



Physiologic stress among surgeons who take in-house call

Caitlin Robinson^a, Ryan Lawless^a, Ben L. Zarzaur^b, Lava Timsina^b, David V. Feliciano^c,
Jamie J. Coleman^{a,*}

^a Denver Health Medical Center, University of Colorado School of Medicine, USA

^b Indiana University School of Medicine, USA

^c University of Maryland School of Medicine, USA

ARTICLE INFO

Article history:

Received 15 March 2019

Received in revised form

6 July 2019

Accepted 24 August 2019

ABSTRACT

Introduction: Burnout and depression is higher in trauma surgeons as compared to surgeons in other specialties. Clinical practice for many acute care surgeons (ACS) includes in-house call (IHC). The goal of this study was to quantitate physiologic stress among ACS who take IHC.

Methods: ACS with IHC responsibilities from two Level I trauma centers were studied. Participants wore a fitness and heart rate variability (HRV) device over 3 months. HRV was categorized as normal if 85% of baseline, moderate stress when HRV <85% but >50%, and high stress when HRV < 50%.

Results: 1421 nights were recorded among 17 surgeons (35.3% female; mean age 45.5 years). Excluding IHC, mean HRV = 32.23, and 95.63% of days were consistent with moderate or high stress. Post-call day 2 had significantly highest percentage of high stress (65.82%, $p = 0.0495$). High and moderate stress levels returned to baseline on post-call day 3.

Conclusions: High and moderate stress beyond IHC is common among ACS. Future study is needed to determine consequences of persistent stress and identify factors which impact recovery after IHC.

© 2019 Elsevier Inc. All rights reserved.

Introduction

Burnout, a syndrome characterized by emotional exhaustion, depersonalization and a decreased sense of efficacy, along with work-related stress, has become an increasingly popular topic in medical circles over the past few years.^{1–9} Stress is commonly defined as a physical, mental or emotional state of strain or tension.^{1,3,6,7,10,11} Just as the reaction to a stressor can be either physical or emotional, the stressors themselves can be of physical, mental or emotional origin^{3,5–7,11–13}. At times, these reactions to stress can be helpful in maintaining alertness, improving memory, and even boosting physical performance as part of the body's "fight or flight" response.^{14–16} Chronic stress and repeated exposure to stress-inducing situations without adequate recovery, however, results in significant physiologic changes such as immune response suppression, hyper and hypophagia, hyperglycemia, hypertension, and an increased risk of mortality.^{17–20} Additionally, chronic work-related stress has been shown to predispose individuals to burnout, depression, and even suicide.^{3,6,8,11–13,21}

A career in surgery requires complex decision making, technical dexterity, and long hours in the operating room, which are all significant mental and physical sources of stress.^{3,4,7,22} When viewed in this context, it is not surprising that the practice of surgery is associated with a high level of stress and subsequent development of burnout. Reported burnout rates are higher in surgical than non-surgical medical specialties.^{2,5,12} Within surgical specialties, the discipline of trauma surgery has reported rates of burnout significantly higher than other surgical subspecialties.^{2,5}

The practice of trauma and acute care surgery, when compared to other surgical specialties, is unique with its combination of a critical care practice, high proportion of emergency surgery, participation in trauma activations, and, often, in-house call responsibilities. Given these additional responsibilities and accompanying stress, it is perhaps unsurprising that trauma surgeons have reported not only the highest workload amongst surgical specialties, but also the lowest mental quality of life score and the highest incidence of burnout.^{2,4,8}

The amount of added physiologic stress that occurs due to in-house call is unknown and has not been previously measured. Heart rate variability (HRV) is an example of a physiological variable affected by physical, mental, and emotional stress.^{23–25} It is the variation in time interval between each heartbeat and is modulated

* Corresponding author. 777 Bannock Street, MC 0206, Denver, CO, 80204, USA.
E-mail address: jamie.coleman@dhha.org (J.J. Coleman).

by both the sympathetic and parasympathetic nervous systems.^{10,26} Specifically, the sympathetic nervous system increases heart rate and decreases HRV. Conversely, the parasympathetic nervous system decreases heart rate and increases HRV. HRV has been used extensively in the study of stress, as it has been shown to have measurable responses to both physical and emotional stress and therefore an effective tool in studying work-related stress.^{27–29} Overall, the higher the HRV, the more capable the body is to adapt to stress, and is a sign of recovery after stress.^{30,31} Studies show that even during sleep, stress can lead to changes in HRV further impacting sleep quality.¹⁰ The purpose of this study was to physiologically measure and categorize stress in trauma and acute care surgeons as well as identify periods of recovery after in-house call.

Material and methods

After approval by the Institutional Review Board of Indiana University School of Medicine, a prospective 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 three months. Both hospitals are American College of Surgeons verified Level 1 trauma centers in Indianapolis, Indiana. Eligible enrollees included attending trauma or acute care surgeon with in-house trauma or emergency general surgery call responsibilities at either hospital. There were no exclusion criteria within this cohort. Trauma and acute care surgeons who volunteered to participate in the study were given a fitness and sleep tracking device called Whoop!TM, which measures multiple physiologic parameters including heart rate variability. In addition to the device, surgeons downloaded the accompanying smartphone application and created a de-identified profile. During the three month study period, participants wore the device continuously either on the wrist or upper arm. They were also required to log into the smartphone application daily to ensure uninterrupted data collection for call and non-call nights.

The Whoop! device is a wearable biometric instrument 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. Heart rate variability is calculated using the root mean square of successive differences (RMSDD). Through heart rate, heart rate variability, and movement detection, the device automatically detects sleep and sleep stage. Whoop!TM has been internally validated in a laboratory setting by comparison against graded polysomnography conducted by a certified polysomnography technologist. Whoop!TM was shown to have 96% accuracy, 93% sensitivity, 98% specificity.

Data collected for each trauma and acute care surgeon included age, gender, schedule of in-house call, resting heart rate, heart rate variability, and sleep patterns. Heart rate variability was categorized as normal if $\geq 85\%$ of baseline, moderate stress when heart rate variability was between $\geq 50\%$ and $<85\%$ of baseline, and high stress was defined as heart rate variability $<50\%$ of baseline. The baseline heart rate variability was calculated for each surgeon by

individual review of the highest recorded heart rate variability that occurred in the setting of high quality sleep and low resting heart rate.

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 all were approached to volunteer for the study. Eighteen surgeons consented to participate, with one surgeon terminating participation prior to the conclusion of the trial due to non-compliance of device wear. A total of 1421 nights, including 227 nights of in-house call, were recorded amongst the remaining 17 participants. The majority of participants were male ($n = 11$, 64.7%), with a mean age of 45.5 years (range 37–65).

Including nights of in-house call, the mean heart rate variability was 33.0 and 95.97% of days recorded were consistent with moderate or high stress. Among all participants, there was a significant difference between mean HRV when comparing nights of in-house call to post-call day 4 ($p = 0.0452$).

Overall, the majority of the participants demonstrated a higher propensity towards stress (low HRV) as opposed to moderate or baseline HRV across all nights measures. The highest percentage of low HRV was experienced when participants were on-call (65.6% low, 32.1% moderate HRV) and post-call day 2 (65.8% low, 33.1% moderate HRV). Compared to the night before in-house call, post call day 2 had a significantly higher percentage of high stress levels (HRV = 59.5% vs 65.8%, $p = 0.0495$). Furthermore, there was a nonspecific trend toward a lower mean HRV on post-call day 2 compared to in-house call values (31.5 vs 34.8 respectively, $p = 0.06$). Values of high stress and moderate stress heart rate variability returned to pre-call levels on post call day 3 (Table 1).

Discussion

Embarking on a career in medicine has multiple beneficial attributes. Physicians are provided with the tools to achieve excellence in the privilege of taking care of patients. Physicians are often unprepared, however, for the physiologic stress that comes with this privilege. Although training has been shown to improve the body's physiological response to stress, simulation and virtual reality scenarios do not elicit the same level of stress response as real-life situations.^{32,33}

Surgery, particularly the high-stress practice of trauma surgery, ranks highest among surgical subspecialties for burnout and has high rates of depression and suicidal ideation/suicide.^{2,7,8}

Heart rate variability (HRV) is a physiologic parameter which measures the variation in beat-to-beat intervals of the heart. It is a culmination of several physiologic parameters which impact heart rate as controlled by the sinoatrial node, which in turn is modulated by the sympathetic and parasympathetic nervous systems. In general, sympathetic activity tends to increase heart rate and decrease HRV, and parasympathetic nervous system activity has

Table 1
Mean HRV.

	Call Status					
	On-call	Precall	Postcall1	Postcall2	Postcall3	Postcall4
Mean HRV	34.84	33.38	34.49	31.54	32.65	31.02
High vs. Moderate Stress						
High (no. nights (%))	145 (65.6%)	125 (59.5%)	126 (57.8%)	104 (65.8%)	75 (60.5%)	63 (61.2%)
Moderate (no. nights (%))	71 (32.1%)	76 (36.2%)	80 (36.7%)	49 (31.0%)	41 (33.1%)	34 (33.0%)

the opposite effect (decrease in heart rate and increase in HRV).³⁴ Goffeng et al. has described multiple studies in which night work and extended work hours decrease heart rate variability. The results of this study are concordant with these studies and others that evaluate heart rate variability within other medical practice disciplines. In this study population, there is a significant difference in mean HRV when comparing nights of in-house call to post-call day 4. Studies done in Emergency Medical Technicians (EMT) showed that there was a significant difference in HRV between work days and non-work days.³⁵ Goffeng et al. (2017) showed that among daytime, shift-working, nursing home care providers, stress levels were the highest on the first shift of the work cycle. The lowest stress levels were identified on the final, fourth shift. Furthermore, sleep parameters, sleep latency, disturbances, and early awakening improved over the work cycle.³⁴

This study demonstrates that a night of in-house call creates a significant amount of physiologic stress as measured by a reduction in HRV. The physiologic stress of in-house call affects more than the day of and the day following that call night. Reductions in HRV are seen into post-call day 2, with baseline physiology not being achieved until post-call day 3. One night of call changes physiology for 48 or more hours.

The present study differs from those which have analyzed heart rate variability among shift workers in that trauma and ACS surgeons, while having call shifts, are typically in the hospital for longer periods of time and therefore afforded less time for recovery between nights of in-house call. The above mentioned study, which evaluated nurses taking overnight shifts, evaluated those who worked four consecutive days of nights. That study showed higher levels of cardiovascular stress on the first versus fourth night, and a recovery to baseline following these long shifts.³⁴ This is at odds with data in the present study demonstrating that physiologic recovery from a night of in-house call in trauma and ACS surgeons is not achieved until post-call day 3.

This study demonstrates that a night of in-house call has detrimental effects on human physiology. Surgery, particularly the high-stress practice of trauma surgery, ranks highest among surgical subspecialties for burnout and has high rates of depression and suicidal ideation/suicide.^{2,7,8} With burnout increasing at what has been referred to as an “alarming rate”, it has become imperative that all contributing factors, both psychological and physiological, be studied and understood.⁵

Do the specific events of the night matter? Does the amount of overnight sleep, if any, change physiologic stress levels? What happens if a second in-house call occurs before baseline physiology is achieved? Does physical activity have an effect on recovery time from in-house call?

Conclusions

Measurements of high and moderate physiologic stress are common among trauma and acute care surgeons and persist beyond nights of in-house call. The highest prevalence of high and moderate stress occurred on post-call day 2, with recovery to baseline heart rate variability occurring on post-call day 3. Future investigation is needed to determine the potential health consequences of persistent physiologic stress, identify factors which impact physiologic recovery after in-house call and further elucidate the relationship between stress and burnout.

Conflicts of interest

The authors have nothing to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amjsurg.2019.08.023>.

References

- Balch CM, Shanafelt TD, Dyrbye L, et al. Surgeon distress as calibrated by hours worked and nights on call. *J Am Coll Surg*. 2010;211(5):609–619.
- Balch CM, Shanafelt TD, Sloan JA, Satele DV, Freischlag JA. Distress and career satisfaction among 14 surgical specialties, comparing academic and private practice settings. *Ann Surg*. 2011;254(4):558–568.
- Balch CM, Shanafelt T. Combating stress and burnout in surgical practice: a review. *Adv Surg*. 2010;44:29–47.
- Campbell Jr DA, Sonnad SS, Eckhauser FE, Campbell KK, Greenfield LJ. Burnout among American surgeons. *Surgery*. 2001;130(4):696–702. discussion -5.
- Dimou FM, Eckelbarger D, Riall TS. Surgeon burnout: a systematic review. *J Am Coll Surg*. 2016;222(6):1230–1239.
- Dyrbye LN, West CP, Satele D, et al. Burnout among U.S. medical students, residents, and early career physicians relative to the general U.S. population. *Academic medicine. J Assoc Am Med Coll*. 2014;89(3):443–451.
- Joseph B, Parvaneh S, Swartz T, et al. Stress among surgical attending physicians and trainees: a quantitative assessment during trauma activation and emergency surgeries. *J Trauma Acute Care Surg*. 2016;81(4):723–728.
- Pulcrano M, Evans SR, Sosin M. Quality of life and burnout rates across surgical specialties: a systematic review. *JAMA Surg*. 2016;151(10):970–978.
- Shanafelt TD, Balch CM, Bechamps G, et al. Burnout and medical errors among American surgeons. *Ann Surg*. 2010;251(6):995–1000.
- Hall M, Vasko R, Buysse D, et al. Acute stress affects heart rate variability during sleep. *Psychosom Med*. 2004;66(1):56–62.
- Levine R, Bryant SG. The Depressed Physician: A Different Kind of Impairment. 2000. 67-73 pp..
- Shanafelt TD, Balch CM, Bechamps G, et al. Burnout and career satisfaction among American surgeons. *Ann Surg*. 2009;250(3):463–471.
- Center C, Davis M, Detre T, et al. Confronting depression and suicide in physicians: a consensus statement. *Jama*. 2003;289(23):3161–3166.
- McCarty R. Chapter 4 - the fight-or-flight response: a cornerstone of stress research. In: Fink G, ed. *Stress: Concepts, Cognition, Emotion, and Behavior*. San Diego: Academic Press; 2016:33–37.
- Raglin JS. Psychological factors in sport performance. *Sport Med*. 2001;31(12):875–890.
- Vine SJ, Uiga L, Lavric A, Moore LJ, Tsaneva-Atanasova K, Wilson MR. Individual reactions to stress predict performance during a critical aviation incident. *Anxiety Stress Coping*. 2015;28(4):467–477.
- Cohen S, Janicki-Deverts D, Miller GE. Psychological stress and disease. *Jama*. 2007;298(14):1685–1687.
- Razzoli M, Bartolomucci A. The dichotomous effect of chronic stress on obesity. *Trends Endocrinol Metab*. 2016;27(7):504–515.
- Priyadarshini S, Aich P. Effects of psychological stress on innate immunity and metabolism in humans: a systematic analysis. *PLoS One*. 2012;7(9):e43232.
- Lucini D, Di Fede G, Parati G, Pagani M. Impact of chronic psychosocial stress on autonomic cardiovascular regulation in otherwise healthy subjects. *Hypertension*. 2005;46(5):1201–1206.
- Shanafelt TD, Balch CM, Dyrbye L, et al. Suicidal Ideation Among American Surgeons.
- Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. *Am J Surg*. 2006;191(1):5–10.
- Berntson GG, Cacioppo JT. Heart rate variability: stress and psychiatric conditions. *Dyn Electrocardiography*. 2004:57–64.
- Taelman J, Vandepuut S, Spaepen A, Van Huffel S. Influence of mental stress on heart rate and heart rate variability. In: *4th European Conference of the International Federation for Medical and Biological Engineering*. 2009: Springer Berlin Heidelberg; 2009:1366–1369.
- Thayer JF, Ahs F, Fredrikson M, Sollers 3rd JJ, Wager TD. A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. *Neurosci Biobehav Rev*. 2012;36(2):747–756.
- Stein PK, Pu Y. Heart rate variability, sleep and sleep disorders. *Sleep Med Rev*. 2012;16(1):47–66.
- Orsila R, Virtanen M, Luukkaala T, et al. Perceived mental stress and reactions in heart rate variability—a pilot study among employees of an electronics company. *Int J Occup Saf Ergon*. 2008;14(3):275–283.
- van Amelsvoort LG, Schouten EG, Maan AC, Swenne CA, Kok FJ. Occupational determinants of heart rate variability. *Int Arch Occup Environ Health*. 2000;73(4):255–262.
- Kristiansen J, Mathiesen L, Nielsen PK, et al. Stress reactions to cognitively demanding tasks and open-plan office noise. *Int Arch Occup Environ Health*. 2009;82(5):631–641.
- Fohr T, Tolvanen A, Myllymaki T, et al. Physical activity, heart rate variability-based stress and recovery, and subjective stress during a 9-month study period. *Scand J Med Sci Sport*. 2017;27(6):612–621.
- Dong SY, Lee M, Park H, Youn I. Stress resilience measurement with heart-rate variability during mental and physical stress. *Conf Proc IEEE Eng Med Biol Soc*.

- 2018;2018:5290–5293.
32. Rimmele U, Zellweger BC, Marti B, et al. Trained men show lower cortisol, heart rate and psychological responses to psychosocial stress compared with untrained men. *Psychoneuroendocrinology*. 2007;32(6):627–635.
 33. Wetzel CM, George A, Hanna GB, et al. Stress management training for surgeons—a randomized, controlled, intervention study. *Ann Surg*. 2011;253(3):488.
 34. Goffeng EM, Nordby K-C, Tarvainen MP, et al. Fluctuations in heart rate variability of health care workers during four consecutive extended work shifts and recovery during rest and sleep. *Ind Health*. 2018;56(2):122–131.
 35. Neufeld EV, Carney JJ, Dolezal BA, Boland DM, Cooper CB. Exploratory study of heart rate variability and sleep among emergency medical services shift workers. *Prehospital Emerg Care*. 2017;21(1):18–23.