to call night	Hours slept	Hour difference (when compared with)	p Value
1 night before call	6.45	+0.09 (average)	
Post-call day 1	6.96	+0.42 (night before call)	0.0016*
Post-call day 2	6.33	−0.63 (post-call day 1)	0.0006*
Post-call day 3	6.65	+0.2 (night before call)	0.274
Post-call day 3	6.65	+0.32 (post-call day 2)	0.1149

*Statistically significant.

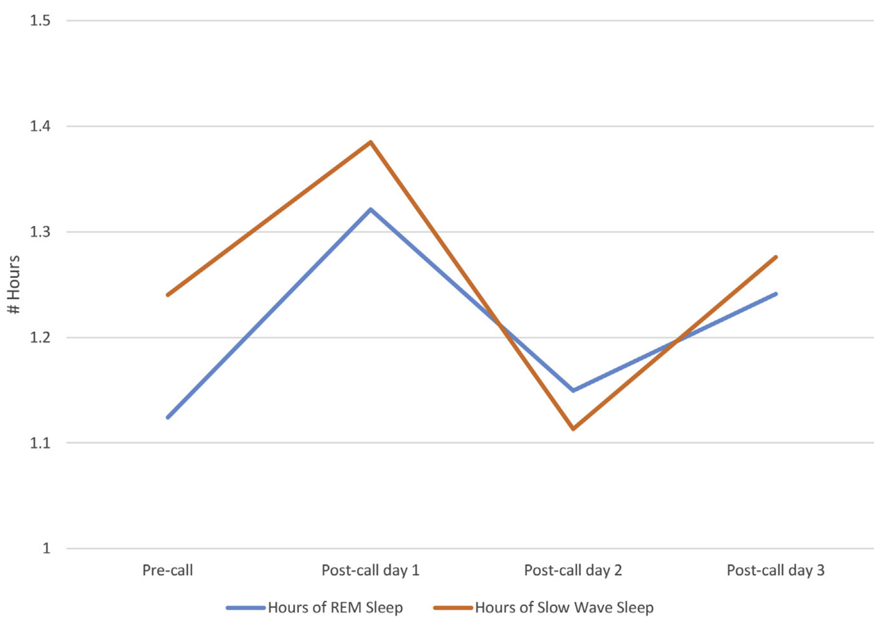

Figure 2. Trend of hours spent in rapid eye movement (REM) and slow wave sleep, with lowest amount recorded on post call day 2 (REM, p = 0.0767; slow wave sleep, p = 0.0016).

baseline sleep patterns was achieved on post-call day 3. Sleep deprivation can occur when either the amount or the quality of sleep is poor and is self-reported to occur in 20% of American adults.[14] In this study, this population of attending trauma and acute care surgeons with in-house call responsibilities experiences both forms of sleep deprivation, with almost half of post-call day 1 nights showing patterns of acute sleep deprivation.

Table 2. Total Hours of Rapid Eye Movement and Slow Wave Sleep

Night as related to call night, sleep cycle	Hours	Hour difference	p Value
1 night before call			
REM	1.12	–	–
Slow wave	1.24	–	–
Post-call day 1 as related to night before call			
REM	1.32	+0.20	0.021*
Slow wave	1.38	+0.14	0.0069*
Post-call day 2			
REM	1.15	+0.03	0.007*
Slow wave	1.11	-0.13	0.0016*
Post-call day 3			
REM	1.24	+0.12	0.87
Slow wave	1.28	+0.04	0.07

REM, rapid eye movement.
*Statistically significant.

Acute sleep deprivation is defined by periods of wakefulness that extend beyond 16 to 18 hours.[14] A single episode of sleep deprivation has been shown to result in impairment of memory and response time, reduced threshold for stress, and decrease in constructive thinking, and cognitive processing speed.[24-26] Chronic sleep deprivation occurs when too little or poor quality sleep is achieved over multiple nights. It is associated with neurobehavioral alterations as in acute sleep deprivation, as well as an increased risk of cardiovascular disease, hypertension, obesity, and type 2 diabetes mellitus.[27-29] Also, elevated cortisol levels and changes in immune function via natural killer cell activity and lymphokine-activated killer cell activity have been demonstrated in people with a sleep debt.[30,31] In addition, an elevated mortality risk has been found in adults reporting less than 6.5 hours of sleep per night.[32]

Wakefulness and sleep are highly regulated brain activities, and a balance between REM and non-REM sleep is also crucial to optimal neurobehavioral performance, learning, memory, and daily functioning.[1,17,33,34] Typically, young, healthy adults should spend 7 to 9 hours a night sleeping, with 20% to 25% or 1.40 to 2.25 hours spent in REM sleep.[13] Slow-wave sleep typically comprises 13% to 23% (0.9 to 2.1 hours) of sleep time. In comparison to results of this study, participants ranged from 17.1% to19% of sleep spent in REM and 17.0% to 19.8% of sleep spent in slow wave.

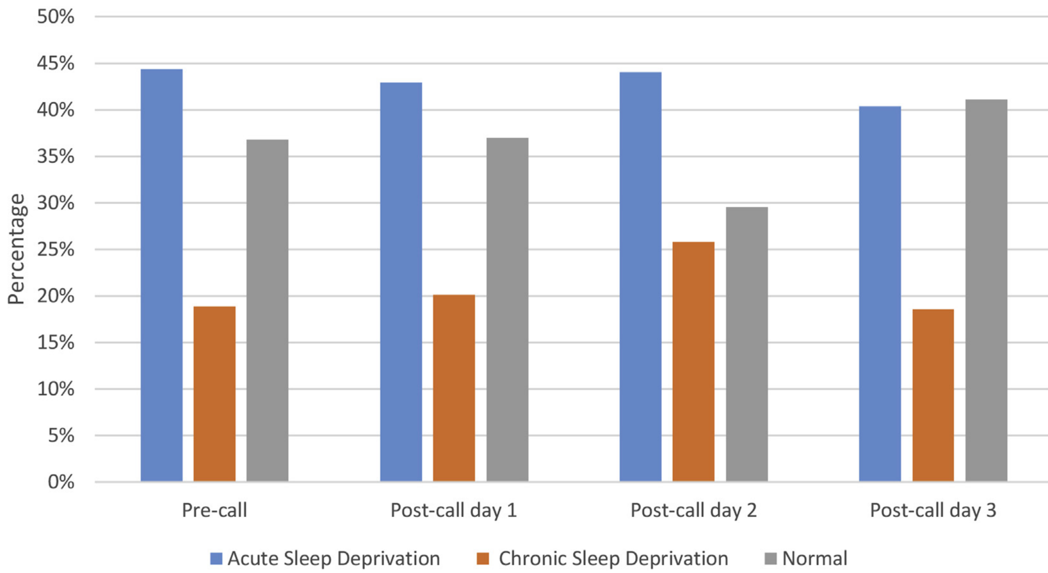

Figure 3. Percentage of acute sleep deprivation, chronic sleep deprivation, and normal patterns of sleep in relation to call. Lowest percentage of normal sleep patterns occurred on post-call day 2, with highest percentage recorded on post-call day 3 ($p = 0.0445$).

In addition to the health consequences of sleep deprivation, a lack of sleep has been shown to affect performance in the workplace. Outside of the medical field, impaired and shortened sleep is one of the most common causes of accidents in industry and transportation.[35,36] An increase in sleep deprivation has been shown to lead to higher levels of stress and fatigue and is associated with lower levels of situational awareness, leading to workplace accidents that cost billions of dollars annually.[1] The detrimental effects of sleep deprivation on cognitive performance have been compared with the effects of acute alcohol intoxication. A 17-hour period of wakefulness produces a decrease in performance equivalent to a blood alcohol level of 0.05%, and a full 24 hours without sleep is similar to legal intoxication with a blood alcohol level of 0.10%.[37-39]

Table 3. Percentages of Sleep Patterns Present

Type of sleep pattern, post-call day	Percent consistent with pattern	p Value
Acute sleep deprivation		0.53
Post-call day 2	44.0	
Post-call day 3	40.2	
Chronic sleep deprivation		0.14
Post-call day 2	25.8	
Post-call day 3	18.6	
Normal sleep pattern		
Pre-call night	36.8	
Post-call day 1	37.0	
Normal sleep pattern		0.0485*
Post-call day 2	29.8	
Post-call day 3	41.1	

*Statistically significant.

Another indicator of sleep deprivation is sleep latency, which is defined as the amount of time it takes to fall asleep. This study population had an average sleep latency time of 4 minutes, 37 seconds, which is widely considered to be pathologic and a symptom of behaviorally induced insufficient sleep syndrome (BIISS).[40,41] Typically measured by the Multiple Sleep Latency Test (MSLT), latency time of less than 5 minutes is known to correlate with several pathologic sleep disorders, including narcolepsy.[40,42] Given the high rates of sleep deprivation recorded in this study, it is likely that this short sleep latency time is due to BIISS, rather than narcolepsy or another sleep disorder.

How performance changes from sleep deprivation translate into the realm of surgery is unclear, although it has been shown that restricted sleep can result in significant neurocognitive deficits, such as executive processing, sustained attention, and long-term memory.[43] Interestingly, Mohtashami and colleagues[44] evaluated laparoscopic tasks performed in a simulator by 9 gynecologists in both a sleep-deprived (<3 hours of sleep in previous 24 hours) and a legally intoxicated (>0.08 mg/mL) state. For easy tasks, the efficiency and errors ratings were similar between the sleep deprived and intoxicated states. For complex tasks, however, the errors were significantly higher when the gynecologists were intoxicated as compared with when they were sleep deprived. Gerdes and associates[45] examined the effect of fatigue on both surgical residents and attending surgeons in a simulation setting and found an increase in error rates associated with post-call status. Cognitive error rates for both attending surgeons and residents increased post-call, but to a significantly lesser degree among the former. Differences shown in simulation have not as yet translated into differences in patient outcomes. Govindarajan and coworkers[46] examined the outcomes of patients who underwent procedures during the day performed by attending surgeons who had treated patients between the previous midnight and 7:00 AM. This study, which included 38,978 patients, did not find an increase in the risk of adverse outcomes for patients being treated by physicians who worked the night before. Participants in this study returned to baseline on post-call day 3, which is an area of research that requires further study to determine if this is also associated with cognitive error rates when compared with post-call day 1. Future studies hope to accomplish not only recommendations regarding frequency of in-house call scheduling, but also tools to aid in physiologic and cognitive recovery after nights of call.

Although the relationship between sleep deprivation and patient outcomes is unclear, the relationship between sleep deprivation and mood has been extensively studied. Fatigued individuals show lower emotional empathy, less ability to regulate emotions, and an increase in negative affect.[5,47] Chronic sleep deprivation has been shown to increase the prevalence and risk of depression.[48,49] Although the rates of depression among American surgeons are similar to those of the general population, the rate of suicide is much higher.[50]

Trauma and acute care surgeons are a unique population, even within surgical subspecialties; the former report the highest number of work hours and call nights per week.[11] Also, trauma and acute care surgeons are more likely to take in-house call as attending surgeons, predisposing them to irregular sleep patterns. In addition to the known stress caused by performing surgery, trauma and acute care surgeons routinely participate in additional stressful situations including trauma activations, patient resuscitations, and difficult conversations with patients and families.[18,51]

Limitations of this study include small sample size and a lack of knowledge regarding medical history, social habits among participants, and exclusion of call night sleep analysis. Participants were not asked to disclose their medical history or social habits, including medication or alcohol use. Medications such as benzodiazepines, tricyclic antidepressants, monoamine oxidase inhibitors, and some serotonin reuptake inhibitors are known to alter sleep patterns that mimic either acute or chronic sleep deprivation. In addition, alcohol intake, especially within 2 hours of sleep onset, can increase slow wave and suppress REM sleep, creating a pattern of acute sleep deprivation. Caffeine intake, which can affect heart rate, was also required to be recorded by participants. Travel, especially across time zones, is also known to disrupt normal sleep patterns, yet travel activity was not recorded by participants. Call-night sleep patterns were extremely disrupted and overall were unable to be analyzed for distribution of REM vs non-REM sleep cycles. Whoop! measures REM vs non-REM sleep cycles through heart rate variability, which has been shown to match sleep cycles.

CONCLUSIONS

In conclusion, acute care surgeons with in-house call responsibilities commonly exhibit sleep patterns consistent with sleep deprivation. Additional research into how surgeons with mixed coverage patterns, such as physicians and surgeons who take call from home, would add insight to the extra burden potentially faced by trauma and acute care surgeons who take in-house call. Further study in a multicenter trial is needed to generalize the current data; further clarify the timeline of recovery after in-house call; identify factors that aid or hinder recovery; examine the impact of age, sex, and years of experience; and define the relationship between sleep deprivation and feelings of burnout.

Author Contributions

Study conception and design: Coleman, Zarzaur, Timsina
Acquisition of data: Coleman, Timsina
Analysis and interpretation of data: Coleman, Robinson, Zarzaur, Timsina
Drafting of manuscript: Coleman, Robinson
Critical revision: Zarzaur, Rozycki, Feliciano

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