Quality of Emergency Care on the Night Shift

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Abstract

Objectives: To determine whether performance decrements at night actually translate into worsened measures of quality of patient care in the emergency department (ED). Emergency physicians and healthcare workers are sleepier and less cognitively proficient at night than during the day. Despite a lack of data, medical errors have been attributed to these deficits, and pharmacologic solutions recently have been suggested.

Methods: The authors studied 36 months of emergency care and measured quality indicators, including early mortality (deaths occurring after arrival in the ED or within 48 hours of hospital admission), frequency of return after ED discharge, time to thrombolysis in acute myocardial infarction (AMI), frequency of aspirin use in AMI, and performance of endotracheal intubation. Comparisons were by time of day in eight-hour epochs.

Results: There were 345,000 patient encounters in the study period. The distribution in time was determined for 25,079 sampled ED visits, 3,666 admissions, and 507 early deaths. Estimated early mortality was 0.5% (95% CI = 0.0 to 1.0%) greater at night compared with during the day. There was no effect of time of day on 1,828 returns with admission after ED discharge. In 257 patients who received thrombolytics for AMI, mean time-to-treatment and frequency of aspirin use were not worse at night. In 443 emergent endotracheal intubations, there was no difference at night in the duration or number of attempts required, or in protocol adherence.

Conclusions: Quality indicators used in this study do not demonstrate marked deficits in patient care occurring at night. A very small, but measurable, increase in early mortality was identified. Improved measures to counter circadian disruption warrant study but may result in minimal improvements in patient care.

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Society has increasingly come to involve human activities performed at every hour of the day and night, but this 24-hour society also has increasingly exposed the limitations of human diurnal behavior. In critical operations, like emergency medical care, there has been increasing interest in developing methods to minimize performance decrements that can result either directly from circadian disruption or as a result of sleep deprivation secondary to circadian disruption. With the recent approval of modafinil for shift-work syndrome, the prospect of pharmaceutical intervention to modify the effects of circadian disruption now looms over all shift workers, including those who provide emergency medical care. Medical errors are commonly attributed to practitioners being fatigued or sleepy,[1] but there are few data to support this claim.[2–4]

Before we can consider the potential benefits to our patients of new efforts to treat the circadian disruption experienced by doctors, nurses, and other health care providers, however, a more thorough understanding of the existing risks to patients is needed. Evaluation of the effect of time of day on measures of emergency care quality allows assessment of the potential importance to patients of new interventions to reduce circadian disruption in health care shift workers. We hypothesized that decreased performance of medical staff at night, caused by circadian disruption, will result in lower quality care of patients treated at night compared with those treated during the day, as measured by established quality markers. We used markers crossing multiple domains

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of performance, including clinical outcome, process of care, and psychomotor procedural success.

METHODS

Study Design

This is a retrospective observational study using preexisting clinical and quality assurance (QA) databases at two hospitals. Institutional review board approval was obtained at both hospitals.

Study Setting and Population

The two hospitals were a university hospital with an annual emergency department (ED) census of about 65,000, and a non-teaching community hospital with an annual ED census of about 50,000. The patient care analyzed was provided in the ED of these hospitals or by the air medical service of the university hospital. Outcome measures were studied at the university hospital, process measures were studied at the community hospital, and psychomotor measures were studied in the air medical program. Thirty six months of patient care data (January 1999 to December 2001) were analyzed for all ED measures. Sixty months of patient care data were analyzed for the air medical transport team (January 1997 to December 2001).

Study Protocol and Measurements

Metrics of quality of care selected for this study included two markers of clinical outcome, two markers of clinical process, and markers of psychomotor procedural success.

Outcome markers included early mortality (mortality after arrival in the ED or within 48 hours of hospital admission) and the frequency of patients who returned and were admitted to the hospital within 72 hours of being seen and discharged from the ED. Patients with out-of-hospital cardiac arrest treated in the ED were not included in the early mortality measure in this QA database. Deaths occurring after discharge from the ED and returns to other hospitals were not captured in this database. The time distribution (the number of patients who arrive at each hour of the day) of all patients with subsequent hospital admissions, and of all patient visits, was obtained by sampling five randomly selected months in the 36-month study period. Computerized random number generation was used to select study months. This provided a sample size large enough to ensure a highly accurate measurement of the time distribution, with an average standard error of proportion of <0.002 in each hour-epoch. Because there are far fewer deaths and return ED visits, all deaths and all return ED visits in the study period were analyzed to determine their time distribution with an anticipated standard error of proportion of about 0.005 to 0.010 per hour-epoch.

To measure quality of ED processes, we evaluated all patients who were treated with thrombolytics for acute MI during the study period. Process metrics in these patients included the door-to-needle time, defined as the time from arrival of the patient in the ED until the bolus infusion of thrombolytics is initiated. We analyzed both the mean door-to-needle time and the frequency with which door-to-needle time was less than 30 minutes. We also looked at the frequency of aspirin use in patients treated with thrombolytics. Patients were scored as appropriately treated with aspirin if they were given aspirin in the ED or had taken aspirin on the day of presentation. They also were scored as appropriately treated if documentation indicated that aspirin had been withheld because of prior anaphylaxis to aspirin or because the patient was adequately anticoagulated with warfarin.

Psychomotor procedural success in emergent endotracheal intubation performed by the air medical transport team was also measured. Data were analyzed from all patients who were intubated by the team in the study period. Performance was assessed by measuring the number of attempts and the number of minutes required to successfully intubate the patient and by measuring the frequency of strict compliance with the flight service's protocol for airway management. Time to intubate was that from initiation of laryngoscopy or blind tube insertion until initial ventilation via a correctly placed tube. Protocol violations included the following: any incorrect medication dose (>10% variance from weight appropriate dose), rapid sequence intubation (RSI) of children (weight, <35 kg) without pretreatment with atropine, or failure to provide sedation after successful RSI and intubation.

Data Analysis

Quality markers were analyzed by the time of day that the patient arrived (time of registration) for ED measures, and by the time of helicopter arrival at the scene or referring hospital for air medical service measures. Time of day was categorized in eight-hour epochs. Day was defined as 7:00 AM to 3:00 PM, evening as 3:00 PM to 11:00 PM, and night from 11:00 PM to 7:00 AM. Categorical data were analyzed by contingency tables and chi-square test. Continuous data were analyzed by ANOVA with post hoc t-tests as appropriate. Differences were considered significant for $p < 0.05$. Ninety-five percent confidence intervals (95% CI) of differences between groups were calculated. Exploratory analysis by one-hour epochs was also performed and evaluated graphically.

RESULTS

For the two outcome markers we sampled 25,079 of 180,568 visits, and 3,666 of 26,395 admissions occurring during the study period. We evaluated all 1,828 returns with admission and evaluated all 507 deaths in the first 48 hours.

Mortality was slightly greater (by approximately 0.5%) at night as compared with during day and evening epochs (Table 1). This was statistically significant. The distribution of admissions and deaths by eight-hour epoch shows that both were more common during the day and evening because of higher patient volumes in those periods, but 24% of deaths occurred at night even though only 20% of admissions occurred at night (Table 2).

Distribution by one-hour epoch is shown in Figure 1. In this figure, time-of-day runs along the horizontal axis from midnight to midnight. The distribution of patients as a percentage of all patients at each hour is indicated

Table 1
Mortality by Shift at Time of ED Registration

Time of ED Registration	Estimated Admissions	Mortality at 48 hr: n (%; 95% CI)	Mortality at 48 hr: 95% CI of Difference Compared with Other Shifts Combined (%)
Day	9,475	179 (1.9; 1.6 to 2.2)	−0.3 to 0.3
Evening	11,707	204 (1.7; 1.5 to 2.0)	−0.7 to 0.0
Night	5,213	124 (2.4; 1.9 to 2.8)	0.1 to 1.0
		p = 0.02 (χ^2 = 7.84)	

Confidence intervals (CIs) are of proportions and difference in proportions; p-values are from contingency table analysis using chi-square (2 degrees of freedom).

on the vertical axis. The excess deaths on the night shift, as compared with the number of patient visits and admissions, appear to occur in a small peak at about 4:00 to 6:00 AM (Figure 1A).

The distribution of patients with returns requiring admission after initial ED discharge (Table 2) reflects the distribution of ED patient visits overall. There were no differences between day, evening, and night epochs. The superimposed distribution patterns, when analyzed by one-hour epochs, confirm the lack of any differences related to time of day (Figure 1B).

Process markers were evaluated in 308 patients who were treated with thrombolytics for acute MI during the study period. Mean door-to-needle time for treatment with thrombolytics was not longer on the night shift than on other shifts but was slightly longer (by about 14 minutes) in the evening than during the day (Table 3). This difference was statistically significant but is unlikely to be caused by fatigue, which does not peak during this epoch. The frequency of treatments under 30 minutes and the frequency of appropriate aspirin use were not statistically different between epochs. Graphically, there also was no pattern to aspirin use by time of day in one-hour epochs (Figure 1C).

The distribution of door-to-needle times by time of day for each patient is shown in a scatter plot (Figure 2). As before, time runs along the X axis from midnight to midnight. The black line shows the mean door-to-needle time in one-hour epochs. The gray horizontal line indicates the 30-minute target. Although treatment times are longer in the evening, this effect appears to be slight in this analysis.

Procedural performance data were analyzed on 443 patients in whom intubation was attempted. All patients were successfully intubated. Intubation was performed in the helicopter or at the scene of injury in 36% and at a referring hospital in 64% of patients. Intubations were orotracheal in 90% of patients, nasotracheal in 8%, and through a cricothyrotomy in 2%.

There was no effect of time of day or shift on performance measures in flight crew endotracheal intubation. Mean time to intubation, number of attempts, and proportion of protocol violations were equivalent in each eight-hour epoch and are shown in Table 4. No temporal patterns were present in the analysis of one-hour epochs.

DISCUSSION

Emergency medical care is needed 24 hours a day, requiring emergency physicians and other members of the emergency health care team to work in shifts. Shift work, however, may cause the overlapping problems of fatigue, circadian disruption, and sleep deprivation. For purposes of this discussion, *fatigue* is the sensation of feeling tired (but not necessarily sleepy) at the end of a hard shift. It happens during day shifts and night shifts, even to workers who are well rested. *Circadian disruption* is what makes workers feel tired and sleepy in the middle of the night, even if they slept well all day before going in for an overnight shift. Shift workers are also often sleep deprived as a result of insufficient or poor quality daytime sleep. *Sleep deprivation* makes a worker feel sleepy even in the middle of the day, even if not fatigued. Although fatigue, circadian disruption, and sleep deprivation are distinct, they all make workers feel tired, they are compounded at night, and they all adversely affect performance.

Although the nature of the work may select for individuals who do not object to nighttime shift work,

Table 2
Distribution by Shift of Deaths and Return Visits Compared with Distribution by Shift of All Admissions or All ED Visits

	Deaths within 48 hr vs. All Admissions from ED			Returns Requiring Hospital Admission within 72 hr after Discharge vs. All ED Visits		
Shift	Deaths, n (%)	Admissions, n (%)	95% CI of Difference (%)	Returns, n (%)	Visits, n (%)	95% CI of Difference (%)
Day	179 (36)	1,316 (36)	−5, 4	723 (40)	9,460 (38)	−1, 4
Evening	204 (40)	1,626 (44)	−8, 1	779 (42)	11,313 (45)	−5, 0
Night	124 (24)	724 (20)	1, 8	326 (18)	4,306 (17)	−1, 2
		p = 0.036 (χ^2 = 6.62)			p = 0.12 (χ^2 = 4.30)	

Confidence intervals (CIs) are of difference in proportions (deaths vs. admissions and returns vs. visits); p-values are from contingency table analysis using chi-square (2 degrees of freedom).

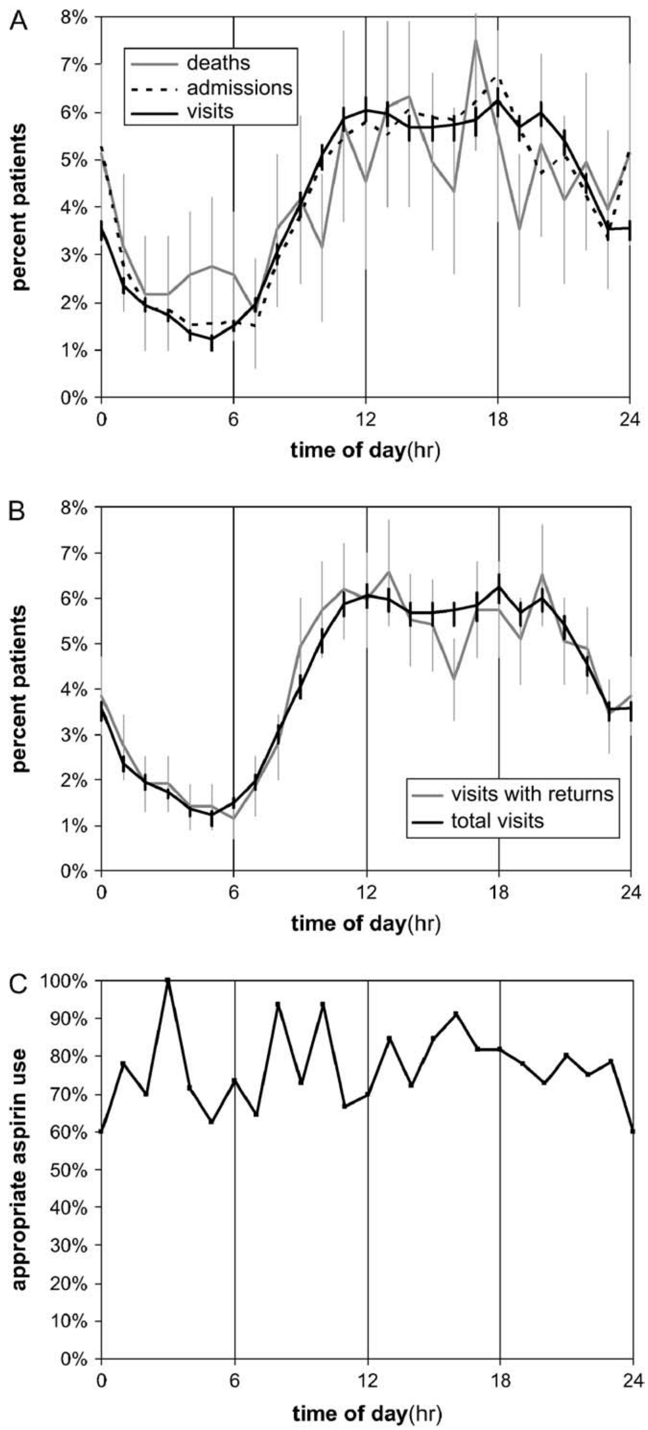

Figure 1. **One-hour epochs of (A) patients dying within 48 hours of admission, all admitted patients, and all patient visits and of (B) patients admitted to the hospital within 72 hours of ED discharge and all patient visits. (C) Frequency of aspirin use in AMI patients by one-hour epochs. Error bars represent 95% confidence intervals.**

emergency physicians and other ED staff are not nocturnal. Even though some people are better suited to nights than are others, almost everybody suffers some diminished capacity when they stay awake working all night. Experimental evidence of this is abundant throughout the sleep psychology literature[5] and is plentiful in the wider medical literature.[6,7] There even are sufficient data specifically about emergency physicians in the medical literature.[8] Dula et al. showed a decline in an intelligence test battery in residents working a series of ED night shifts[9]; Rollison and colleagues demonstrated declines in memory, vigilance, and psychomotor tests during just one night in the ED[10]; and Smith-Coggins et al. demonstrated specific declines in performance of simulated endotracheal intubation and simulated catheter placement among other measures in several experimental studies.[11]

Decrements in cognition and psychomotor performance at night suggest that it may be better to be a patient in the ED during the daytime than at nighttime, but predicting clinical outcomes may be more complicated than that. Performance on tests and simulations may not equate to performance in patient care. Motivation is a key factor in these tests and may not be the same for an IQ test as for diagnosing an MI in the ED.[12] When tired, many people try to compensate for deficiencies by doing things like going slower and double-checking themselves. Furthermore, sympathetic activation in emergent clinical situations releases adrenalin that can keep practitioners alert for critical procedures even when tired. These existing countermeasures are both conscious and unconscious and are buttressed by routine medical safeguards designed to reduce error and promote patient safety, but are they sufficient?

There are few empirical data to determine whether it is better to be a patient in the ED during the daytime than the nighttime, but even these few data have not identified deficiencies in quality at night. Rollinson et al. used a study database of chest pain patients to show that diagnostic accuracy of acute coronary syndromes was just as good at night as during the day.[4] Similarly, Carmody and colleagues used a trauma registry to show that, after correcting for severity of injury, mortality was the same for patients who were admitted to the trauma service during the day and during the night.[3]

In this study, we have identified measurable but very small increases in mortality in patients receiving emergency care at night. Door-to-needle time in patients treated with thrombolysis for acute myocardial infarction (AMI), a process measure, also varied by time of day, but was worse in patients who were seen in the ED in the evening as compared with the day, and it was not worse at night. All other measures of quality of care were not influenced by time of day. The small difference identified here is probably of insufficient magnitude to be clinically relevant or important. Although these are only five of many possible QA measures in many performance domains, and comparisons across epochs are potentially confounded by differences in disease severity, patient volume, and ED staffing levels, this first step in looking for disparity in performance at night is encouraging. Given these results, improved countermeasures (pharmacologic or otherwise) may, at best, result in only quite modest improvements in general measures of quality patient care.

Looking for these circadian patterns does not necessarily tell us about all of the possible adverse effects of providing patient care at night. Future study of the effects of circadian disruption may need to examine other types of patient-oriented outcomes, such as the

Table 3
Mean Time to Thrombolytic Treatment, Frequency of Treatment in <30 Min, and Frequency of Appropriate Aspirin Use by Time of Registration for All Patients Treated with Thrombolysis for AMI

	Thrombolytic Door-to-Needle Time			ASA Use	
Time of Registration	Minutes, mean (SD)	≤30 min, *n* (%)	>30 min, *n* (%)	Yes, *n* (%)	No, *n* (%)
Day	34(24)	78 (63)	45 (37)	99 (77)	30 (23)
Evening	48(47)	43 (49)	44 (51)	68 (81)	16 (19)
Night	43(37)	40 (56)	31 (44)	67 (71)	28 (29)
	p = 0.019 (ANOVA) post hoc p < 0.5 day vs. evening only	p = 0.13 (χ^2 = 4.11)		p = 0.26 (χ^2 = 2.73)	

Values of p are from multifactor ANOVA and post hoc *t*-tests for continuous variables and from contingency table analysis using chi-square (2 degrees of freedom) for categorical values.
AMI = acute myocardial infarction.

frequency of rare but dramatic medical errors, and adverse events such as those identified as sentinel events or those that result in malpractice cases. Such events may not affect overall quality of care but are still important.

Alternatively, circadian disruption may not be a patient care problem at all. Focus may be better directed toward the health of medical professionals themselves, using measures such as the quality and amount of sleep of these workers or their job longevity and satisfaction. Finally, the most important effects of tired health care workers may be on their driving on the way home.[13] Most emergency physicians know someone who was injured or killed on the way home from a night shift. It is significant that traffic safety affects both the driver and the community.

LIMITATIONS

There are several important limitations to this study. Because of several potential confounders, differences in patient care at night may not reflect the performance of the health care team. Characteristics of patients who present at night, such as severity of disease, may differ from those of patients who present during the day. Although we did not have the data to adjust mortality for severity of illness or injury on an individual patient basis, there may be reasons to suspect that the small increase in mortality seen at night in this study is the result of sicker patients presenting on that shift. A secondary post hoc analysis on the time distribution of patients given a Level 1 triage category, indicating high acuity, demonstrated that the proportion of patients triaged to this highest acuity category is greatest between 4:00 AM and 6:00 AM, the same period in which we found excess mortality. This is also consistent with existing data in the literature suggesting that children with critical illness,[14] and adults with cardiopulmonary and vascular emergencies,[15] present relatively more frequently in the morning. Other confounders include variability in patient volume, staffing levels, and health system resources that can change with the time of day. Effects of overcrowding also may be sensitive to time of day.

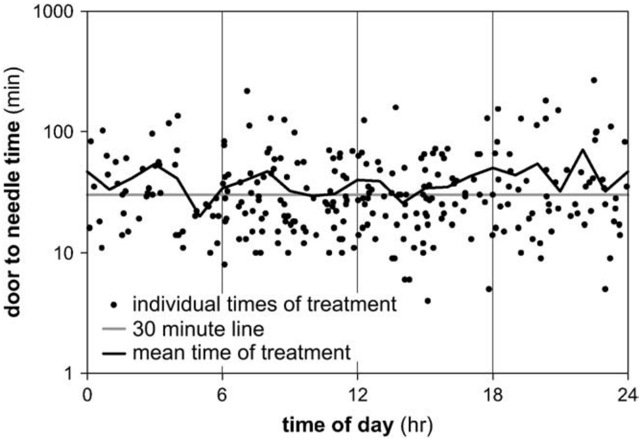

Figure 2. Scatter plot of all door-to-needle times for thrombolytic administration in 308 patients with AMI by time of day and mean time in one-hour epochs.

We do not have access to the specific shift schedules of the physicians, nurses, medics, and other team members during this period, but we note that in each of these roles a variety of work schedules, including both fixed nights and rotation, were used. Staffing in this period was modeled after the distribution of patient presentation to attempt to maintain constant ratios of nurses and physicians to patients per hour. A different mix of work schedules could yield different results.

Another limitation that may affect the accuracy of the ED outcome measures is that this analysis used time of registration on patient arrival to provide a consistent and reliable time indicative of the time of patient care. When wait times are long, however, the time of arrival in the ED may not accurately reflect the time or even the epoch in which the patient was actually treated.

The relatively small numbers of patients used in the evaluation of process and psychomotor quality measures is also a limitation. The use of larger national quality assurance databases, such as the National Registry of Myocardial Infarctions or the National Emergency Airway Registry, may identify circadian patterns with small effect sizes but statistical significance. Given the inherent confounding of circadian patterns, however, small effect sizes should be interpreted very carefully, even if statistically significant.

Finally, although we selected quality markers to represent several different domains of performance, this is a small subset of many possible quality markers.[16] Other markers may show different effects. Other candidate

Table 4
Mean Minutes and Mean Number of Attempts Needed for Endotracheal Intubation, and Frequency of Airway Protocol Violations by Time of Day of Flight Team Arrival

		Endotracheal Intubation Attempts				
Period of Flight Team Arrival	*n*	Minutes, Mean (SD)		Number of Attempts, Mean (SD)		Protocol Violations, *n* (%)
Day	111	3.6	(3.9)	1.2	(0.7)	38 (34)
Evening	223	3.6	(5.1)	1.2	(0.8)	77 (35)
Night	109	3.2	(4.6)	1.2	(0.7)	30 (28)
		p = 0.71 (ANOVA)		p = 0.98 (ANOVA)		p = 0.41 (χ^2 = 1.78)

Values of p are from multifactor ANOVA for continuous variables and from contingency table analysis using chi-square (2 degrees of freedom) for categorical values.

markers that have been proposed include time to first dose of antibiotics in patients admitted with pneumonia, beta agonist and steroid use in asthma patients, and appropriateness of thrombolytic use in AMI. We also suspect that errors in less tangible areas, such as interpersonal communication, or in less critical tasks, such as completeness of documentation, may be more affected by diurnal patterns.

CONCLUSIONS

Quality indicators used in this study do not demonstrate marked deficits in patient care occurring at night. A very small, but measurable, increase in early mortality was identified. Given the limitations of this study, such a small increase is of unclear clinical significance. Because human performance is known to decline at night, as well as with fatigue and sleep deprivation, improved measures to counter circadian disruption in emergency health care workers warrant study. Such measures, however, may result in minimal improvements in patient care.

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