

Diagnostic Reasoning for ST-Segment Elevation Myocardial Infarction (STEMI) Interpretation Is Preserved Despite Fatigue

ADAM R. KELLOGG, MD
 RYAN A. COUTE, BS
 GREGORY GARRA, DO

Abstract

Background Fatigue and sleepiness contribute to medical errors, although the effect of circadian disruption and fatigue on diagnostic reasoning skills is largely unknown.

Objective To determine whether circadian disruption and fatigue negatively affect the emergency medicine (EM) resident's ability to make important clinical decisions based on electrocardiogram (ECG) interpretation.

Methods Senior EM residents at 2 programs completed a questionnaire consisting of various measures of fatigue followed by an ECG test packet of ST-segment elevation myocardial infarction (STEMI) and STEMI mimics. Participants were asked to examine each ECG and determine whether cardiac catheterization laboratory activation (CLA) was indicated, and to report their confidence in their decision making on an 11-point, numeric rating scale. The primary outcome measured

was a pairwise difference in accuracy of CLA between daytime and overnight testing.

Results A total of 23 residents were enrolled in 2011 and 2012. Subjects demonstrated significant differences in multiple measures of sleepiness and fatigue during overnight periods. The median (interquartile range [IQR]) accuracy of CLA was not significantly different between daytime and overnight (70% [IQR, 50–80] versus 70% [IQR, 60–70], $P = .82$). There were no significant differences in the median number of overcalls (CLA when not a STEMI) and undercalls (no CLA when a STEMI was present; $P = .57$ and $.37$, respectively). Diagnostic confidence and confidence in CLA were not statistically different between daytime and overnight.

Conclusions Despite a measurable degree of fatigue, senior EM residents experienced no decrease in their ability to accurately make CLA decisions based on ECG interpretation.

Introduction

Fatigue generally refers to an overwhelming sense of tiredness and feeling of exhaustion associated with impaired physical and/or cognitive function.¹ Sleep

circadian disruptions, physician duty hours, and work overload are established contributors to fatigue.² Sleep loss, either short term (recent 24-hour complete sleep loss) or chronic, partial sleep deprivation (less than 6 hours of sleep per night on average for at least 1 week) results in both sleepiness and fatigue.

Most studies quantifying the effects of sleep loss and fatigue in physicians measure psychomotor skills instead of diagnostic reasoning.^{3–14} Sleep loss and circadian disruption associated with 24-hour call result in reduced alertness, impaired memory and decision making, as well as prolonged reaction time and poor communication skills.^{15–18} Similar effects have been reported in overnight shift workers.⁶

The effect of sleep deprivation, fatigue, and circadian rhythm disturbances on diagnostic reasoning skills is less established. Diagnostic reasoning involves the integration of intuitive and analytic skills, a process commonly referred to as *dual process theory* or systems 1 and systems 2 reasoning.¹⁹ These skills depend heavily on the prefrontal cerebral cortex, which is particularly vulnerable to sleep loss.²⁰ Electrocardiogram (ECG) interpretation and diagnosis is dual process theory at work because there is both

Adam R. Kellogg, MD, is Assistant Professor, Department of Emergency Medicine, Baystate Medical Center; Ryan A. Coute, BS, was Research Coordinator, Department of Emergency Medicine, Baystate Medical Center, and is now a Medical Student, Kansas City University of Medicine and Biosciences; and Gregory Garra, DO, is Associate Professor, Department of Emergency Medicine, Stony Brook University.

Funding: The authors report no external funding source for this study.

Conflict of interest: The authors declare they have no competing interests.

This study was presented at the 2012 American College of Emergency Physician Research Forum and the 2013 Accreditation Council for Graduate Medical Education Annual Educational Conference.

The authors would like to thank Jeff Love, MD, Gloria Kuhn, DO, PhD, and Sally Santen, MD, for their guidance with the project. The authors would also like to thank Jorge Fernandez, MD, and Elizabeth Edelstein, MD, for assisting with the development of the ECG testing tool.

Corresponding author: Adam R. Kellogg, MD, Baystate Medical Center, 759 Chestnut Street, Springfield, MA 01199, 413.794.5999, fax 413.794.8070, adam.kellogg@baystatehealth.org

Received January 24, 2014; revision received July 23, 2014; accepted August 29, 2014.

DOI: <http://dx.doi.org/10.4300/JGME-D-14-00056.1>

initial intuitive pattern recognition and subsequent systematic analysis for diagnostic criteria.

Our objective was to assess emergency medicine (EM) residents' ability to make important clinical decisions based on their ECG interpretation when sleepy and fatigued. We hypothesized that sleepiness and fatigue from working overnight shifts would decrease the accuracy of EM resident interpretation of ECGs for ST-segment elevation myocardial infarction (STEMI) and impair their ability to make critical treatment decisions.

Methods

This prospective, multicenter, within-subject study on the accuracy of clinical decision making during daytime and overnight shifts was conducted at the emergency departments (EDs) of Baystate Medical Center (an urban, community-based, academic, tertiary care center with 115 000 ED visits per year) and Stony Brook University Medical Center (a suburban, university-based, tertiary care center with 90 000 ED visits per year). The EM residents in their third year of training were eligible to participate in the study on a voluntary basis. Written consent was obtained from all participants.

We identified a list of STEMI and STEMI mimics based on the literature.²¹ The ECGs representing these conditions were identified at study sites and selected only if diagnostic confirmation was available. The final testing tool consisted of 10 ECGs from this sample, intentionally chosen for being uncommon or subtle. When pretested on attending physicians and graduating senior residents, their accuracy of decision making was 67%.

We assessed the subjects at 2 time points: during a weekly resident conference (daytime) and at the completion of the first night of a series of overnight shifts (overnight). Previous studies have shown that the first overnight shift is associated with the most significant deterioration in cognitive performance²² and manual dexterity.⁹ At both time points, subjects completed a questionnaire and an ECG test packet. The questionnaire consisted of the Stanford Sleepiness Scale (SSS); a 100-mm, unhatched, horizontal visual analog scale (VAS) addressing sleepiness, mental fatigue, and physical fatigue; and the Occupational Fatigue Exhaustion Recovery (OFER-15) scale. The SSS quantifies progressive sleepiness,²³ and the OFER-15 distinguishes well between acute and chronic fatigue states.²⁴ For each of the ECGs in the test packet, subjects were provided with the same patient scenario: a 55-year-old man, nonsmoker, with hypertension and a prior ECG "abnormality" who has been experiencing 2 hours of progressively worsening retrosternal chest discomfort with radiation to the left shoulder, accompanied by nausea and

What was known and gap

Sleep loss reduces cognitive performance, though the extent to which this affects diagnostic reasoning in emergency medicine residents has not been studied.

What is new

There was no negative impact on sleep-deprived residents' decisions to activate the catheterization laboratory activation (CLA) based on electrocardiogram interpretation.

Limitations

Small sample increases risk for type II error; limited choices for subjects do not authentically represent real clinical situations.

Bottom line

Despite reporting fatigue, resident ability to make CLA decisions was not affected.

diaphoresis. For each ECG, subjects were instructed to record (yes or no) whether the patient required catheterization laboratory activation (CLA), as well as their confidence in the treatment decision using an 11-point numeric rating scale (NRS), ranging from "no confidence" to "complete confidence."

Retesting overnight occurred a minimum of 1 month after the daytime testing to allow for memory decay (washout). The ECGs used for testing following the overnight shift were the same as the ECGs used during the rested state but were provided in a randomized order, and no answers were provided or discussed with the study participants to minimize learning from the daytime testing.

All data were recorded by the subjects on data collection sheets and later transferred to SPSS software for data analysis. The study investigator at each site graded the ECG tests by recording "correct" or "incorrect" for each ECG. Incorrect decisions to activate the cardiac catheterization laboratory were further classified as overcalls (CLA when not a STEMI) or undercalls (no CLA when a STEMI was present).

Our primary outcome measure was the percentage of appropriate CLA decisions. Secondary measures included confidence in treatment decisions measured on the NRS and the number of overcalls and undercalls. We also measured a subject's sleepiness and fatigue at both testing times: SSS, 100-mm VAS for sleepiness, mental and physical fatigue, and OFER-15.

Ethical approval of this study was granted by the Institutional Review Boards of Baystate Medical Center and Stony Brook University.

The data obtained were analyzed with SPSS version 21 (IBM Corp). Pairwise differences in the accuracy of CLA between daytime and overnight conditions were assessed with Wilcoxon signed-rank test. Measures of fatigue were compared with nonparametric tests. Sample size calcula-

TABLE 1 MEASURES OF FATIGUE

Scale	Daytime, Median (IQR)	Overnight, Median (IQR)	P
Stanford Sleepiness Scale	2 (2–3)	5 (3–6)	> .001
Degree of sleepiness, VAS, mm	30 (14–43)	72 (62–81)	> .001
Degree of physical fatigue, VAS, mm	36 (20–59)	68 (59–80)	> .001
Degree of mental fatigue, VAS, mm	33 (20–59)	74 (59–80)	> .001
Occupational Fatigue Exhaustion Recovery scale (OFER-15)	34 (29–42)	34 (29–43)	.48

Abbreviations: IQR, interquartile range; VAS, visual analog scale.

tions predicted that 23 paired observations would demonstrate, with 80% power and a 0.05 chance of error (2 tailed), a 10% difference in the primary outcome of appropriate CLA decisions.

Results

We enrolled 23 third-year EM residents in the study during 2011 and 2012, all of whom completed data collection. On both the SSS and VAS of subjective sleepiness, the subjects were not at peak alertness when assessed during the day. They were significantly sleepier at the end of their first overnight shift. They also demonstrated significantly increased physical and mental fatigue on the subjective VAS. There was no difference between scores on the OFER-15 (TABLE 1).

The residents showed no significant changes in the primary measure of appropriate CLA based on their

interpretation of the ECG. Daytime appropriate CLA (interquartile range) was 70% (50–80) and overnight was also 70% (60–70; $P = .82$). Overall accuracy and confidence for each of the 10 ECGs are shown in TABLE 2.

Confidence in their decision making did not change significantly from daytime to overnight. There were no significant differences in median overcalls and undercalls ($P = .57$ and $P = .37$, respectively). TABLE 3 shows the breakdown of overcalls and undercalls between daytime and overnight testing.

Discussion

We examined differences in the accuracy of CLA based on ECG interpretation for STEMI between daytime and overnight shifts of third-year EM residents. We found that measures of sleepiness and fatigue were significantly different on the first in a series of overnight shifts compared

TABLE 2 INDIVIDUAL ELECTROCARDIOGRAM ACCURACY AND CONFIDENCE RESULTS

	Accuracy, %		P	Confidence NRS, Median (IQR)		P
	Daytime	Overnight		Daytime	Overnight	
IWMI	75	40	.22	8 (6–10)	9 (7–10)	.08
Pericarditis	50	70	.22	7 (6–8)	7 (5–9)	.92
LBBB	65	80	.51	8 (6–9)	8 (7–10)	.73
LBBB with IWMI	80	85	.13	8 (6–10)	7 (5–8)	.53
RBBB with MI	50	60	.55	7 (6–8)	7 (5–8)	.75
RBBB	80	60	.69	7 (5–9)	7 (6–8)	.97
LVH	60	55	> .99	7 (5–9)	7 (6–8)	.94
Posterior wall MI	55	50	> .99	7 (7–9)	7 (6–8)	.06
Anteroseptal MI	75	65	> .99	7 (5–8)	6 (5–8)	.75
AIVR	70	35	.03	7 (5–9)	6 (5–8)	.57

Abbreviations: NRS, numeric rating scale; IQR, interquartile range; IWMI, inferior wall myocardial infarction; LBBB, left bundle branch block; RBBB, right bundle branch block; MI, myocardial infarction; LVH, left ventricular hypertrophy; AIVR, accelerated idioventricular rhythm.

TABLE 3 UNDERCALLS AND OVERCALLS						
	Undercall, No.		<i>P</i>	Confidence NRS, Median (IQR)		<i>P</i>
	Daytime	Overnight		Daytime	Overnight	
IWMI	5	11	.07	8 (5–10)	8 (7–9)	.59
LBBB with IWMI	5	2	.38	8 (6–10)	7 (5–8)	.29
RBBB with MI	12	9	.58	6 (6–8)	6 (5–7)	.94
Posterior wall MI	9	10	> .99	7 (7–8)	6 (5–8)	.33
Anteroseptal MI	6	5	> .99	7 (5–8)	6 (5–8)	.92
LBBB	8	4	.34	8 (6–8)	8 (7–10)	.57
Pericarditis	11	5	.11	7 (6–8)	6 (5–8)	.20
RBBB	4	6	.69	7 (5–9)	7 (6–8)	.97
LVH	8	8	> .99	7 (5–9)	7 (6–8)	.94
AIVR	6	12	.03	7 (5–9)	6 (5–8)	.57

Abbreviations: NRS, numeric rating scale; IQR, interquartile range; IWMI, inferior wall myocardial infarction; LBBB, left bundle branch block; RBBB, right bundle branch block; MI, myocardial infarction; LVH, left ventricular hypertrophy; AIVR, accelerated idioventricular rhythm.

with daytime shifts. Despite subjective sensations of fatigue and sleepiness, residents did not demonstrate a difference in the accuracy of CLA.

The ED shift work demands vigilance at night, typically without any opportunity for rest. Overnight workers fight a natural instinct to sleep, which disrupts the body’s internal clock, forcing it to alter the activity-rest cycle. This disruption contributes to overall fatigue. Lapses in vigilance are worse at the circadian nadir, between 2:00 AM and 9:00 AM.²⁵ Cognitive and psychomotor performance parallel circadian variation with the performance nadir occurring between 3:00 AM and 5:00 AM. In our study, residents reported an increase in sleepiness and fatigue during overnight shifts compared with daytime. However, it should be noted that even in their “rested” state, subjects did not have a mean SSS of 1 “feeling active, alert, vital, and wide awake.”

Not all clinical processes, or clinicians, appear to be subject to the same deleterious effects of fatigue as previous studies have demonstrated mixed results. Sleep deprivation in anesthesia specialists demonstrated impairment in attention, working memory, and performance after 24-hour shifts.^{3–5} Reducing duty hours in an intensive care unit setting demonstrated decreased sleepiness, attentional failures, and medical errors.^{13,14}

Emergency physician performance at intubation and frequency of errors increases when working night shifts,⁶ and the risk of motor vehicle accidents after night shift increases as well.⁷ Attending surgeons have increased rates of procedural complications when operating after a sleep-

deprived night on call,⁸ and resident laparoscopic skills suffer with sleep deprivation.^{9,10} However, other studies of sleep-deprived surgeons have seen no significant decline in performance on a surgical simulator,¹¹ and no negative effect on surgical residents’ ability to learn laparoscopic skills.¹²

In our study, despite being tested during their circadian nadir, when sleepy and fatigued, the residents experienced no significant change in their ability to accurately interpret an ECG for STEMI and make appropriate treatment decisions. This suggests that EM residents are able to preserve performance in diagnostic reasoning, at least in an area of frequent experience.

Our study has several limitations. An ECG packet with an answer sheet does not mimic real-life situations. The lack of clinical fidelity leaves the potential for subjects to be less thoughtful in their decision making. However, this format did allow for each subject to assess multiple ECGs. In addition, the decision choices placed before the subjects were limited. They were given only the option of CLA or no CLA, without the frequently used practice of consultation with interventional cardiology or with a colleague. This was necessary for study purposes to get commitment, but may have led to more conservative decision making. The small power of the study, dictated by the available number of third-year EM residents, placed limitations on our study design. Testing daytime followed by nighttime may have resulted in a type II error. The deleterious effects of fatigue may have been masked by clinical maturation or study subsequent to the first test. With greater numbers, a

crossover design where half of the subjects were first tested in a fatigued state and retested while rested could have been employed. Retesting with the same set of ECGs, although more than a month later, in a different order, and with no answers or feedback provided after the initial test, does create the possibility of recall by subjects to improve their performance on the retest.

Further study is needed to determine whether this finding is generalizable to all senior EM residents. There are significant variations among hospitals in the frequency of STEMI, the role residents take in management, ECG teaching, work hours, and scheduling. Despite including residents from 2 separate training programs, these unique aspects may be responsible for the lack of difference.

Conclusion

Third-year EM residents report sleepiness and fatigue at the end of an overnight shift. Despite worsening fatigue, these residents showed no significant decrease in their ability to make CLA decisions based on their interpretation of the ECG.

References

- Shen J, Barbera J, Shapiro CM. Distinguishing sleepiness and fatigue: focus on definition and measurement. *Sleep Med Rev*. 2006;10(1):63–76.
- Rogers AE, Hwang WT, Scott LD, Aiken LH, Dinges DF. The working hours of hospital staff nurses and patient safety. *Health Aff*. 2004;23(4):202–212.
- Bartel P, Offermeier W, Smith F, Becker P. Attention and working memory in resident anaesthetists after night duty: group and individual effects. *Occup Environ Med*. 2004;61(2):167–170.
- Howard SK, Gaba DM, Smith BE, Weinger MG, Herndon C, Keshavacharya S, et al. Simulation study of rested versus sleep-deprived anesthesiologists. *Anesthesiology*. 2003;98(6):1345–1355.
- Gander P, Millar M, Webster C, Merry A. Sleep loss and performance of anaesthesia trainees and specialists. *Chronobiol Int*. 2008;25(6):1077–1091.
- Smith-Coggins R, Rosekind MR, Hurd S, Buccino KR. Relationship of day versus night sleep to physician performance and mood. *Ann Emerg Med*. 1994;24(5):928–934.
- Steele MT, Ma OJ, Watson WA, Thomas HA Jr, Muellemann RL. The occupational risk of motor vehicle collisions for emergency medicine residents. *Acad Emerg Med*. 1999;6(10):1050–1053.
- Rothschild JM, Keohane CA, Rogers S, Gardner R, Lipsitz SR, Salzberg CA, et al. Risks of complications by attending physicians after performing nighttime procedures. *JAMA*. 2009;302(14):1565–1572.
- Leff DR, Aggarwal R, Rana M, Nakhjavani B, Purkayastha S, Khullar V, et al. Laparoscopic skills suffer on the first shift of sequential night shifts: program directors beware and residents prepare. *Ann Surg*. 2008;247(3):530–539.
- Eastridge BJ, Hamilton EC, O'Keefe GE, Rege RV, Valentine RJ, Jones DJ, et al. Effect of sleep deprivation on the performance of simulated laparoscopic surgical skill. *Am J Surg*. 2003;186(2):169–174.
- Lehmann KS, Martus P, Little-Elk S, Maass H, Holmer C, Zurbuchen U, et al. Impact of sleep deprivation on medium-term psychomotor and cognitive performance of surgeons: prospective cross-over study with a virtual surgery simulator and psychometric tests. *Surgery*. 2010;147(2):246–254.
- DeMaria EJ, McBride CL, Broderick TJ, Kaplan BJ. Night call does not impair learning of laparoscopic skills. *Surg Innov*. 2005;12(2):145–149.
- Landrigan CP, Rothschild JM, Cronin JW, Kaushal R, Burdick E, Katz JT, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med*. 2004;351(18):1838–1848.
- Lockley SW, Cronin JW, Evans EE, Cade BE, Lee CJ, Landrigan CP, et al. Effect of reducing interns' weekly work hours on sleep and attentional failures. *N Engl J Med*. 2004;351(18):1829–1837.
- Everson CA. Physiological consequences of sleep deprivation. *J Musculoskelet Pain*. 1998;6(3):93–101.
- Harrison Y, Horne JA. The impact of sleep deprivation on decision making. *J Exp Psychol Appl*. 2000;6(3):236–249.
- Pilcher JJ, Huffcutt AI. Effects of sleep deprivation on performance: a meta-analysis. *Sleep*. 1996;19(4):318–326.
- Harrison Y, Horne JA. One night of sleep loss impairs innovative thinking and flexible decision making. *Organ Behav Hum Decis Process*. 1999;78(2):128–145.
- Croskerry P. A universal model of diagnostic reasoning. *Acad Med*. 2009;84(8):1022–1028.
- Drummond SP, Brown GA, Stricker JL, Buxton RB, Wong EC, Gillin JC. Sleep deprivation-induced reduction in cortical functional response to serial subtraction. *Neuroreport*. 1999;10(18):3745–3748.
- Brady WJ, Perron A, Ullman E. Errors in emergency physician interpretation of ST-segment elevation in emergency department chest pain patients. *Acad Emerg Med*. 2000;7(11):1256–1260.
- Santhi N, Horowitz TS, Duffy JF, Czeisler CA. Acute sleep deprivation and circadian misalignment associated with transition onto the first night of work impairs visual selective attention. *PLoS One*. 2007;2(11):431–436.
- Hoddes E, Zarcone V, Smythe H, Phillips R, Dement WC. Quantification of sleepiness: a new approach. *Psychophysiology*. 1973;10(4):431–436.
- Winwood PC, Lushington K, Winefield AH. Further development and validation of the Occupational Fatigue Exhaustion and Recovery (OFER) scale. *J Occup Env Med*. 2006;48(4):381–389.
- Doran SM, Van Dongen HP, Dinges DF. Sustained attention performance during sleep deprivation: evidence of state of instability. *Arch Ital Biol*. 2001;139(3):253–267.