The Effects of Consecutive Night Shifts on Neuropsychological Performance of Interns in the Emergency Department: A Pilot Study

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Study objective: We obtain preliminary information on the neuropsychological performance of house officers at the beginning and end of a shift while they worked consecutive night shifts in the emergency department.

Methods: We prospectively studied interns working 12-hour consecutive night shifts in an urban Level I trauma center ED. All consecutive non–emergency medicine interns rotating for 1 month were eligible except those older than 40 years and those with sleep disorders or depression (identified by using the Profile of Mood Scale, Sleep Diagnostic Questionnaire). We tested research subjects at the beginning of a day shift and at the beginning and end of night shifts 1 and 3 of 4 consecutive night shifts at times of estimated baseline wakefulness (10 PM) and maximum fatigue (3 AM). We used 3 standardized neuropsychological tests: (1) Delayed Recognition Span Test (visual memory capacity); (2) Continuous Performance Test (attentional function, vigilance); and (3) Santa Ana Form Board Test (psychomotor speed, coordination). We analyzed data with mixed-model analysis, with research subject as a random effect.

Results: Thirteen interns were eligible, and 1 declined. Twelve interns (6 men and 6 women; age range 25 to 35 years) were enrolled. The Delayed Recognition Span Test (number correct before first error) revealed significant deterioration from the beginning of the shift to the end of the shift (mean difference –2.2; 95% confidence interval –3.1 to –1.3). This represents an 18.5% decrease in visual memory capacity. There were no significant differences found for the other tests.

Conclusion: Interns working nights demonstrated a significant reduction in visual memory capacity across the night shift. Research involving neuropsychological performance during night shifts in the ED is important. It might provide valuable insights into ways to improve our performance during night shifts.

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INTRODUCTION

Emergency physicians are particularly vulnerable to sleep deprivation because of the 24-hour continuous operation of emergency departments. The need to staff the ED around the clock creates work schedules that involve working overnight (requiring daytime sleep) and working rotating shifts (changing sleep patterns) multiple times per week. Working fixed night shifts might affect neurocognitive function by virtue of decreased recovery sleep during daytime hours.[1-3] However, considerably less information is known about the effect of a rotating schedule on neurocognitive function. Preliminary evidence suggests that rotating shifts might have a particularly disruptive effect on circadian rhythm function.[4]

In previous studies, emergency physicians demonstrated decreases in certain performance tasks during sporadic night shifts and lower IQ test scores the morning after working serial night shifts.[5-7] Research has not been conducted while physicians were actually at work during consecutive night shifts in the ED.

The Patient and Physician Safety and Protection Act of 2001 was introduced to the Congress in November 2001.[8] This bill was a federal response to a report from the Institute of Medicine demonstrating a potential link between resident sleep deprivation and preventable medical errors. This new legislation was proposed 17 years after the Libby Zion case linked the purported actions of a sleep-deprived resident to a fatal medical error.[9] Data to support the bill came in part from The Harvard Medical Practice study, which reviewed more than 30,000 New York State medical records in 1984 and defined the scope of adverse events in hospitalized patients.[10,11] Despite the absence of a documented correlation between resident physician sleep deprivation and medical errors in these studies, the federal government has initiated safeguards against an overextended resident work schedule in the form of this new bill.[8]

The purpose of this study was to obtain preliminary information on the neuropsychological performance of house officers as the shift progressed while they were actually at work during consecutive nights in the ED. Our hypothesis was that scores would decrease at the end of the shift.

METHODS

We prospectively studied house officers working 12-hour rotating shifts in an urban Level I trauma center ED, with a volume of more than 60,000 visits per year, and an emergency medicine residency program. The house officer work schedule consisted of repetitive blocks of 4 consecutive day shifts (7 AM to 7 PM), 2 days off, 4 serial night shifts (7 PM to 7 AM), and then 2 nights off.

We used non–emergency medicine interns rotating through the ED who had no other clinical responsibilities outside of their ED shifts. This allowed us to remove research subjects from their jobs for the testing periods, with minimal disruption to the flow of patients through the ED.

Eligibility for enrollment included all interns younger than 40 years of age on rotation in the ED for at least 1 month. We excluded research subjects if they had sleep disorders or depression, as determined by using the Sleep Diagnostic Questionnaire and the Profile of Mood Scale administered immediately before initiation of the testing.[12,13] We obtained approval for the study by the investigational review board of the medical center and informed consent from all research subjects.

We tested research subjects in the ED in a quiet room not used for patient care. Two of the investigators (DCR, NKR) and 4 trained nurses administered the tests, according to a predetermined standard procedure, as instructed by one of the neuropsychologists (RK). Research subjects practiced each test before starting the entire battery to avoid a learning effect. The tests were presented in the same order each time during each testing period, with day shift first and then night shift. The testing sessions lasted approximately 15 minutes. We conducted the tests during the second 2 weeks of each intern's rotation to allow accommodation to the ED schedule. We obtained beginning-of-shift values at 7 AM during the second consecutive day shift and 10 PM on the first and third of 4 consecutive night shifts. We obtained end-of-shift values at 3 AM on the first and third of 4 consecutive night shifts. We selected the 3 AM time to assess the effects of maximum fatigue and circadian rhythm disturbance on performance.[14]

Three brief neuropsychological evaluations of higher cognitive function were administered to each research subject at the beginning of the day shift and at the beginning and end of 2 night shifts. These standardized tests measure critical functions that we believe are required of emergency physicians. These include the ability to acquire new knowledge and memory (the Delayed Recognition Span Test), concentration and attentional function (the Continuous Performance Test), and fine motor skills and coordination (the Santa Ana Form Board Test).[15-17]

The Delayed Recognition Span Test evaluates visual memory capacity. The research subject identifies a new stimulus among an increasing array of serially presented stimuli. The test contains 14 pages of black dots. Page one contains one dot, and then on each consecutive page, a new dot is added in a new spatial location, while the previously seen dots remain in their spatial position. As the pages are turned, the research subject identifies which dot has been added. The outcome measure for this test is span length (ie, the number of correct pages before making the first error), with a higher score indicating a better performance. The range of possible scores is 0 to 14, with a perfect score equal to 14 pages. Clinically, this test is used to evaluate memory capacity in patients with memory disorders. The ability to process and commit new information to memory is critical to emergency physicians because they are continuously acquiring new data that mandate intervention by means of history taking, physical examination, and testing.

The Continuous Performance Test evaluates attentional function and vigilance. The research subject listens to an audiotaped recording of 300 letters of the alphabet presented one at a time every second in a pseudorandom fashion. The research subject must work through the alphabet by identifying the letters A through Z in the correct order. The outcome measure is the total number of correct letters identified. The possible range of scores is 0 to 26, with a perfect score equal to 26 letters. A higher score indicates a better performance. Clinically, this test measures attention to detail and concentration, which are critically important skills required of the emergency physician caring for many sick patients simultaneously.

The Santa Ana Form Board Test measures psychomotor speed and coordination. Research subjects are timed while they rotate a series of round-appearing pegs 180° into square holes. The outcome measure is the time (in seconds) that it takes to complete the test without an error. A shorter completion time indicates a better performance. Fine motor skills and coordination are important to emergency physicians because of the time-sensitive procedural interventions that are required in critical situations.

We instructed research subjects to keep a sleep log for the study period, including work schedule, number of hours slept during off hours, and amount of caffeinated beverages consumed.

We analyzed all data with SAS version 8.1 software (SAS Institute, Inc., Cary, NC).

We used the mixed-effects model with random slopes to compare the beginning-of-shift and end-of-shift scores for the 2 night shifts on the Delayed Recognition Span Test and the Continuous Performance Test. We used the sign test to compare scores on the Santa Ana Form Board Test.

RESULTS

Thirteen research subjects were eligible for participation, and 1 declined for personal reasons. We did not exclude anyone because of results on the Sleep Diagnostic Questionnaire or Profile of Mood Scale. Twelve research subjects, 6 men and 6 women, were enrolled and completed the study. One research subject did not complete the fifth testing period for personal reasons and refused to complete the Continuous Performance Test after the first 2 sessions. There were insufficient data to use her Continuous Performance Test scores in the final analysis. The age range of the research subjects was 25 to 35 years, with a mean of 28 years. The research subjects were enrolled in internships in the following specialties: general surgery (n=5), obstetrics and gynecology (n=3), internal medicine (n=2), oral surgery (n=1), and rotating internship (n=1).

Neuropsychological test results are reported in the Table and in Figures 1 to 3. We found a significant difference between beginning-of-shift and end-of-shift scores for the Delayed Recognition Span Test but not for the other 2 tests. Delayed Recognition Span Test scores were 2.2 points lower at the end of the shift compared with those at the beginning of the shift (mean difference –2.2; 95% confidence interval –3.1 to –1.3). This represents an 18.5% decrease in visual memory performance. There were no significant differences between beginning-of-shift and end-of-shift scores for the Continuous Performance Test or the Santa Ana Form Board Test. None of the interns completed the sleep log.

DISCUSSION

Our study is unique because we tested interns as they were actually at work in the ED. One of the most salient findings was a decrease in visual memory capacity across the night shift. Although it is difficult in a study like this to determine the clinical effect of this decrease, it is nonetheless important for individuals who rely heavily on their memory (eg, emergency physicians) to be able to predict when this skill might be operative at suboptimal levels. It is plausible that for emergency physicians, this finding might have clinical relevance in the study and interpretation of medical records and changes in results of ECG, radiographic, and laboratory test results.

Jenkins and Dallenbach[18] first described the relationship between sleep and memory more than 75 years ago, showing that recall in human subjects improved after an intervening night of sleep. Although many early

Table.
Neuropsychological test results.

	DRST, Mean (95% CI) (N=12)	CPT, Mean (95% CI) (N=11)	SAFBT, Median (25th–75th Percentile) (N=12)
Beginning of shift	11.9 (11.2–12.6)	25.6 (25.3–25.9)	46.4 (41.2–55.0)
End of shift	9.7 (8.9–10.5)	25.4 (25.0–25.8)	49.3 (43.9–60.2)

DRST, Delayed Recognition Span Test; **CPT,** Continuous Performance Test; **SAFBT,** Santa Ana Form Board Test; **CI,** confidence interval.

Figure 1.
Delayed Recognition Span Test (means). Higher span length signifies better performance.

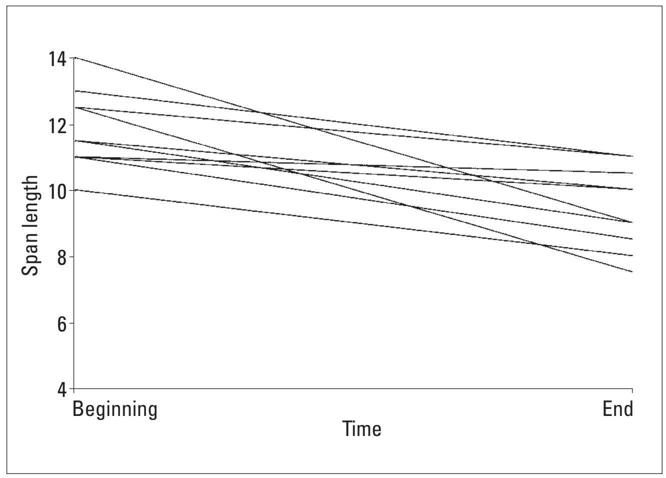
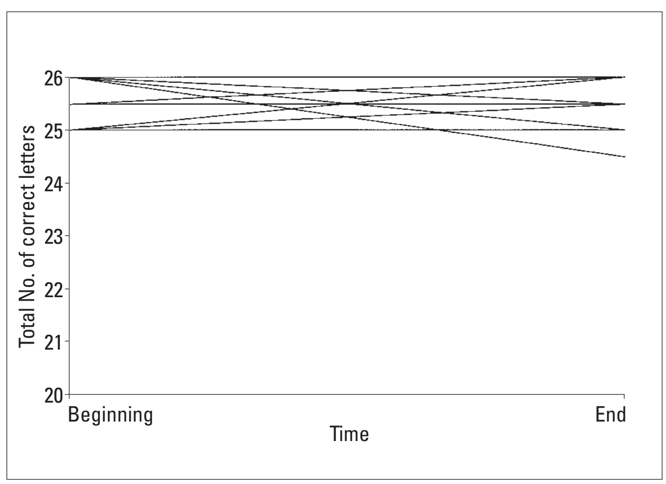


Figure 2.
Continuous Performance Test (means). Higher number of correct letters signifies better performance.



studies looked at the beneficial effects of recovery sleep after a period of relative sleep deprivation, subsequent studies showed memory loss after periods of more acute sleep deprivation, a situation similar to that experienced by the emergency physicians in our study.[19] Emergency physicians, by the very nature of their work schedule, are called on to make critical life-and-death decisions on an acute basis and often without the buffering effects of an intervening night of recovery sleep.[3]

Selective impairment of visual memory capacity (as measured by using the Delayed Recognition Span Test) over attention and vigilance (as measured by using the Continuous Performance Test) should be viewed with interest. We might have expected a similar decrease in the Continuous Performance Test scores if sleepiness was the primary determinant of decreased cognitive performance.

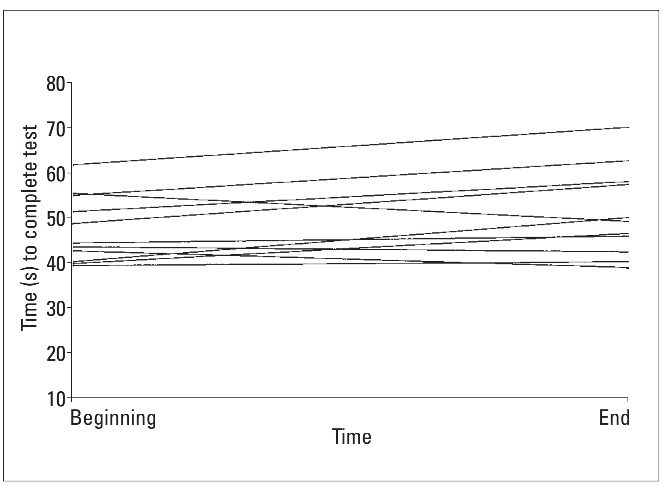
The 3 neuropsychological tests used in this study were administered within 15 minutes. It is possible that interns pulled from their jobs while working were able to focus their attention acutely to enhance their cognitive efforts during the Continuous Performance Test and Santa Ana Form Board Test, much in the way that physicians respond to codes. However they were unable to enhance their ability to retain new information toward the end of their 12-hour night shift (as measured by using the Delayed Recognition Span Test). This finding is alluded to in a study by Jacques et al[20] of 353 family practice residents taking a 4-hour in-service examination. They found decreases in examination scores to be associated with decreased sleep on the night before the examination. It appears that by the end of the night shift, memory capacity is negatively affected in such a way that no reserve exists to compensate for the decrease. However, short-term attention (as measured by using the Continuous Performance Test) and the ability to perform manual tasks for brief periods (as measured by using the Santa Ana Form Board Test) are either not affected, or the individuals are able to sufficiently compensate for any changes on the tests we used.

Similar findings were also reported in 2 studies by Smith-Coggins et al.[5,6] In the first study, emergency attending physicians working the night shift took longer to intubate mannequins and were more likely to omit a portion of the 7-step mannequin intubation procedure as the night shift progressed.[5] Physicians working nights also took longer to complete a simulated triage test. Physicians made more errors in the triage test as their shift progressed, regardless of whether it was a night shift or a day shift.

In the second study by Smith-Coggins et al,[6] physicians working nights demonstrated slower vigilance reaction times (as measured by using a 10-minute psychomotor vigilance task) and slower mannequin intubation times.[6] However, there were no significant differences in physician ECG analysis between the night shift and day shift. This lack of difference might be related to the ability of the emergency attending physicians to rapidly and expertly interpret ECGs as a rote skill.[6]

Dula et al[7] found a decrease in test scores on the Fluid Scale of the Kaufman Adolescent and Adult Intelligence Test given to emergency medicine residents at the end of five 8-hour consecutive night shifts compared with 3 or more 10-hour consecutive day shifts. The Fluid Scale measures hypothesis and decisionmaking. The length of time required for each testing session is not men-

Figure 3.
Santa Ana Form Board Test (medians). Shorter completion time signifies better performance.



tioned, but the test reportedly requires high levels of thinking skills.

The effects of fatigue and sleep deprivation on physician performance are important and unique problems in emergency physicians working rotating shifts. We faced many challenges while conducting this research in real time during the most vulnerable hours of the circadian clock. We initially planned a testing period toward the end of the day shift to capture the midafternoon circadian nadir. This would have involved removing house officers from their jobs at 3 PM, which was not possible because of the volume of the ED at this time of day.

We were not able to test emergency medicine residents because of their value to the clinical operations of the ED. This substitution of non–emergency medicine house officers for emergency medicine residents allowed us to conduct this pilot study in real time but compromised the ability to generalize results to emergency medicine residents.

The inability to conduct a 3 PM test (end of day shift) precluded analysis of beginning-of-shift and end-of-shift data for the day shift. Therefore, the 7 AM results were not used in the final analysis because there was no corresponding end-of-shift measurement. Furthermore, we believed that the test results from the beginning of the day shift might be qualitatively different than those from the beginning of the night shift because of circadian influences.

Although the assessment of normality is not plausible with only 12 residents, the nonparametric sign test provided results similar to those of the mixed-effects model for the Delayed Recognition Span Test and Continuous Performance Test comparisons. In these cases, we used the mixed-effects model because it is a more powerful tool to detect change over time. However, for the Santa Ana Form Board Test comparison, the mixed-effects model and sign test provided different results, and we used the sign test to be conservative.

It was difficult to know in advance which neuropsychological tests would be the most relevant and useful in lieu of studying clinical practice. We used 3 standardized neuropsychological tests that we thought would represent tasks performed in the ED (motor skills, attention, and visual memory) and could be performed quickly to avoid keeping physicians away from patient care for prolonged periods of time. We also thought that these tests would be fair to use with house officers in different residency programs (as opposed to ECG interpretation, which might be better performed by those with a stronger background in internal medicine). However, perhaps a longer testing period and tests requiring higher levels of thinking skills (10-minute psychomotor vigilance tasks, Fluid Scale Kaufman Adolescent and Adult Intelligence Test, Delayed Recognition Span Test) are needed to detect differences in test scores in physicians.

The lack of significant findings in the Continuous Performance Test and Santa Ana Form Board Test might also be the result of several other factors, such as small sample size, not rotating the order in which tests were administered, a learning effect, and the high level of innate capacities found in research subjects working in this environment.

The interns in our study readily cooperated for testing while working but were not willing to complete sleep logs. Sleep data would have added to our knowledge about the effect of sleep deprivation and performance.

The Patient and Physician Safety and Protection Act of 2001 limits resident work hours to a total maximum of 80 hours per week, limits ED shifts to no longer than 12 hours, and guarantees 1 day off in 7 and at least 1 full weekend off per month.[8] The ED schedule of interns in our study met these requirements, yet the interns still experienced a decrease in visual memory performance as their night shift progressed. We are unable to conclude whether this finding would have occurred at the end of a 12-hour day shift as well. More research needs to be conducted to determine the ideal schedule for 24-hour continuous physician coverage of the ED.

In summary, we found that interns working nights demonstrated a significant reduction in visual memory capacity across the night shift. Despite the inherent challenges of conducting research on the neuropsychological performance of emergency physicians while they are working, this research is important. It might provide valuable insight into ways to improve performance during night shifts.

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