AJCC American Journal of Critical Care

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Am J Crit Care. 2006;15: 30-37

Published online http://www.ajcconline.org

AJCC, the American Journal of Critical Care, is the official peer-reviewed research journal of the American Association of Critical-Care Nurses (AACN), published bimonthly by The InnoVision Group, 101 Columbia, Aliso Viejo, CA 92656. Telephone: (800) 899-1712, (949) 362-2050, ext. 532. Fax: (949) 362-2049.

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Effects of Critical Care Nurses' Work Hours on Vigilance and Patients' Safety

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• Background *To minimize the occurrence of adverse events among patients, critical care nurses must be alert to subtle changes in patients' conditions, perform accurate clinical assessments, and respond expediently. However, little is known about the effects of the nurses' work hours on vigilance and patients' safety.*

• Objectives *To describe the work patterns of critical care nurses, determine if an association exists between the occurrence of errors and the hours worked by the nurses, and explore whether these work hours have adverse effects on the nurses' vigilance.*

• Methods *Data were obtained from a random sample of critical care nurses in the United States. Nurses eligible for the study were mailed two 14-day logbooks to fill out. Information collected included the hours worked, the time of day worked, overtime hours, days off, and sleep-wake patterns. On days worked, the respondents completed all work-related questions and questions about difficulties in remaining awake while on duty. Space was provided for descriptions of any errors or near errors that might have occurred. On days off, the nurses completed only those questions about sleep-wake patterns, mood, and caffeine intake.*

• Results *The 502 respondents consistently worked longer than scheduled and for extended periods. Longer work duration increased the risk of errors and near errors and decreased nurses' vigilance.*

• Conclusions *The findings support the Institute of Medicine recommendations to minimize the use of 12-hour shifts and to limit nurses' work hours to no more than 12 consecutive hours during a 24-hour period. (American Journal of Critical Care. 2006;15:30-37)*

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Although healthcare providers are not expected to make errors, mistakes do occur, and some mistakes have resulted in serious injury or death. Each year, approximately 1.3 million patients are injured because of error during their hospitalization,[1] and more than 100 000 deaths due to preventable adverse events occur.[2] The effects of human error may be more significant for patients in critical care units (CCUs). These patients are not only exposed to more medications and treatments than are patients in general care areas but are also seriously ill, with little natural resilience or ability to defend themselves from the consequences of healthcare mishaps. Of the

5 million patients admitted to CCUs in a year, all will experience at least one preventable adverse event.[3]

Of the 5 million patients admitted to critical care units in a year, all will experience at least one preventable adverse event.

Approximately one fifth (19%) of medication errors in critical care are potentially life threatening, and almost half (42%) are clinically important enough[4] to warrant additional life-sustaining treatments.[5] In addition, the rate of preventable adverse drug events in critical care is nearly twice the error rate in non–critical care settings[6] and has been associated with substantial increases in patients' morbidity and mortality.[7,8] Although system failures,[9] organizational factors,[4,10] deviations from standards of practice and protocols,[11] interruptions and distractions,[11,12] and ineffective communication[11,13] have been implicated as causes of errors, another contributing factor may be the work hours of critical care nurses.[14]

Background

Several recent studies have indicated that long work hours have adverse effects on the performance of healthcare providers. For example, in a survey[15] of 3604 resident physicians, residents who worked more than 80 h/wk reported experiencing more irritability and making more fatigue-related errors than did residents who worked fewer than 80 h/wk. Critical care residents also made significantly more errors in writing orders when their work hours exceeded 16 consecutive hours.[16,17]

Despite concerns expressed by nurses about the ability to provide high-quality care when working overtime and/or extended shifts for many years,[18-20] the relationship between staff nurses' work hours and patients' safety has been examined in only a few empirical studies. Although most investigators[21-23] who evaluated the safety of 12-hour shifts did not find increases in medication errors, Mills et al[20] showed that nurses who worked 12-hour shifts made more errors in grammatical reasoning and chart reviewing than did nurses who worked shorter shifts. Unfortunately, these early studies, conducted soon after the implementation of 12-hour shifts, lacked sufficient power to provide reliable data on increases in medical errors. In addition, typically the number of incident reports completed was used to determine the frequency of errors, an approach that is no longer considered a reliable measure of error rates.[24-26]

Until recently, the only available source of information on nurses' work hours was the National Sample survey.[27] Although in the most recent survey,[27] conducted in 1990, participants were asked about their weekly work hours, they were not asked to indicate the duration of the shifts worked or the frequency of overtime worked. Likewise, the focus of studies[28-30] of nurses who work traditional and rotating shifts has been the nurses' ability to remain awake and vigilant at night and the duration of the nurses' daytime sleep; in these studies, no information was obtained on the duration of the work shifts. Nonetheless, investigators[31,32] have found that nurses who work night and rotating shifts often have difficulty remaining awake on duty. Gold et al[32] suggested that an association might exist between alertness and errors among nurses, because nurses who worked nights and rotating shifts reported making twice as many errors as nurses who worked day and evening shifts. However, the sample in this study[32] included both registered (94%) and licensed practical (6%) nurses, who were asked to recall if they had made any errors in the 6 months preceding the survey. Therefore, the results should be viewed with caution because of the lack of information about the work hours of the participants, the inclusion of participants who were not registered nurses, and the potential for recall bias.

In 2004, findings from a large-scale prospective study[14] of hospital staff nurses indicated that nurses regularly work long hours. All of the 393 nurses surveyed by Rogers et al[14] reported working longer than scheduled (ie, overtime) at least once during the 28-day data-gathering period. In addition, more than 80% of the 5317 shifts examined in the study involved overtime, and 38.7% of the shifts exceeded 12.5 hours. These findings are particularly disturbing because they indicate that the risks of making an error were significantly elevated when nurses worked more than 12.5 consecutive hours (odds ratio 3.29, $P = .001$) or worked longer than scheduled (odds ratio 2.06, $P = .005$).

Furthermore, almost two thirds of the nurse participants reported struggling to stay awake at least once during a 28-day data-gathering period.[33] Although this finding is similar to the results of earlier investigations of nurses who work traditional work shift patterns, in contrast to the findings in earlier studies, episodes of drowsiness and impaired alertness were not confined to the night shift when circadian influences make staying awake more difficult.[14] In fact, 47% of the episodes of drowsiness and 29% of the actual sleep episodes occurred between 6 AM and midnight. Although drowsiness and falling asleep on duty were associated with significantly greater risks of making an error, the rela-

tionship between shift duration and difficulties remaining awake on duty remains unclear.

Drowsiness and impaired alertness are not confined to the night shift, with almost half of these episodes occurring between 6 AM and midnight.

Because they provide the bulk of care to patients with oftentimes unstable conditions, critical care nurses must be alert to subtle changes in patients' conditions, perform accurate clinical assessments, and respond in an expedient manner. Unfortunately, it is not known if the work patterns of critical care nurses are similar to those reported by hospital staff nurses working in other clinical areas,[14] if the risk of errors is greater when critical care nurses work prolonged shifts, or if these nurses have difficulties remaining alert at work. Therefore, the specific aims of this replication study were to describe the work patterns of critical care nurses, determine if an association exists between the occurrence of errors and the hours worked by the nurses, and explore whether or not these work hours have adverse effects on the nurses' vigilance.

Method

Design

The method used for this descriptive, exploratory study was similar to that of the Staff Nurse Fatigue and Patient Safety study.[14] Instead of the membership list of the American Nurses Association, the membership list of the American Association of Critical-Care Nurses was used to recruit a random sample of critical care nurses. The list used consisted of 24 550 names. The random sample was derived by establishing a sampling fraction of one quarter and a second fraction that eliminated every seventh name selected. A random starting point of 14 776 was chosen by using a table of random numbers. As a result, a cover letter introducing the study, a demographic questionnaire, and eligibility criteria were mailed to 5261 critical care nurses, reflecting 21% of the membership.

Of the 2184 nurses who returned their demographic forms to the Survey Research Institute at Temple University in Philadelphia, only 1148 were eligible to participate in this study. The requirements for participation were membership in the American Association of Critical-Care Nurses and full-time employment (ie, 36 h/wk) as a critical care hospital staff nurse providing direct care to patients. Nurses who had participated in the previous study[14] on staff nurses' fatigue and patients' safety and nurses who were employed as clinical specialists/advanced practice nurses, nurse managers, or in other specialized roles such as discharge planning were not eligible for the study.

On the basis of these inclusion and exclusion criteria, eligible nurses were mailed two 14-day logbooks, directions for recording information, and prepaid envelopes to return the completed instruments. A modified Dillman method, combined with remuneration of participants, was used to maximize the response rate. Participants received up to $140 upon receipt of their completed logbooks. The study was approved by the institutional review boards of the University of Pennsylvania and Grand Valley State University.

Instruments

Logbooks were used to collect information about the hours worked (both scheduled and actual hours), the time of day worked, overtime hours, days off, and sleep-wake patterns during a 28-day period. On days worked, the respondents completed all worked-related questions (items 16-32) and questions about difficulties remaining awake while on duty. Space was provided for the nurses to describe any errors or near errors that might have occurred during the work period. This method allowed the respondents to provide information about any perceived deviation from current standards of practice. On days off, the nurses completed questions on sleep-wake patterns, mood, and caffeine intake (items 1-15). Reliability and validity of the logbooks have been previously reported.[11,14]

Data Management and Analysis

Descriptive statistics and frequency tables were used to summarize the data obtained from the demographic questionnaire and the logbooks. Scheduled and actually worked hours per shift were computed and were aggregated over the study period on a weekly and individual nurse level. Shift durations of 8.5 hours and 12.5 hours were categorized as 8-hour and 12-hour shifts to allow for the typical 30-minute transition time between shifts. A work shift was considered an overtime shift if the duration of actual work time exceeded the duration of the scheduled work shift or if the nurse worked on a scheduled day off.

The primary outcome variable was the occurrence or no occurrence of an error during the work shift; the occurrence or no occurrence of an error that was intercepted (a near error) during the work shift was treated as a secondary variable. Univariate analyses with generalized estimating equation logistic regression models were used to examine relationships between risk of mak-

ing an error or near error and shift duration and overtime. The magnitude of the associations was estimated by using odd ratios and the associated 95% CIs. Generalized estimating equations were used to account for nondependence between multiple shifts worked by the same nurse and to provide valid and strong estimates of odds ratios for nonindependence between repeated measures.[34] In addition, the effect of overtime was explored by stratifying work shifts by their expected duration. The same regression analyses were used to evaluate the risk of falling asleep and of episodes of drowsiness at work according to various shift durations. Multivariate procedures were used to examine adjusted relationships between errors and near errors and work hours and overtime while controlling for demographic and other work-related variables such as hospital size and type of unit. Information about patients' characteristics or the number of patients cared for during the work shift was not collected. Significance tests were 2-tailed, with an α level established a priori at .05.

Results

Characteristics of the Sample

A total of 502 nurses provided data for the study, a final response rate of 43.7%. The sample was predominantly white (86.7%) women (92.8%) who were in their mid-forties (mean age 44.3 years, SD 8.0, range 23-66) and were experienced registered nurses (mean years of experience 18.4, SD 8.5). The majority were hired for 12-hour shifts (87.8%) in day-shift positions (54.8%), among hospitals with a capacity of 100 to 300 (41.8%) or more than 300 (49.9%) beds. All of the respondents worked full-time in a CCU, such as a combined intensive care unit (ICU)–CCU (37.8%), a surgical ICU (17.9%), an ICU (15.6%), a CCU (11.3%), a pediatric ICU (6.5%), a medical ICU (6.3%), and a neonatal ICU (1%). Approximately 4% of the respondents reported working in the emergency department or other types of specialized CCUs.

Study participants left work at the end of their scheduled work period just 13% of the time.

An examination of 6017 work shifts indicated that the nurses worked longer than scheduled on a regular basis (Table 1). Although 44% of the work shifts were scheduled for 12 hours or more, the duration of 4053 shifts (67%) exceeded 12 consecutive hours. In addition, 54 respondents (10.8%) worked more than 16 hours at least once during the study; 1 nurse reported working at least 16 consecutive hours on 6 different occasions during the 28-day data collection period. For 30 shifts, nurses were scheduled to work 16 or more consecutive hours, and for 85 shifts, they actually worked 16 hours or more. The longest scheduled work shift was 17 hours (n = 3), and the longest actual work shift was 23 hours and 30 minutes.

Table 1 Critical care nurses' work patterns

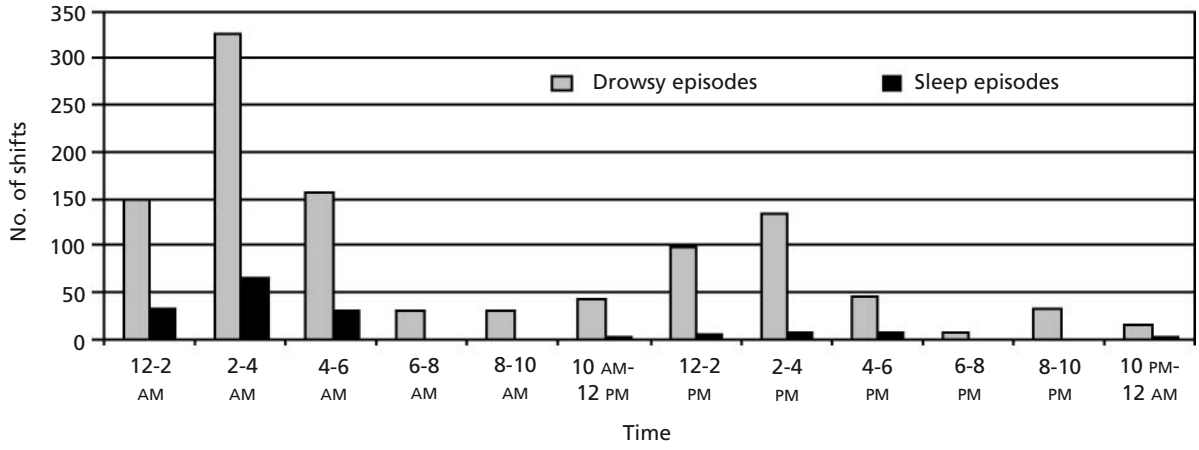
Work pattern	No. of shifts	%
Scheduled work shifts, hours*		
≤8.5	1550	26
>8.5 to <12.5	1798	30
≥12.5	2613	44
Actual work shifts, hours†		
≤8.5	543	9
>8.5 to <12.5	1720	29
≥12.5	3748	62
No. of overtime shifts	5201	86
No. of mandatory overtime shifts	236	4

* Fifty-six shifts with missing data.
† Six shifts with missing data.

For 86% of the shifts, the nurses worked longer than scheduled. As a result, the nurses left work at the end of their scheduled work period for only 808 shifts (13%). On average, the respondents worked almost an additional hour (49 minutes) beyond their scheduled shift (mean 0.82 hours, SD 1.5) regardless of the scheduled duration of the shift. All but 1 of the 502 nurses worked overtime at least once during the 28-day study period, and more than half (60.8%) worked overtime 10 or more times. Although the nurses worked longer than scheduled on 5201 occasions, only 1443 (28%) of these were identified as overtime shifts. Of these shifts, 236 were reported as mandatory overtime shifts (16.4%), and 152 shifts were reported as "coerced" voluntary overtime (10.5%). Nurses worked a mean of 40.8 h/wk (SD 13.4, range 1.66-91.7).

Almost two thirds of the participants struggled to stay awake at least once during the study period, and 20% fell asleep at least once during their work shift.

Almost two thirds (65%) of the nurses (324/502) reported struggling to stay awake at work at least once during the study period, and 20% (64/324) of these nurses reported falling asleep at least once during their work shift. In total, nurses reported they struggled to stay awake during 1203 shifts and actually fell asleep



Frequency of critical care nurses' episodes of drowsiness and of sleep.

during 178 shifts. Furthermore, the occurrences of drowsiness and actual sleep episodes were not confined to nighttime hours; 479 episodes of drowsiness (40%) and 40 episodes of sleep (23%) occurred between 6 AM and midnight (see Figure).

More than one quarter of nurses made at least one error, and more than one third made at least one near error during the study period.

More than one quarter (27%) of the nurses reported making at least 1 error, and more than one third (38%) reported making at least 1 near error during the study period. Although most nurses reported making only 1 error or 1 near error, 1 nurse reported making 7 errors, and 2 other nurses reported making 11 near errors each. As a result, a total of 224 errors and 350 near errors were reported by the respondents. The majority of the errors (56.5%) and the near errors (28.2%) involved administration of medications. Other errors reported were procedural (19.6%), charting (1%), and transcription (0.8%) mistakes. Approximately 21% of the errors and 66% of the near errors could not be categorized because of insufficient information. Table 2 gives examples of the errors and near errors described.

Longer shift durations increased the risk of errors and near errors and were associated with decreased vigilance. In particular, the risk for making an error almost doubled when nurses worked 12.5 or more consecutive hours (odds ratio 1.94, $P = .03$). As shown in Table 3, the likelihood of a nurse catching himself or herself before making an error also increased when nurses worked more than 12.5 consecutive hours (odds ratio 1.57, $P = .05$). Finally, working more than 40 h/wk had a significant effect on both errors (odds ratio 1.46, $P = .01$) and near errors (odds ratio 1.93, $P < .001$).

Table 2 Narrative examples of errors and near errors reported by critical care nurses

Gave digoxin to the wrong patient
Hung dobutamine instead of dopamine
Dosage calculation for dopamine drip; misread mg for mcg; same for Prostin drip
Major med error: Pt received 12500 bolus of heparin; Pt ended up going back to OR
When using rapid infuser, instilled air from blood product bag into central line of patient
Patient just returned from OR, restless, looking for IV access on tubing; different from institution norm; almost put MS into ICP drain

Abbreviations: ICP, intracranial pressure; IV, intravenous; MS, morphine; OR, operating room; Pt, patient.

The risk for making an error almost doubled when nurses worked 12.5 or more consecutive hours.

Nurses who worked more than 12.5 consecutive hours were more likely than those who worked fewer hours to struggle to stay awake at work (odds ratio 1.5, $P = .007$; Table 4). Additionally, the risk of falling asleep at work almost doubled when shifts exceeded 8

Table 3 Association between work hours, errors, and near errors

Work duration, hours*	Shifts, No. (%)	Shifts with at least 1 error, No. (%)	Odds ratio (*P*)	Shifts with at least 1 near error, No. (%)	Odds ratio (*P*)
≤8.5	543 (9)	11 (2)	1.00	27 (5)	1.00
>8.5 to <12.5	1720 (29)	46 (3)	1.42 (.30)	72 (4)	1.13 (.59)
≥12.5	3748 (62)	146 (4)	1.94 (.03)	247 (7)	1.64 (.05)
Total	6011	203	NA	346	NA

*The duration of 6 work shifts could not be classified because of missing data.
Abbreviation: NA, not applicable.

hours (odds ratio 1.9, $P = .04$) and increased even more when shifts exceeded 12 or more consecutive hours (odds ratio 2.4, $P = .01$; Table 5). However, we found no association between decreased vigilance (eg, struggling to stay awake or falling asleep) and increased risk of errors.

Working more than 40 hours per week increased both errors and near errors.

Discussion

Our results support earlier findings that work shifts for hospital staff nurses are often quite prolonged. Like other groups of hospital staff nurses,[14] the nurses in our study rarely left work on time. In fact, only 1 of the 502 respondents reported leaving work at the end of all his or her scheduled shifts during the 28-day data-gathering period. Almost two thirds of the participants worked overtime 10 or more times during the 4-week study period. Even though most shifts were extended a mean of only 49 minutes, this extension usually occurred when nurses had already worked 12.5 consecutive hours, thus clearly exceeding the work hour limits suggested in the recent Institute of Medicine Report.[35]

We found that longer work duration increased the likelihood for errors and near errors among nurses, similar to the likelihood for other hospital staff nurses,[14] physician residents, intensivists, and anesthesiologists.[36-39] Experience in other industries suggests that accident rates increase when workers work 12 hours or more.[40-44] Although data on accidents in healthcare facilities are not available, Landrigan et al[16] found that interns made more errors in writing orders and other types of errors when the interns worked more than 16 consecutive hours.

The duration of the shifts worked by the nurses in our study, particularly those shifts that lasted 16 or more hours, requires that the nurses remain awake for prolonged periods at work. Nevertheless, the importance of remaining awake for long periods is often underappreciated, especially by healthcare professionals. Studies have indicated that remaining awake for 19 consecutive hours slows cognitive function and reaction times to a level comparable to that associated with a blood alcohol concentration of 0.05%.[45,46] Remaining awake for 24 consecutive hours slows reaction times to a level approximating the times in a person with a blood alcohol concentration of 0.1%, a concentration that exceeds the legal standard for operating a motor vehicle.[45]

Remaining awake for 24 hours slows reaction times to a level approximating the times in a person with a blood alcohol level that exceeds the legal standard for operating a motor vehicle.

Our findings also indicate that extended work shifts are associated with significantly decreased levels of alertness (or vigilance). Almost two thirds of the nurses reported struggling to stay awake at work at least once, despite frequent interactions with other healthcare professionals and the typical high activity levels found in most CCUs. However, contrary to our expectations, we did not find an association between decreased vigilance (ie, struggling to stay awake or falling asleep) and increased risk of errors. Several reasons could account for the lack of a relationship between decreased alertness and an increased risk of errors. First, the number of episodes might have been too small to test the association. This explanation seems unlikely because nurses

Table 4 Association between work duration and drowsiness

Work duration, hours*	Shifts No. (%)	Shifts with drowsiness at work, No. (%)	Odds ratio (*P*)
≤8.5	543 (9)	77 (14)	Reference
>8.5 to <12.5	1720 (29)	279 (16)	1.1 (.70)
≥12.5	3748 (62)	847 (23)	1.5 (.007)
Total	6011	1203	NA

*The duration of 6 work shifts could not be classified because of missing data.
Abbreviation: NA, not applicable.

Table 5 Association between work duration and episodes of sleep

Work duration, hours*	Shifts, No. (%)	Shifts with episodes of sleep at work, No. (%)	Odds ratio (*P*)
≤8.5	543 (9)	4 (0.7)	Reference
>8.5 to <12.5	1720 (29)	30 (1.7)	1.9 (.04)
≥12.5	3748 (62)	144 (3.8))	2.4(.01)
Total	6011	178	NA

*The duration of 6 work shifts could not be classified because of missing data.
Abbreviation: NA, not applicable.

reported struggling to stay awake during 1203 shifts, and nurses fell asleep during an additional 178 shifts. Second, the brief naps taken during the shift may have actually improved alertness and thus reduced the number of errors. Nurses who reported struggling to stay awake might have actually fallen asleep, thereby improving their level of alertness for the duration of the shift.[47,48] Even if the nurses did not fall asleep, their drowsiness may not have interfered with the accuracy of their performance, a finding supported by both laboratory and field studies.[49,50]

Contrary to expectations, no association between decreased vigilance and increased risk of errors was found.

Of note, several factors may limit the generalizability of our findings, such as the use of subjective measures of drowsiness, self-report of errors, and the representativeness of the sample. Because persons are often poor judges of their own fatigue or degree of sleepiness, some respondents might not have reported that they struggled to stay awake or might have reported that they struggled to stay awake when they had briefly fallen asleep.[51-53] Second, reliance on self-reporting of errors may have resulted in an underestimation of the number of errors made by the nurses. Studies[10,25,26,54] have indicated that because of fears of disciplinary actions, only the most serious or life-threatening errors are reported. Because we purposefully did not collect any data that could be used to identify the respondents or their employers in order to minimize fears associated with error reporting, we think that the nurses who participated in our study felt at ease disclosing information about errors. Not all errors reported were serious or life threatening, suggesting that nurses are willing to report errors if the nurses' anonymity is protected. The use of standardized categories for error reporting would have allowed the nurses to specify types of errors or near errors. However, the method we used allowed the nurses to disclose information that might have been unattainable with such specificity.

Finally, our results are based on a relatively small sample of nurses, a situation that could limit the generalizability of the findings. However, the nurses in the sample were similar in terms of age, sex, and ethnicity to nurses who had participated in previous probability-based studies on fatigue among hospital staff nurses[14] and critical care nurses[55] and to nurses described in the National Sample of Registered Nurses.[27] The percentages of shifts in which the participants in our study worked beyond their scheduled work hours, the number and types of errors and near errors, and the increased risks associated with working longer than 12.5 hours are also consistent with previous findings.[14]

Although 12-hour shifts are popular, our findings are congruent with other reports[14,35] that recommend minimizing the use of 12-hour shifts or at least limiting nurses' work hours to no more than 12 consecutive hours during a 24-period. As it becomes increasingly clear that long work hours are associated with errors, we must accept the obligation of all healthcare providers and consumers to ensure that patients are safe, beginning with the elimination of extended work shifts.

ACKNOWLEDGMENTS

Financial support for this study provided by the Agency for Healthcare Research and Quality (grant R01 HS11963-01), the American Association of Critical-Care Nurses, and an American Nurses Foundation Julia Hardy Scholar Award (L. D. Scott).

Commentary by Mary Jo Grap (see shaded boxes).

REFERENCES

1. Leape LL. The preventability of medical injury. In: Bogner MS, ed. *Human Error in Medicine.* Hillsdale, NJ: Lawrence Erlbaum Associates; 1994:13-25.
2. Kohn L, Corrigan J, Donaldson M, eds. *To Err Is Human: Building a Safer*

Health System. Washington, DC: National Academies Press; 1999.
3. Berenholtz SM, Dorman T, Pronovost PJ. Improving quality and safety in the ICU. *Contemp Crit Care.* 2003;1:1-8.
4. Tissot E, Cornette C, Demoly P, Jacquet M, Barale F, Capellier G. Medication errors at the administration stage in an intensive care unit. *Intensive Care Med.* 1999;25:353-359.
5. Osmon S, Harris C, Dunagan WC, Prentice D, Fraser VJ, Kollef MH. Reporting of medical errors: an intensive care unit experience. *Crit Care Med.* 2004;32:727-733.
6. Cullen DJ, Sweitzer BJ, Bates DW, Burdick E, Edmondson A, Leape LL. Preventable adverse drug events in hospitalized patients: a comparative study of intensive care and general care units. *Crit Care Med.* 1997;25: 1289-1297.
7. Bates DW, Cullen DJ, Laird N, et al. Incidence of adverse drug events and potential adverse drug events: implications for preventions. ADE Prevention Study Group. *JAMA.* 1995;274:29-34.
8. Karch FE, Lasagna L. Adverse drug reactions: a critical review. *JAMA.* 1973;234:1236-1241.
9. van den Bemt PMLA, Fijn R, Van Der Voort PHJ, Goosen AA, Toine CG, Brouwers JRBJ. Frequency and determinants of drug administration in the intensive care unit. *Crit Care Med.* 2002;30:846-850.
10. Meurier CE. Understanding the nature of errors in nursing: using a model to analyse critical incident reports of errors which had resulted in an adverse or potentially adverse event. *J Adv Nurs.* 2000;32:202-207.
11. Balas MC, Scott LD, Rogers AE. The prevalence and nature of errors and near errors reported by hospital staff nurses. *Appl Nurs Res.* 2004;17:224-230.
12. Ebright PR, Patterson ES, Chalko BA, Render ML. Understanding the complexity of registered nurse work in acute care settings. *J Nurs Adm.* 2003;33:630-638.
13. Donchin Y, Gopher D, Olin M, et al. A look into the nature and causes of human errors in the intensive care unit. *Crit Care Med.* 1995;23:294-300.
14. Rogers AE, Hwang W-T, Scott LD, Aiken LH, Dinges DF. The working hours of hospital staff nurses and patient safety. *Health Aff (Millwood).* 2004;23:202-212.
15. Baldwin DC, Daugherty SR, Tsai R, Scotti M. A national survey of residents' self-reported work hours: thinking beyond specialty. *Acad Med.* 2003;78:1154-1164.
16. Landrigan CP, Rothschild JM, Cronin JW, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med.* 2004;351:1838-1848.
17. Lockley SW, Cronin JW, Evans EE, et al. Effect of reducing interns' weekly work hours on sleep and attentional failures. *N Engl J Med.* 2004;351: 1829-1837.
18. Hutto CB, Davis LL. 12-Hour shifts: panacea or problem? *Nurs Manage.* August 1989;20:56A, 56D, 56F, passim.
19. Ugrovics A, Wright J. 12-Hour shifts: does fatigue undermine ICU nursing judgements. *Nurs Manage.* January 1990;21:64A, 64D, 64F-64G.
20. Mills ME, Arnold B, Wood CM. Core 12: a controlled study of the impact of 12-hour scheduling. *Nurs Res.* 1983;32:356-361.
21. Eaton P, Gottselig S. Effects of longer hours, shorter week for intensive care nurses. *Dimens Health Serv.* 1980;57:25-27.
22. Price C, Niemeier DF, Healey S. The 12-hour shift: is it viable? *Nurs Outlook.* July-August 1984;32:193.
23. Girotti MJ, Garrick C, Tierney MG, Chesnick K, Brown SJL. Medication administration errors in an adult intensive care unit. *Heart Lung.* 1987; 16:449-453.
24. Walters JA. Nurses' perceptions of reportable medication errors and factors that contribute to their occurrence. *Appl Nurs Res.* 1992;5:86-88.
25. Wakefield DS, Wakefield BJ, Uden-Holman T, Blegen MA. Perceived barriers in reporting medication administration errors. *Best Pract Benchmarking Healthc.* 1996;1:191-197.
26. Leape LL. Out of the darkness: hospitals begin to take mistakes seriously. *Health Syst Rev.* November-December 1996;29:21-24.
27. Spratley E, Johnson A, Sochalski J, Fritz J, Spenser W. *The Registered Nurse Population: National Sample of Registered Nurses—March 2000.* Washington, DC: US Dept of Health and Human Services, Health Resources and Services Administration; 2001.
28. Totterdell P, Spelten E, Barton J, Smith L, Folkard S. On-shift and daily variations in self-report and performance measures in rotating-shift and permanent night nurses. *Work Stress.* 1995;9:187-197.
29. Takahashi M, Arito H, Fukudo H. Nurses' workload associated with 16-h night shifts: effects of a nap taken during the shift. *Psychiatry Clin Neurosci.* 1999;53:223-225.
30. Borges FN, Fischer FM. Twelve-hour night shifts of healthcare workers: a risk to the patients? *Chronobiol Int.* 2003;20:351-360.
31. Lee KA. Self-reported sleep disturbances in employed women. *Sleep.* 1992;15:493-498.
32. Gold DR, Rogacz S, Bock N, et al. Rotating shift work, sleep, and accidents related to sleepiness in hospital nurses. *Am J Public Health.* 1992;82: 1011-1014.
33. Rogers AE. Hospital staff nurses regularly report fighting to stay awake on duty. *Sleep.* 2003;26(suppl):A424-A425.
34. Liang K-Y, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika.* 1986;73:13-22.
35. Institute of Medicine. *Keeping Patients Safe: Transforming the Work Environment of Nurses.* Washington, DC: National Academies Press; 2004.
36. Flaatten H, Hevroy O. Errors in the intensive care unit (ICU). *Acta Anaesthesiol Scand.* 1999;43:614-617.
37. Runciman WB, Sellen A, Webb RK, et al. The Australian Incident Monitoring Study: errors, incidents and accidents in anaesthetic practice. *Anaesth Intensive Care.* 1993;21:506-519.
38. Baldwin DC, Daugherty SR. Sleep deprivation and fatigue in residency training: results of a national survey of first- and second-year residents. *Sleep.* 2004;27:217-223.
39. Gaba DM, Howard SK. Fatigue among clinicians and the safety of patients. *N Engl J Med.* 2002;347:1249-1255.
40. Rosa RR. Extended workshifts and excessive fatigue. *J Sleep Res.* 1995; 4(suppl 2):51-56.
41. Hanecke K, Tiedemann S, Nachreiner F, Grzech-Sukalo H. Accident risk as a function of hour at work and time of day as determined from accident data and exposure models for the German working population. *Scand J Work Environ Health.* 1998;24(suppl 3):43-48.
42. Akerstedt T. Work injuries and time of day: national data [abstract]. Presented at: Consensus Development Symposium entitled "Work Hours, Sleepiness, and Accidents," September 8-10, 1994; Stockholm, Sweden.
43. National Transportation Safety Board. *A Review of Flightcrew-Involved Major Accidents of US Air Carriers, 1978 Through 1990.* Washington DC: National Transportation Safety Board; 1994. NTSB publication SS-94-01/PB94-917001.
44. Hamelin P. Lorry drivers' time habits and their involvement in traffic accidents. *Ergonomics.* 1987;30:1323-1333.
45. Dawson D, Reid K. Fatigue, alcohol, and performance impairment. *Nature.* 1997;388:235.
46. Williamson AM, Feyer AM. Moderate sleep deprivation produces impairments to cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. *Occup Environ Med.* 2000;57:649-655.
47. Hayashi M, Chikazawa Y, Hori T. Short naps versus short rest: recuperative effects during VDT work. *Ergonomics.* 2004;47:1549-1560.
48. Neri DF, Oyung RL, Colletti LM, Mallis MM, Tam PY, Dinges DF. Controlled breaks as a fatigue countermeasure on the flight deck. *Aviat Space Environ Med.* 2002;73:654-664.
49. Frey DJ, Badia P, Wright KP Jr. Inter- and intra-individual variability in performance near the circadian nadir during sleep deprivation. *J Sleep Res.* 2004;13:305-315.
50. Dinges DF, Kribb NB. Performing while sleepy: effects of experimentally induced sleepiness. In: Monk TH, ed. *Sleep, Sleepiness, and Performance.* New York, NY: John Wiley & Sons; 1991:97-128.
51. Dinges DF, Graeber RC, Rosekind MR, Samuel A, Wegman HM. *Principles and Guidelines for Duty and Rest Scheduling in Commercial Aviation.* Moffett Field, Calif: National Aeronautics and Space Administration; 1996. NASA Technical Memorandum 110404.
52. Howard SK, Gaba DM, Rosekind MR. Subjective assessment of sleepiness and sleep onset perceptions of resident anesthesiologists [abstract]. *Anesthesiology.* 1995;83:A1009.
53. Howard SK, Gaba DM, Rosekind MR. Evaluation of daytime sleepiness in resident anesthesiologists [abstract]. *Anesthesiology.* 1995;83:A1007.
54. Osborne J, Blais K, Hayes JS. Nurses' perceptions: when is it a medication error? *J Nurs Adm.* April 1999;29:33-38.
55. Ruggiero JS. Correlates of fatigue in critical care nurses. *Res Nurs Health.* 2003;26:434-444.