What Happens on Call Doesn't Stay on Call. The Effects of In-house Call on Acute Care Surgeons' Sleep and Burnout

Results of the Surgeon Performance (SuPer) Trial

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Objective: We sought to quantify the effects of in-house call(IHC) on sleep patterns and burnout among acute care surgeons (ACS).

Background: Many ACS take INC, which leads to disrupted sleep and high levels of stress and burnout.

Methods: Physiological and survey data of 224 ACS with IHC were collected over 6 months. Participants continuously wore a physiological tracking device and responded to daily electronic surveys. Daily surveys captured work and life events as well as feelings of restfulness and burnout. The Maslach Burnout Inventory (MBI) was administered at the beginning and end of the study period.

Results: Physiological data were recorded for 34,135 days, which includes 4389 nights of IHC. Feelings of moderate, very, or extreme burnout occurred 25.7% of days and feelings of being moderately, slightly, or not at all rested occurred 75.91% of days. Decreased amount of time since the last IHC, reduced sleep duration, being on call, and having a bad outcome all contribute to greater feelings of daily burnout ($P < 0.001$). Decreased time since last call also exacerbates the negative effect of IHC on burnout ($P < 0.01$).

Conclusions: ACS exhibit lower quality and reduced amount of sleep compared with an age-matched population. Furthermore, reduced sleep and decreased time since the last call led to increased feelings of daily burnout, accumulating in emotional exhaustion as measured on the MBI. A reevaluation of IHC requirements and patterns as well as identification of countermeasures to restore homeostatic wellness in ACS is essential to protect and optimize our workforce.

Keywords: acute care surgeon, acute care surgery, burnout, physician burnout, physician wellness, sleep deprivation, trauma surgeon, trauma surgery, wellness

(*Ann Surg* 2023;278:497–505)

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K.E.H. is a paid employee of and has an equity interest in WHOOP Inc. J.K. is a paid employee of WHOOP Inc. WHOOP Inc. had no financial interest in this study and did not participate in study design or approval of the results or manuscript. The remaining authors report no conflicts of interest.

ISSN: 0003-4932/23/27804-0497
DOI: 10.1097/SLA.0000000000005971

The practice of acute care surgery is characterized by clinical activities in the realms of surgical critical care, emergency general surgery, and trauma, all of which require around-the-clock clinical coverage. As such, work schedules for acute care surgeons (ACS) often require an in-house call (IHC). Although there is considerable variability in call requirements among ACS, the median call expectation for a 1.0 FTE (full-time employment) at a Level I trauma center is five 12-hour call shifts per month.[1] This call burden is in addition to any elective clinical work as well as academic, educational, and administrative responsibilities performed independently of call. Compared with other surgical specialties, trauma surgeons report among the highest number of total hours and nights on call, with one survey revealing $>65\%$ of trauma surgeons reported regularly working >70 hours per week.[2] Total work hours and nights on call lead to burnout, and thus it is no surprise that out of 14 different surgical specialties, trauma surgeons reported the highest percentage of burnout and the lowest mental quality of life.[2,3]

Burnout is a clinical syndrome comprised of symptoms in the 3 areas of emotional exhaustion, depersonalization, and a decreased sense of personal accomplishment related to one's profession. The reported incidence of burnout in surgeons is between 40% and 50%.[4,5] Physicians with burnout have double the risk of making a medical error and 17% increased odds of being involved in a malpractice suit.[6–9] On an individual level, surgeons who perceive they have made a major medical error or have recent involvement in a malpractice suit have a higher risk of depression and suicidal ideation.[8,10] When medical errors and malpractice suits are coupled with the decreased productivity and increased turnover associated with physician burnout, the estimated annual cost to the health care system of physician burnout is over 2 billion US dollars.[11]

IHC at night has previously been shown to result in disrupted sleep patterns as well as acute and chronic sleep deprivation outside of the immediate postcall period.[12] Sleep deprivation can result from a lack of quantity or quality of sleep or improperly timed sleep. Poor sleep quality and sleep deprivation lead to a disrupted inflammatory state placing individuals at an increased risk for hyperglycemia, type II diabetes mellitus, obesity, stroke, Alzheimer disease, coronary artery disease, atrial fibrillation, and cancer.[13–18] Disrupted sleep also results in decreased empathy, increased negative emotions, feelings of depression, and risk of suicide.[19–21]

The best evidence to date suggests poor sleep quality and sleep deprivation in surgeons has costly consequences for patients and surgeons, but research in this area has been limited by small numbers of participants, reliance on self-reports to assess sleep, and lack of contextual information about overall

work hours and culture, medical history, and personal habits. New technology enables continuous biometric monitoring of daily stress, strain, and sleep, which now allows for objective assessment of the effects of call. The purpose of the current study was to pair comprehensive daily surveys with biometric measures of sleep in a large and diverse cohort of ACS to assess the effects of IHC on sleep and burnout.

METHODS

After approval by the Colorado Multiple Institutional Review Board, a 6-month prospective observational study of ACS with IHC responsibilities was performed. Attending ACS at any trauma center with IHC responsibilities were eligible for enrollment and were invited to participate via email and social media. A 94-item enrollment survey included questions regarding personal and work demographics as well as the Maslach Burnout Inventory (MBI).[22] After completion of the enrollment survey, ACS were sent a validated sleep wearable (WHOOP Inc.).

Participants registered on the accompanying mobile application using a deidentified pseudonym and were given detailed instructions on how to wear and charge the device. Participants were instructed to wear the device on their wrist or upper arm in a continuous manner over the 6-month study period. Daily surveys were sent via text message and included work hours, call hours, number of operations and trauma activations, exercise, alcohol intake, and feelings of burnout and restedness. After 6 months, participants were sent a 121-item survey that included the MBI and questions regarding changes in their work or home life during the study period.

The biometric instrument used was WHOOP 2.0, which continuously measures heart rate, heart rate variability, respiratory rate, and movement (via a 3-axis accelerometer) 100 times per second. Sleep is automatically detected without requiring user input and sleep stages are identified. The WHOOP has been validated against polysomnography for detecting sleep-wake determinations with specificity and sensitivity to sleep reported at 89 and 95%, respectively.[23] Sleep stages were recorded as light, slow wave sleep, or rapid eye movement, which we summed to an overall measure of hours of sleep. Sleep consistency was measured via a proprietary metric of the WHOOP platform adapted from the Sleep Regularity Index (SRI).[24] The WHOOP sleep consistency measure, like the SRI developed by Phillips et al,[24] calculates the percentage of concordance in individuals being the in the same state (asleep vs awake) at the same time point across different days. Whereas the SRI compares 2 time points 24 hours apart, WHOOP sleep consistency compares time points over a 4-day interval [eg, time point 1 (T1), T1+24 hours, T1+48 hours, T1+72 hours], which comparisons of intervals further apart assigned progressively lower weights in calculating sleep consistency scores. Scores converted to a 0% to 100% scale, with higher scores reflecting lower variability in an individual's sleep timing. For example, a WHOOP sleep consistency score of 50 demonstrates that a person who is asleep at 2:00 AM on a Monday has a 50% chance of also being asleep at 2:00 AM across the prior 4 days. We compared the sleep duration and consistency of our cohort to a nonphysician 10:1 age-matched cohort of WHOOP-monitored users.

Several types of statistical analysis were conducted. Comparisons between cohorts were conducted with a 2-sample *t* test. To compare summary differences in sleep and feelings of restedness and burnout, within-participant analyses of variance were conducted. To assess the extent to which IHC predicted sleep disruption, and the extent to which sleep disruption predicted daily feelings of burnout, linear mixed-effects (multilevel) models were run in the lme4 package for the R software environment.[25,26] These analyses nested daily data within surgeons and separated within-person from between-person effects. Ordinary least squares regression assessed whether overall call frequency predicted sleep consistency and duration, whether sleep consistency and duration predicted daily feelings of restedness and burnout, and whether daily burnout and restedness predicted emotional burnout on the MBI.

RESULTS

A total of 224 surgeons met the inclusion criteria of IHC responsibilities, volunteered for the study, and completed the enrollment survey. The final survey was completed by 86% (n = 181) of participants, and 39,129 daily surveys were completed. A total of 34,135 days of continuous 24/7 biometric monitoring were recorded including 4389 nights of IHC.

Personal Demographics

A slight majority of participants were male (n = 111, 51.2%) with a mean age and body mass index of 43 years (range: 31–73 years) and 26.88, respectively. Exercise was common in participants, with 99% (n = 207) reporting at least 1 episode of exercise and an average of 63.5 (range: 1–170) workouts recorded per participant. In all, 206 ACS (98.6%) reported alcohol use, with 74.6% (n = 156) reporting at least 1 night of 3 or more drinks. Alcohol intake of at least 1 drink was reported on 43% of noncall nights (Table 1).

Work Demographics

In all, 147 (68.1%) ACS were within 10 years of training completion, and 114 (53.8%) reported clinical work assignment as 1.0 FTE. Overall, 209 (93.3%) worked in an academic or academic-affiliated setting and 188 (86.6%) at a verified Level I trauma center. In all, 134 (62.6%) reported working at trauma centers with volumes > 2500 patients annually. In the enrollment survey, 42.9% of ACS reported weekday calls at their center were scheduled for a duration between 12 and 14 hours, 34.6% between 15 and 24 hours. Almost half (46.1%) of ACS reported scheduled weekend call durations between 15 and 30 hours (Table 2).

Mean duration of measured IHC was 18.3 hours, with a mean of 4.3 hours spent in the hospital before the start of IHC. There were a mean number of 3.6 IHC per month reported by 1.0 FTEs. Mean number of trauma activations and operations performed on IHC were 5 and 2.6, respectively (Table 3).

TABLE 1. Personal Demographics

	n (%)
Sex (male)	111 (51.2%)
Age [median (range)] (yr)	43.3 (31–73)
Married	170 (79.1)
Children living at home	143 (63.6)
No. surgeons who reported using alcohol	206/209 (98.6)
No. drinks/night	
None	15,038 (57.03)
1–2 drinks	9037 (34.27)
3–4 drinks	1848 (7.01)
> 4 drinks	445 (1.69)
No. surgeons who reported exercising	207 (99)
Average number of workouts over study period [median (range)]	63.5 (1–170)

TABLE 2. Work Demographics

	n (%)		n (%)
Years out from training		Work assignment	
<5	90 (41.7)	FTE 1.0	114 (53.8)
6–10	57 (26.4)	FTE 0.5–0.9	88 (41.5)
11–15	27 (12.5)	FTE <0.5	10 (4.7)
16–20	27 (12.5)		
>20	15 (6.9)		
Practice type			
Academic	143 (63.8)		
Academic-affiliated	66 (29.5)		
Community	15 (2)		
Trauma center verification		Trauma center volume	
ACS Level 1	169 (77.9)	<1500	14 (6.5)
ACS Level 2	23 (10.6)	1500–2500	57 (26.6)
State Level 1	19 (8.8)	2501–3500	58 (27.1)
State Level 2	6 (2.8)	3501–4500	32 (15)
		>4500	44 (20.5)
Typical scheduled weekday call duration		Typical scheduled weekend call duration	
12–14 h	93 (42.9)	12–14 h	49 (22.6)
15–24 h	75 (34.6)	15–24 h	56 (25.8)
25–30 h	42 (19.4)	25–30 h	100 (46.1)
>30 h	7 (3.2)	>30 h	12 (5.5)

ACS indicates acute care surgeons; FTE, full-time employment; IHC, in-house call.

Sleep

When not on call, 6.57 mean hours of sleep were obtained, which is significantly lower than the age-matched cohort mean of 6.81 hours ($P < 0.001$). On nights of IHC, nearly 3 hours of total sleep per night were lost. The average time of sleep onset was 22:55 on nights without IHC and 01:41 on nights of IHC. Sleep consistency throughout the study period was 67.3, which is significantly lower than 72.5 as measured in the age-matched cohort ($P < 0.001$). On nights of IHC, sleep consistency dropped from 69.3 to 53.2, and feelings of restedness also decreased from "moderately rested" to "slightly rested." Multilevel models confirmed these effects at the within-person level, showing IHC is associated with decreases in sleep duration ($P < 0.001$), sleep consistency ($P < 0.001$), and feelings of restedness ($P < 0.001$). IHC in which ACS experienced a highly stressful event or bad outcome was associated with *additional* decreases in sleep duration ($P < 0.001$), sleep consistency ($P < 0.001$), and restedness ($P < 0.001$). When sleep duration and consistency were included with IHC as predictors of restedness, both were significant (P's < 0.001) and the direct effect of IHC was reduced ($P < 0.001$). Similarly, when sleep duration and consistency were included as predictors along with experiencing a highly stressful event or bad outcome, both were again significant (P's < 0.001) and the direct effect of a highly stressful event/bad outcome on restedness was again reduced ($P < 0.001$). These findings suggest IHC, as well as experiencing a highly stressful event or bad outcome, resulted in decreased feelings of restedness in part, but not solely via losses in sleep duration and consistency. Finally, the time elapsed since the last IHC (winsorized at 3 weeks to reduce positive skew) interacted with the current IHC in predicting sleep duration and restedness (P's < 0.001), such that the current IHC resulted in greater decreases in sleep and restedness when less time had elapsed between the current and the most recent episode of IHC (Table 4).

TABLE 3. IHC Characteristics

Mean number of IHC/month	
FTE <0.5	2.85
FTE 0.5–0.9	3.17
FTE 1.0	3.6
Mean number of trauma activations per call	5.02
Mean number of operations per call	2.55
Mean length of call	18.3
Mean number of hours spent in hospital before call	4.24

ACS indicates acute care surgeons; FTE, full-time employment; IHC, in-house call.

Burnout

Mean scores on the emotional exhaustion subscale of the MBI increased significantly over the course of the study, as did the percentage of surgeons reporting high burnout. In all, 30.5% reported high burnout (≥ 27) on the emotional exhaustion subscale at study onset, whereas 40.4% reported high burnout on this subscale at completion. Average feelings of daily burnout were higher after IHC than after nights when participants were not on call ($P < 0.001$), with a very large effect size (Table 4).

Multilevel models confirmed these effects at the within-person level, with IHC associated with an increase in daily burnout ($P < 0.001$) and IHC in which the participant experienced a highly stressful event or bad outcome during trauma activation or surgery associated with an *additional* increase in daily burnout ($P < 0.001$). When sleep duration and consistency were included with IHC as predictors of daily burnout, both were significant (P's < 0.01), and the direct effect of IHC was reduced ($P < 0.001$), suggesting IHC increased feelings of daily burnout in part via losses in sleep duration and consistency. In contrast, the inclusion of sleep duration and consistency as predictors did not appreciably change the effect of a highly stressful event or bad outcome on daily burnout ($b = 0.218$, SE = 0.035, $P < 0.001$), suggesting such events have their effects on burnout through other mechanisms (Table 5).

The Effects of Call on Sleep and Burnout

To compute the summary effects of IHC on burnout over the course of the study and to determine whether the effects of IHC on burnout and restedness were mediated through sleep consistency and duration, a mediational analysis using ordinary least squares regression was conducted with averaged scores across the study session. To examine change in the emotional exhaustion subscale of the MBI, the first step in the model was to regress emotional exhaustion scores at the end of the study on emotional exhaustion at the beginning. Any remaining variance in emotional exhaustion represents change over the course of the trial. Higher rates of IHC were associated with poorer sleep consistency ($P < 0.001$), which in turn was associated with higher feelings of daily burnout ($P < 0.05$). Finally, higher levels of daily burnout were associated with increases in emotional exhaustion, ($P < 0.001$); these analyses control for prior levels of emotional exhaustion as well as feelings of restedness and sleep duration (Fig. 1).

DISCUSSION

Extended periods of wakefulness and inconsistent sleep-wake times are inherent to practice in acute care surgery. We present here for the first time biometrically captured data which show extensive and prolonged sleep disruptions from IHC that

TABLE 4. Effects of IHC on Sleep Duration, Consistency, and Feelings of Restedness and Burnout

Measures	Not on call	On call	*F*	η_P^2	*P*
Total sleep hours	Mean = 6.570 SD = 0.932	Mean = 3.668 SD = 1.029	1293.07	0.859	< 0.0001
REM sleep hours	Mean = 1.642 SD = 0.429	Mean = 0.913 SD = 0.354	663.31	0.758	< 0.0001
SWS sleep hours	Mean = 1.383 SD = 0.273	Mean = 0.800 SD = 0.266	813.70	0.793	< 0.0001
Sleep consistency	Mean = 69.311 SD = 6.407	Mean = 52.443 SD = 10.422	491.35	0.709	< 0.0001
Feeling rested today	Mean = 3.005 SD = 0.607	Mean = 1.881 SD = 0.631	965.77	0.817	< 0.0001
Feeling burned out today	Mean = 1.904 SD = 0.746	Mean = 2.298 SD = 0.932	158.24	0.423	< 0.0001

IHC indicates in-house call; REM, rapid eye movement; SWS, slow wave sleep.

are directly associated with validated measures of burnout. Despite the chronic sleep disruption measured in our study, our cohort did not obtain recovery sleep and in fact, slept less even while not on call than an age-matched and sex-matched cohort. Indeed elite athletes, special military operators, and the general public routinely exhibit strain from physical and emotional activity which recovers during periods of later rest. A nonphysician age-matched and sex-matched cohort was used intentionally in our analysis. Although the physiological *need* for sleep does not change because of one's occupation, our sleep habits and behaviors do. While not on call, ACS obtained 14.4 minutes less of sleep than their age-matched nonsurgeon cohort. This decreased amount of sleep might appear insignificant, suggesting ACS exhibit close to normal sleep habits when not on call. In the context of ACS losing almost 3 hours of sleep per night of IHC, however, this finding actually highlights a lack of recovery sleep. In other words, there was no evidence ACS increased their amount of sleep while not on call to offset the slept debt incurred while on IHC. The exact amount of recovery sleep required after periods of restriction is not well quantified across populations, but data suggest restoration of alertness and cognitive performance near to or at baseline with 1 to 4 consecutive nights of 9 to 12 hours of sleep,[27–29] which did not occur in our cohort. Even as little as 23 minutes of recovery sleep leads to improvements in mental health with decreased levels of perceived stress.[30] In contrast to acute episodes of sleep loss, chronic sleep deprivation results in reduced feelings of sleepiness.[31] This may contribute to a lack of behavioral changes needed to obtain recovery sleep and highlights the need for personalized objective measurements when evaluating one's own sleep needs.

In addition to less sleep and nonexistent recovery, ACS in this study had poorer sleep consistency than age-matched cohorts. Indeed, the sleep consistency scores of ACS with IHC result in sleep schedules that are essentially random. Data has shown that sleep consistency (the time of onset of sleep and awakening) is crucial to health, recovery, and wellness comparable to sleep duration. For example, people with greater sleep variability have a higher body mass index and lower subjective well-being.[32]

The stability of sleep onset is critical for the entrainment of the circadian rhythm, suggesting the level of inconsistency shown in our study has dangerous effects.[33] Exposure to light between midnight and 04:00 and a high level of night-to-night variability in time of sleep onset reduces melatonin production.[14,34] Melatonin not only promotes subjective sleepiness but is also an anti-inflammatory and antioxidative compound, playing a key role in the regulation of glucose metabolism, inflammatory homeostasis, and the repair process of damaged DNA.[14,35] Through these mechanisms, sustained night work confers an increased risk of insulin resistance, hyperglycemia, cardiovascular disease, and breast, colorectal, and prostate cancer.[14,17,36,37] This evidence regarding sleep consistency explains why shift workers (defined as people working between the hours of 7 PM and 9 AM) have a 17% to 24% higher risk of cardiovascular events compared with nonshift workers and this risk increases for every additional 5 years of night work.[38,39] Women who work at least 1 night per week over a period of 10 years have a 60% increased risk of breast cancer, and women who primarily work at night for > 6 years exhibit a 70% increased risk, with the overall risk increasing as the duration of night work increases.[40–43] Similarly, women working at least 3 nights per month for a period of at least 15 years have an increased risk for colorectal cancer.[16] Men working rotating shifts experience a 19% increased risk of prostate cancer.[44] The exposure to IHC typically begins in medical school and continues throughout all years of surgical training, meaning ACS have already experienced at least 5 to 9 years of disrupted sleep when starting their first job.

Over the past 20 years, the practice of "trauma surgery" has drastically changed. In the face of increasing specialization within surgery, a growing need for emergency general surgery

TABLE 5. Burnout at the Start and End of the Study

Measure	Study onset	Study completion	*F*	η_P^2	*P*
Emotional exhaustion	Mean = 21.382 SD = 10.634 α = 0.910	Mean = 24.053 SD = 11.907 α = 0.915	16.40	0.087	< 0.001
Depersonalization	Mean = 8.858 SD = 5.249 α = 0.688	Mean = 8.858 SD = 6.205 α = 0.754	0.00	0.000	1.000
Personal accomplishment	Mean = 37.006 SD = 5.985 α = 0.679	Mean = 36.409 SD = 7.173 α = 0.684	1.76	0.010	0.186

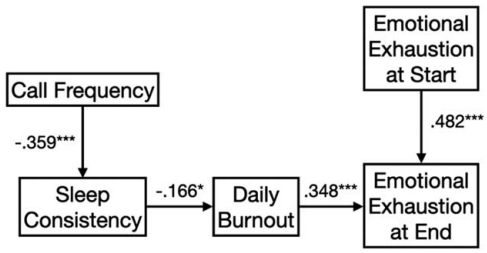

FIGURE 1. Summary effects of call frequency on sleep consistency, daily burnout, and emotional exhaustion. Coefficients are standardized β weights. *$P < 0.05$, ***$P < 0.001$.

coverage, an increasing perception of trauma surgery as a nonoperative and non–lifestyle-friendly specialty, and a corresponding decrease in resident interest in the field, the American Association for the Surgery of Trauma (AAST) and the Committee on Trauma of the American College of Surgeons reorganized the field of trauma and renamed it as Acute Care Surgery.[45,46] The incorporation of surgical critical care, emergency general surgery, and trauma led to an increase of clinical and operative volume and was accompanied by a significant increase in the verification of trauma centers and supervision requirements of trainees—all of which contribute to a greater number of attending surgeons taking IHC and a greater amount of attending workload in the night hours. These changes are reflected in our data, with ACS participating in an average of 5 activations and 2.55 operations per IHC, demonstrating IHC is associated with significantly disrupted sleep due to work obligations.

Surgeon burnout is common, with prior reported rates ranging from 40% to 50%.[3,5] Sleep deprivation, work hours exceeding 60 hours per week, and >1 night of call per week are risk factors for the development of burnout.[5,47,48] Chronic sleep deprivation leads to an increase in depressive symptoms and emotional dysregulation. Engaging in night shift work for at least a period of 4 years adversely affects mental health in both men and women and an increased risk of burnout has been shown in employees with disrupted sleep.[49,50] In this study, 40.1% of ACS reported emotional exhaustion subscale scores consistent with burnout at the completion of the study and significantly less sleep than an age-matched nonsurgeon cohort. Average daily feelings of burnout increased after IHC, and additional increases were shown if a highly stressful event or bad outcome occurred. Our multilevel models show a direct link between daily feelings of burnout and IHC even beyond the effects of sleep loss. These findings demonstrate that burnout in ACS results from a combination of both the physical and emotional exhaustion associated with IHC.

There are limitations to our study. Despite this being the largest cohort of surgeons with continuous biometric monitoring, the number of ACS in this study represents approximately 10% of practicing ACS in academic settings. In addition, our study population skewed towards younger and earlier career surgeons with a mean age of 43.3 years and 68.1% of surgeons within their first 10 years of practice. Exercise was common and frequent among participants, which could be a function of the younger age of the cohort or perhaps interest in fitness might have predisposed surgeons to participate in the study. Most participants practiced in an academic or academic-affiliated setting (93.3%), and in an American College of Surgeons or state-verified Level I trauma center (86.6%). Findings may thus not be similar outside of these practice settings. Sleep and sleep stages are detected and determined by the Whoop device utilizing heart rate, heart rate variability, temperature, and movement. Although the sensitivity and specificity of the Whoop device in the determination of sleep stages is very high in the laboratory setting, it has not been validated in the setting of frequently disrupted sleep that commonly occurs on IHC and it may even overestimate the amount of sleep on IHC.

CONCLUSIONS

Our data show ACS experience significantly irregular and disrupted sleep without evidence of sleep recovery after IHC. This is exacerbated when stressful events occur on IHC and both are directly linked with an increase in daily feelings of burnout. Overall, there was a cumulative effect of IHC, with an increase in the percentage of surgeons experiencing burnout at the conclusion of the study. The verification of trauma centers, addition of emergency general surgery coverage, and increase in supervision requirements of surgical trainees has resulted in a practice pattern of ACS that differs from the trauma surgeons from 20 years ago, with the impact of acute and chronic sleep deprivation and disruption and associated burnout yet to fully be realized. The solution to this serious problem is complex, with factors that can and need to be addressed at the individual, local, and national levels. Maintaining our status quo has the potential for a significant and severe impact to our profession on personal wellness, quality of care, and workforce readiness. Reevaluation of current work patterns, the size of our workforce, and the identification of countermeasures to restore homeostatic wellness in ACS is essential to protect and optimize our specialty and ensure its long-term viability.

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DISCUSSANT

Dr. Gregory J. Jurkovich (Sacramento, CA)

Good afternoon, members, guests, ladies, and gentleman, Drs. Stain, Hunt, and Hawn. I have no disclosures for this commentary.

First of all, I want to thank you for the opportunity to comment on this paper so nicely presented by Jamie Coleman on the effect of sleep deprivation or disruption and how it might contribute to a certain sense of burnout and work-related stress. It follows prior work by Dr. Coleman and others published in JACS in 2019. The background she presented briefly highlights the effects of sleep deprivation or disruption on health and wellness, and they're nicely expanded upon in the manuscript.

The novel nature of this presentation is the data presented by a wearable sleep tracking device and the daily mood assessment, particularly using the Maslach Burnout Inventory in 209 acute care surgeons from 91 trauma centers over six months. That revealed a remarkable 4300 nights on call, and 34,000 days of data that were studied.

Sleep deprivation and sleep disruption are an inherent part of our career. Recognition of the syndrome of burnout is a newer observation. Prior to 2003, there were 2000 articles total in PubMed on burnout. Last year alone, there were 2000 articles on burnout, so exponential increase in that recognition.

Overall, the data probably are not surprising to most, but the fact that we as a profession have largely ignored or accepted this reality for so long might be a point of discussion. Overall, sleep duration, REM, and slow sleep wave sleep were reduced when surgeons took in-house call, when they operated or participated in trauma activations, and after a particularly stressful case or bad outcome. Loss of REM sleep appears to be the most affected. Feelings of moderate, very, or extreme burnout occurred in 25% of the days postcall. The emotional exhaustion of the Maslach Burnout Inventory revealed that 38% of surgeons

met criteria for burnout. This compares to other reports as high as 61% in acute care surgeons. And finally, decreased amount of time between in-house call shifts, reduced sleep duration between those shifts, and having a bad outcome all contributed to greater feelings of burnout and emotional exhaustion.

I have the following questions for the authors. Number one, what should we do with this information that seems intuitively obvious to all of us who take in-house call?

Number two, are there ways to predict if residents and medical students can withstand the stress of sleep disturbance inherent to this career choice? Perhaps we all self-selected long ago without really knowing that this was the reason.

Number three, I think importantly, do the authors recognize a subset of individuals who did not seem to be negatively affected by the sleep disturbances of in-house call? In other words, is there a recognizable pattern to those less affected?

And fourth, should the trauma and acute care surgery community do a better job of defining reasonable expectations, and given the upcoming panel on corporatization of healthcare, should this be a negotiated item of workforce employment?

I'll conclude with this comment. It seems that sleep disruption or sleep deprivation are an inherent part of the career of those who provide emergency and in-house on-call care. It may be more a matter of how to recover from this stress and how to minimize its effects, and perhaps this can be personalized, yet this topic of personalized individual work structuring is another one that will likely engender uncomfortable discussions.

Thank you for the opportunity to comment.

Response From Jamie Coleman

Thank you. Thank you, Dr. Jurkovich. You know, I think you hit the nail on the head here when we start talking about the personalized nature of this issue. You know, when I first started this study, it was interesting because to some extent, like you said, we knew what it was going to show. It was going to show we were tired, right? But I think just like when you look at patients, patients that weigh themselves everyday weigh less. The data matters, and I think for us, the first step is we need to step on the scale as a specialty and figure out where we are because that data is going to help inform us who gets impacted, how they get impacted, and how we can then change or mitigate that. I think that answers a little bit of your second question about the residents and medical students, and I'm going to answer number two and number three kind of together in that we're a little bit behind some other fields here in this. There are entire professional sports teams wearing Whoop, and they're using that to individualize how players are practicing, what they need to recover, and how they play in a game. I think that's where we need to head because I think you're right. Yes, in general there's a personality that goes into medicine, there's a personality that goes into surgery, and there's another personality that goes into trauma surgery as well, but we need to better individualize that. The way to start, though, is just by stepping on the scale and seeing where we are.

Regarding the question about defining reasonable call expectations, thank you for that. You know, overall, call schedules were made by just dividing 365 days divided by how many of us there are. That's how we did it. You know there was very little thought or insight as to how many surgeons are needed to really make this work, and I think at the same time, we have undergone this shift in our specialty over the past 20 years. Call today looks very different from call 20 years ago, and I think that yes, we need to be mindful of recovery. If you're going to put somebody on every other call night, it has a real and measurable impact, and we need to be cognizant of that. Thank you.

Dr. Carla Pugh (Stanford, CA)

Thank you so much for your talk. I am an acute care surgeon, and I love it as well, and I have been wearing the Oura Ring for about five years now and definitely understand that the more information you have, the more you can be proactive in affecting modifiable variables, so my questions for you relate to this area.

First, I believe you said this study focused on in-house call. Were there any persons that did home call? Did you exclude them? The reason I ask is because home call is thought to be more stressful than in-house call. Driving in at 2 a.m. for a trauma is more stressful, so I wonder, did you have any information regarding that?

The other question I have relates to modifiable factors such as diet. For example, the anti-inflammatory diet. I didn't really believe it would make a difference, but it does appear to make a difference in recovery and level of fatigue when you're on call, eating a little less meat and more salad. I don't understand why this is the case. Did you and your team track diet or receive feedback regarding its affect when on call?

The third question relates to mindfulness. What I learned was that my resting heart rate, was higher when I was on call. Normal resting heart rate for me when I'm recovered is 49. When I'm on call, it's 55 to 57, and when I had COVID, it was 65. The data gives you a lot of information that can serve as a marker for when additional measures may be necessary to facilitate recovery. Did any of your participants use mindfulness meditation? Did it have an effect on recovery rate?

Response From Jamie Coleman

Yes, perfect, thank you. Home call, that answer is coming, a coming attraction, because I do think it is different, and so it at times can blur the lines for people in terms of if I'm at the hospital, I'm at the hospital, if I'm home, I'm home, and sometimes that blurring can lead to stress, I agree.

Secondly, I agree with you. There are several individualized factors that we can be utilizing that we're not, not only the type of diet, the anti-inflammatory, which I 100% agree with, but also the timing of when we eat. There's some good evidence that when we eat and over how long a period of time can actually help counteract the proinflammatory state that happens with taking call and living with chronically disrupted sleep.

I think other things in there obviously include exercise and better sleep hygiene. We're sleeping six and a half hours a night when we're not on call. We've got to be better about prioritizing our own health, and I think all those factors will help.

Dr. Karen Brasel (Portland, OR)

Karen Brasel from Portland, Oregon. I have a disclosure. I was a participant in the study. I have two questions. One, how did you deal with or did you include surgeons who participated in the model where they just took nights and went home and slept during the day? You might consider that call. You might consider that that's just their work period.

And second, I also had a very young partner participate in this study. Was there an age difference? Have I learned to be better at this and recover better, or am I actually worse than the younger people in the study? Thank you.

Response From Jamie Coleman

Thank you, Dr. Brasel, so the first question, in terms of night float, because you're right, there are a few select trauma centers across the country that do practice in sort of a night float scenario. The short version is we will be digging into that as well with the data, but we don't currently have the answer. The problem I have with advocating for a "schedule" is there's a difference between what's written on the schedule and what we actually do. As you can see in our data, the average amount of duration of call is 18 hours, but we're in the hospital for hours before that and hours after, even though that isn't "scheduled." I've held back from strongly voicing an opinion on the best "schedule" because if that's not actually how we're living it, then that's not actually going to help us.

And then secondly, same answer for the age differences, yes, there are age differences, and we will be looking at that on secondary analysis. Thank you.

Dr. Steven Stain (Boston, MA)

So thank you, Dr. Coleman. I have two brief questions, so when I looked at your data, 3.6 calls per month was much less than my trauma surgeons' work, so I thought this was a pretty easy schedule, frankly.

Secondly, I think Dr. Brasel said if you're on a night float system, it's completely different if you have to work the next day. I also was struck by the fact that your comparison cohort was nonsurgeons. Were they nonphysicians?

Response From Jamie Coleman

Correct.

Dr. Steven Stain (Boston, MA)

Well, I'm not sure that's a fair comparison because if you're going to compare this to a banker, it's probably not a fair comparison.

Response From Jamie Coleman

So two things. I'm going to answer the second one first. I will say that I actually think it is a fair comparison in the sense that our bodies and sleep needs aren't different because we are surgeons. Our bodies and circadian rhythms are still designed the same. Our bodies are designed to sleep at night. Now granted, we don't get to sleep in until 8 o'clock in the morning, you know, and go to work at 10 a.m., so I agree with you that our schedules are different, but in terms of our physiologic sleep needs, that is regardless of our occupation.

Secondly, I agree with you that that number was surprising to us with the 3.6 calls per month as a mean of the 1.0. That being said, this is aggregate data which does include some of these systems that do kind of a night float where they might take four or five calls and then not take any for the next ensuing couple of months, so that does and can skew the data.

Dr. Andreas Kaiser (Duarte, CA)

I would like to congratulate you on this work. It's obviously very timely and important to look at burnout, et cetera, but there is something mysterious about surgery, and you said it yourself that you like your job despite all this stuff, and I wonder whether you had a chance to look at the positive impact. So you looked at the challenging case, but what happens if you do really a satisfying case? Is that improving your sleep pattern, and how does it work out? How does it affect our wellbeing in general?

Response From Jamie Coleman

Yeah, that's a great question. I don't have the data from this study to answer that directly, but I did want to point out that prior data has shown us that patient interaction, getting us back to the bedside away from the computer next to our patients, is actually protective and mitigates against burnout, and I think that's one of the important things that we really have to stay focused on moving forward is keeping us where we wanted to be in the first place. Why we went to medical school was to be in the operating room and to be with patients, and we need to make sure with EMR and everything else that we're actually maintaining that. Thank you.

Dr. Anna Ledgerwood (Detroit, MI)

Anna Ledgerwood, Detroit. I think I can help answer his question. When I do a stab of the heart, I just feel great for a couple days.

I have two questions.

Why are your surgeons so young? What happened to the old people? I'm 82 years old, and I'm now down to two calls a month and then a supervisor for two more.

I wonder if in your study and one thing you might think about doing is how does this study compare to looking at what general surgeons out in the community practice do when maybe there's three or four or maybe even five surgeons, and they take call every third or fifth night, and they may be up—how does it compare to that group, which is the majority of the surgeons?

Response From Jamie Coleman

Yes, well, first of all, Dr. Ledgerwood, I think we can all agree, you are one of a kind. What happened to the older surgeons? You know, there's selection bias in this, right? I mean if you look at this and you look at the exercise components that were in this, the surgeons in the study averaged on average 10 workouts per month. You know, there's a skew I think again with surgeons who were already interested in personal fitness and were already even potentially on the Whoop platform, so definitely I think there was a skew just in the volunteers. I will say, though, we had some over-70-year-olds in the study. They were in there, I promise.

And then secondly I agree with you. I think we need to get more data. This is a small subset. This represents about 10% of practicing surgeons in academics. This doesn't even touch the surgeons who are at home taking call a week at a time and those sort of additive and cumulative effects. We don't know yet, but we're going to get there.

Dr. Deb Sudan (Durham, NC)

Really brief question. Thank you so much for your talk. I really enjoyed it.

Response From Jamie Coleman

Thank you.

Dr. Deb Sudan (Durham, NC)

I may have missed this at the beginning—forgive me if I did—but what were the years of your study? I'm wondering how much of your findings of increased burnout over time were related to COVID. There's been some really good data out that there's been a substantial increase in burnout across the entire healthcare spectrum, whether it's physicians or nurses or surgeons, advanced practice providers, but over the COVID timeframe.

Response From Jamie Coleman

Absolutely, and we addressed this in the manuscript, so we started this in December of 2019, so it really got rolled out and surgeons became enrolled in this study in January 2020, so we have about three months prior to COVID and three months after, and we will be diving into that data as well. The cumulative effects that we saw were within-person effects. That was not aggregate data. I think that's really important to highlight here on multilevel models that this isn't just, "Oh, everybody got a little bit more …." No, this was seen on individual, within-person effects, and so I think whether this is over the time of COVID or not, it's still an issue. It's still a problem we've got to address.

Dr. Mary Hawn (Stanford, CA)

Quick question to follow up on Past President Ledgerwood's question, your surgeons are young. They probably have a second and/or third job at home in raising families, especially with COVID, maybe being a teacher.

Response From Jamie Coleman

Yes.

Dr. Mary Hawn (Stanford, CA)

Did you account for that work as well and how that's contributing to burnout?

Response From Jamie Coleman

So yes, I mean we know that having children at home and actually even being female predisposes you to an increased risk of burnout, and again, on secondary analysis, we'll be taking a look at the gender component as well as parenting because it's more balls in the air sometimes when you've got a lot going on at home and a lot going on at work. It creates that sense of imbalance that I think we all feel at times. Thank you.