Extended Work Duration and the Risk of Self-reported Percutaneous Injuries in Interns

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EXPOSURES TO CONTAMINATED fluids from percutaneous needlesticks and laceration injuries are serious hazards associated with postgraduate medical training. These injuries may result in the transmission of blood-borne pathogens, including hepatitis and human immunodeficiency viruses, and thus have significant occupational health implications.[1] Factors contributing to the occurrence of these percutaneous injuries (PIs) in physicians have not been well studied. We hypothesized that sleep deprivation may play a role in these incidents.[2]

Polysomnographic recordings of interns (residents in their first postgraduate year) have revealed that sleep deprivation induced by repeated extended-duration ($\geq$24 hours) work shifts doubled the risk of attentional failures during critical care unit rotations.[3,4] Among interns scheduled to

See also pp 1049, 1063, 1071, and 1132.

Context In their first year of postgraduate training, interns commonly work shifts that are longer than 24 hours. Extended-duration work shifts are associated with increased risks of automobile crash, particularly during a commute from work. Interns may be at risk for other occupation-related injuries.

Objective To assess the relationship between extended work duration and rates of percutaneous injuries in a diverse population of interns in the United States.

Design, Setting, and Participants National prospective cohort study of 2737 of the estimated 18 447 interns in US postgraduate residency programs from July 2002 through May 2003. Each month, comprehensive Web-based surveys that asked about work schedules and the occurrence of percutaneous injuries in the previous month were sent to all participants. Case-crossover within-subjects analyses were performed.

Main Outcome Measures Comparisons of rates of percutaneous injuries during day work (6:30 AM to 5:30 PM) after working overnight (extended work) vs day work that was not preceded by working overnight (nonextended work). We also compared injuries during the nighttime (11:30 PM to 7:30 AM) vs the daytime (7:30 AM to 3:30 PM).

Results From a total of 17 003 monthly surveys, 498 percutaneous injuries were reported (0.029/intern-month). In 448 injuries, at least 1 contributing factor was reported. Lapse in concentration and fatigue were the 2 most commonly reported contributing factors (64% and 31% of injuries, respectively). Percutaneous injuries were more frequent during extended work compared with nonextended work (1.31/1000 opportunities vs 0.76/1000 opportunities, respectively; odds ratio [OR], 1.61; 95% confidence interval [CI], 1.46-1.78). Extended work injuries occurred after a mean of 29.1 consecutive work hours; nonextended work injuries occurred after a mean of 6.1 consecutive work hours. Injuries were more frequent during the nighttime than during the daytime (1.48/1000 opportunities vs 0.70/1000 opportunities, respectively; OR, 2.04; 95% CI, 1.98-2.11).

Conclusion Extended work duration and night work were associated with an increased risk of percutaneous injuries in this study population of physicians during their first year of clinical training.

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work every third night, extended-duration work shifts account for half of all work shifts and more than 80% of work hours. Such intense work schedules result in chronic sleep deprivation, with superimposed episodes of acute sleep deprivation when interns have overnight call, because they sleep an average of only 2.6 hours during these extended work shifts and often obtain no sleep at all.[5] This degree of sleep deprivation leads to decrements in vigilance, cognitive performance, and motor function.[6-8] Interns have double the rate of motor vehicle crashes while driving after extended work shifts compared with nonextended shifts.[5] However, the relationship between extended work duration (and night work in general) and rates of PIs at work has not been well studied. We hypothesized that rates of injuries would increase with consecutive work hours and that rates of injuries would be greater during night-time compared with daytime hours.

The purposes of this study were to describe the epidemiology and contributing factors for PIs in interns and to assess the relationship of PIs to extended-duration overnight work. We conducted a national prospective cohort study by using Web-based surveys of self-reported percutaneous exposures in residents in their first postgraduate year who were enrolled in US residency programs from 2002 to 2003.

METHODS

In April 2002, e-mail advertisements about the study were sent by the Association of American Medical Colleges to the 18 447 medical students who had been matched by the National Residency Matching Program (NRMP). In the spring of 2002, we also sent e-mail advertisements to all known e-mail addresses of graduating fourth-year medical students of US programs.[5] The advertisements announced: "We would like to invite you to participate in an exciting study of work hours and health. This is a national survey designed to examine the work schedules of students, dentists, and physicians, and see how these impact health and

safety." These e-mails directed potential participants to a secure Web site that provided detailed information about the study and served as the electronic informed consent. The study purpose was worded like the invitation; all participants were entered into a cash lottery.

In June 2002, password-coded links were sent via e-mail to interns who volunteered to participate in the study. These links directed them to a secure Web site to complete a baseline survey that collected detailed background data, including type of residency program and demographic information; interns who completed this survey were the study participants. Starting in July 2002 and on the 28th of each month thereafter, e-mails were sent to the participants, directing them to a secure Web site to complete a monthly survey. A maximum of 3 reminders was sent each month, and the survey was available on the Web site until the 27th of the next month. A participant could answer each monthly survey only once.

The monthly survey contained detailed questions about work hours, sleep, work rotation during the month (ie, hospital ward, intensive care unit [ICU], vacation, outpatient, hospital consult), days off, and number of extended-duration work shifts (defined as at least 24 continuous hours at work). Each month, interns were also asked the following question: "In the month of ____, did you personally have an occupational exposure to potentially contaminated blood or other body fluid?"

The Web sites were hosted and maintained by Pearson NCS, Inc (Eagen, Minn). Data were electronically transmitted weekly through secure means from Pearson NCS to the Brigham and Women's Hospital. All demographic and potentially identifiable data were stored separately from the main database. A Certificate of Confidentiality was issued by the Centers for Disease Control and Prevention. Because the Agency for Healthcare Research and Quality also supported this research, data confidentiality is protected by federal statute (Public Health Service Act 42 USC). The

Brigham and Women's Hospital/Partners Health Care System Human Research Committee approved the procedures for the protocol.

Documentation of PIs

All respondents who reported an occupational exposure to potentially contaminated blood or body fluid were directed to a detailed supplementary survey that elicited comprehensive information about the incident, including the type of exposure (ie, hollow needlestick, solid sharp stick, splash, bite, other laceration, or other), location of the exposure (ie, preoperative holding area, operating room, procedure room, outpatient clinic, emergency department, labor and delivery, radiology, patient room–non-ICU, patient room–ICU, other), time of exposure, whether the exposure was reported to the occupational health service, and the number of hours at work at the time of exposure. Interns were also asked which of the following contributed to the exposure: leaving a sharp exposed, passing a sharp to another, recapping needle, splashing fluid, patient movement, inadequate lighting, fatigue in you, lapse in concentration in you. Multiple responses were permitted.

To classify the exposure as percutaneous, the event had to be caused by a needlestick or cut with another sharp instrument (eg, scalpel or broken glass). We included only incidents in which the intern documented the location and time of the exposure in the follow-up questions.

Work-Hours Validation

As previously reported,[3] a randomly selected subset of the interns (n=192 [7%]) completed daily work diaries, with reported work hours and extended-duration work shifts validated in a separate study with continuous work-hour monitoring by direct observation and polysomnographic recordings. Individuals completing the work diaries recorded daily work hours for at least 21 of 28 days and completed the corresponding monthly survey. The mean (SD) hours reported on the monthly survey (249.8 [75.3] hours) vs actual hours

worked, as indicated by daily work diaries (244.0 [69.3] hours), were strongly correlated (Pearson $r=0.76$; $P<.001$). In a subset of 40 interns, the mean number of extended-duration work shifts reported on the monthly survey (3.6 [3.3]) was highly correlated with the number of extended-duration work shifts reported in the daily diaries (3.5 [2.8]) ($r=0.94$; $P<.001$).

Statistical Analysis

The monthly rate of PI was calculated by dividing the number of PIs by the time at risk (total number of monthly surveys returned). Rates were calculated for interns in internal medicine, surgery, obstetrics and gynecology, pathology, family medicine, psychiatry, pediatrics, and emergency medicine residency programs. Rates of PI in the various specialties were compared with χ^2 contingency tables to determine whether a significant difference from the mean rate existed. A similar analysis was done to assess rates of reporting to the occupational health service and how they varied with specialty.

Assessing Risk Associated With Extended Work Duration. We determined whether the risks of PI increased in the latter part of an extended-duration work shift (ie, after 20 or more hours at work: extended-work PI) compared with the rate in the first 12 hours of work (nonextended-work PI). To control for time of day and circadian influences, we included only PIs that occurred during what would be considered the regular workday (between 6:30 AM and 5:30 PM). Extended-work PIs represent injuries that occurred during day work after an intern had been working overnight in the hospital. The number of opportunities for extended-work PI to occur in the month was estimated as the number of reported extended-duration work shifts in the month. The number of opportunities for nonextended PIs was estimated as the number of assessed days in the month (28) minus the number of reported days off and extended shifts in that month.

Only months in which the mean reported extended-duration work-shift length was at least 32 hours were included for this analysis because we wanted to study only months during which the interns remained on duty for a substantial interval after working overnight. Months in which interns reported 3 or more weeks of night float activity, worked fewer than 150 hours, worked fewer than 7 days, or for which the reported number of hours worked in the hospital was incongruent were excluded from analysis (see next section).

Assessing Nighttime vs Daytime Risks. To compare the risks of PI between the nighttime (11:30 PM to 7:30 AM) and the daytime (7:30 AM to 3:30 PM), we calculated the number of daytime and nighttime PIs. These intervals were chosen because we believed that nearly all interns not on a day off would be at work during these daytime hours, whereas only interns who were on call would be at work during these nighttime hours. The number of opportunities for daytime PIs in the month was estimated as the number of assessed days in the month (28) minus the number of reported days off in that month. The number of opportunities for nighttime PIs was estimated as the number of self-reported extended-duration work shifts in the month because most interns work at night only when on an extended-duration shift. For each participant, the total numbers and opportunities for PIs were summed for all the monthly surveys returned by the intern.

For this analysis, we included only months in which the intern reported working at least 150 hours (an average of 35 hours per week) and at least 7 days in the month. Months that did not meet these criteria were excluded, assuming that they would represent months including vacation or clinical electives with few extended-duration work shifts and medical procedures (including such months could have exaggerated the differences between nighttime and daytime rates). Months in which interns reported 3 or more weeks of night-float activity were excluded. However, a secondary analysis without these exclusions did not change the results significantly. Months in which the reported number of extended-duration work shifts and the reported number of hours worked in the hospital were incongruent (number of reported work hours <24 times the number of extended-duration work shifts) were also excluded from analysis (203 [1.2%] months).

To assess the relationships between PI risk and either time of day or duration of work, we used a within-person case-crossover design in which each participant acted as a separate stratum, and a combined odds ratio (OR) was generated using a Mantel-Haenszel test.[9,10] Because each participant acts as his or her own control, the case-crossover study design eliminates the need to account for potential between-subject confounders such as differences in age, sex, or medical specialty. Similar analyses were performed after classification of the injuries by location (ie, in the ICU, labor and delivery room, and operating room). For ICU incidents, only months in which interns reported 3 or more weeks of ICU activity were used in the analysis. To assess the possible effects of reporting bias, sensitivity analyses that included data from interns who completed the baseline and all 11 monthly surveys were reported.

We also assessed whether nighttime PIs were more likely to be associated with fatigue or a lapse in concentration than daytime PIs and whether extended-work PIs were more likely to be associated with these 2 factors than non–extended-work PIs. Proportions were compared with a χ^2 test.

In post hoc analyses, we compared results between the first 5 months and last 5 months of the internship year for participants completing all surveys and also by subgroups of sex and age.

SAS version 8.2 (SAS Institute Inc, Cary, NC) was used to perform the statistical analyses. Significance was defined at the .05 level (2-sided tests).

RESULTS

Of the 18 447 medical students matching in the NRMP, 3429 (19%) responded to the initial e-mail announce-

Table 1. Locations and Rates of Percutaneous Injuries by Residency Program

Type of Residency	No. of Intern-Months	No. of Percutaneous Injuries	Rate (95% CI) per Intern-Month*	Reported to OH, % (95% CI)	Location, No.						
					ICU	Procedure Room	OR	L&D	Non-ICU	ED	Other Locations
All	17003	498	0.0293 (0.0268-0.0318)	58 (54-62)	69	20	168	69	59	72	41
Internal medicine	3995	57	0.0143 (0.0106-0.0179)	46 (33-59)	21	1	1	0	23	7	4
Surgery†	1730	124	0.0717 (0.0595-0.0838)	50 (41-59)	16	3	80	0	8	10	7
Family medicine	2008	51	0.0254 (0.0185-0.0323)	40 (27-53)	4	3	12	21	4	5	2
Emergency medicine	1007	40	0.0397 (0.0277-0.0518)	50 (35-65)	10	0	3	2	0	23	2
Pediatrics	2159	24	0.0111 (0.0067-0.0155)	37.5 (18-57)	2	7	0	0	6	7	2
Psychiatry	658	1	0.0015 (0-0.0045)	100 (N/A)	0	0	0	0	1	0	0
Pathology	283	15	0.0530 (0.0269-0.0791)	67 (43-91)	0	0	0	0	0	0	15‡
Obstetrics/gynecology	964	94	0.0975 (0.0788-0.1160)	68 (59-77)	3	3	50	36	1	1	0
Other specialties	4199	92	0.0219 (0.0175-0.0263)	84 (77-91)	13	3	22	10	16	19	9

Abbreviations: CI, confidence interval; ED, emergency department; ICU, intensive care unit; L&D, labor and delivery room; N/A, not applicable; Non-ICU, hospital ward not including the ICU; OH, occupational health department; OR, operating room.
*Rates of percutaneous injuries for interns in surgery, obstetrics/gynecology, and pathology programs were significantly greater than the mean of all residency programs; the rates of percutaneous injuries for interns in internal medicine, pediatrics, and psychiatry programs were significantly lower than the mean (*P*<.001).
†Includes general, neurologic, orthopedic, and urologic surgery.
‡For these injuries, 8 occurred in the pathology laboratory, 3 in the autopsy suite, 2 in the frozen section room, 1 in the morgue, and 1 in the procedure room.

Table 2. Factors Reported by Interns to Have Contributed to the Percutaneous Injuries (N = 448)*

Contributing Factor	No. (%) Reporting
Lapse in concentration in you	286 (63.8)
Fatigue in you	139 (31.0)
Inadequate lighting	31 (6.9)
Patient movement	74 (16.5)
Leaving a sharp exposed	81 (18.1)
Passing a sharp to another	25 (5.6)
Recapping needle	23 (5.1)
Splashing fluid	0

*Based on 448 percutaneous injuries in which at least 1 contributing factor was reported. More than 1 factor could be associated with a single incident. Phrases are as stated in the survey.

ment and electronically volunteered to be enrolled in the study. Of these, 2737 (80%) completed the baseline survey and composed the study cohort. The mean (SD) number of surveys submitted each month was 1548 (376). The mean number of surveys completed by each participant was 7.2 (4.0). Of the participants, 682 (25%) completed all 12 surveys (baseline and 11 monthly surveys). We collected a total of 19 740 surveys (2737 baseline surveys and 17 003 monthly surveys) for a total of 1417 person-years of observation.

The study cohort was 53% women and 47% men, with a mean (SD) age of 28.0 (3.9) years (range, 21-51 years). Of the participants, 2326 (85%) graduated from US medical schools in 43 states and 411 [15%] graduated from

foreign medical schools. Compared with all applicants in the Electronic Residency Application Service database, female resident percentage was greater in our study cohort (53% vs 41%), and the mean age of our interns was lower (28.0 years vs 30.2 years) (data from the Electronic Residency Application Service; P. Jolly, written communication, July 2006). The distribution of medical specialties of the survey participants (79% medical specialties, 11% surgical, 10% other/not specified) differed somewhat from the distribution of specialties matched through the NRMP (88% medical specialties, 12% surgical).[11]

Frequency and Characteristics of PIs

During the study interval, 1551 exposures to contaminated body fluid were reported; 1051 of them were not considered PIs. Most of the non-PI incidents (916) were splashes; exposures to contaminated respiratory secretions, bloody vomitus, and bites were also reported. Few of these non-PI incidents (7.5%) were reported to the occupational health service.

Five hundred PIs were therefore identified. Two of these incidents lacked documentation about time or location of the event and were excluded from further analysis. Of the remaining 498 documented PIs, 294 were due to lac-

erations from a sharp instrument (such as a scalpel), and 204 were due to a needlestick (hollow bore or suture). Rates and locations of exposures by type of residency are shown in **TABLE 1**. Overall, the rate of PIs was 0.0293 per intern-month. However, rates of injuries varied significantly, depending on type of residency (P<.001). Obstetrics/gynecology, pathology, and surgery interns had a rate of PI significantly greater than the mean rate of the 8 specialties, with incidence rates of 0.0975, 0.0530, and 0.0717 injuries per intern-month, respectively. Psychiatry, internal medicine, and pediatrics interns had rates significantly lower than the mean rate. Overall, 58% of PI incidents were reported to the occupational health department, with a significant difference according to specialty (P<.01). Interns in obstetrics/gynecology had a significantly greater proportion of injuries that were reported to the occupational health department, compared with the mean rate, whereas family medicine interns were significantly less likely to report their PIs. The other specialties' PIs were not significantly different from the mean rate.

In 448 (90%) of the 498 injuries, 1 or more factors contributing to the incident were reported (**TABLE 2**). The most commonly reported contributing factor was a lapse in concentration

(286 [63.8%] of the incidents), followed by fatigue (139 [31.0%] of the incidents). The presence of an exposed sharp (18.1%) and an unexpected patient movement (16.5%) were also commonly reported contributing factors.

Risk Associated With Extended Work Duration

The results of the case-crossover within-subjects analysis for extended-work PI vs non–extended-work PI are shown in TABLE 3. Extended-work PI, which followed overnight work, occurred on average at 12:10 PM (95% confidence interval [CI], 11:11 AM to 1:09 PM) after a mean of 29.1 consecutive hours (95% CI, 27.8-30.4 hours) at work. Non–extended-work PIs, which were not preceded by overnight work, occurred on average at the same time of day (12:07 PM; 95% CI, 11:20 AM to 12:53 PM) after a mean of 6.1 consecutive hours (95% CI, 5.4-6.9 hours) at work.

The rate of extended-work PI (1.31 [95% CI, 0.88-1.75] per 1000 opportunities) was significantly greater than the rate of non–extended-work PI (0.76 [95% CI, 0.54-0.98] per 1000 opportunities) (OR, 1.61; 95% CI, 1.46-1.78). The magnitude of this effect was similar regardless of location.

Extended-work PIs were significantly more likely to be associated with fatigue as a contributing factor. Of the 32 extended-work PIs for which at least 1 contributing factor was reported, 14 (44%) cited fatigue as a factor. Of the 38 non–extended-work PIs for which at least 1 contributing factor was reported, fatigue was cited in 7 (18%) ($P=.02$). The proportion of PIs associated with lapses in concentration was not significantly different for extended-work PI vs non–extended-work PI (24 [75%] vs 22 [58%], respectively; $P=.13$).

Risk Associated With Nighttime Work

The results of the analysis for nighttime vs daytime injuries are shown in TABLE 4. Daytime PIs were preceded by

Table 3. Percutaneous Injuries During Daytime Hours (6:30 AM to 5:30 PM) for Nonextended vs Extended Work*

		Nonextended Periods			Extended Periods			Injuries During Extended vs Nonextended Periods, OR (95% CI)
	No. of Intern-Months	No. of Opportunities	No. of Injuries	Rate (95% CI) per 1000 Opportunities	No. of Opportunities	No. of Injuries	Rate (95% CI) per 1000 Opportunities	
All percutaneous injuries	3660	60763	46	0.757 (0.538-0.976)	26667	35	1.310 (0.878-1.750)	1.61 (1.46-1.78)
Injuries reported to OH	3660	60763	21	0.346 (0.198-0.493)	26667	17	0.637 (0.335-0.940)	1.83 (1.48-2.28)
Injuries in the ICU	536	8764	4	0.456 (0.009-0.904)	4974	4	0.804 (0.016-1.590)	1.87† (0.69-5.04)
Injuries in the operating room or labor and delivery	748	12211	25	2.05 (1.25-2.85)	5989	22	3.67 (2.14-5.21)	1.77‡ (1.49-2.09)
Injuries in the ICU, non-ICU, or ED	3660	60763	13	0.214 (0.098-0.330)	26667	12	0.450 (0.195-0.705)	2.17 (1.56-3.00)

Abbreviations: CI, confidence interval; ED, emergency department; ICU, intensive care unit; Non-ICU, hospital ward not including the ICU; OH, occupational health department; OR, odds ratio.
*Includes only months in which mean durations of extended shifts were 32 or more hours, and interns worked at least 150 hours and at least 7 days. Extended work defined as 20 or more consecutive hours; nonextended work defined as 12 or fewer consecutive hours.
†Only interns reporting 3 or more ICU weeks that month.
‡Only obstetrics/gynecology or surgery interns.

Table 4. Percutaneous Injuries Occurring During the Daytime (7:30 AM to 3:30 PM) vs Nighttime (11:30 PM to 7:30 AM)*

		Daytime			Nighttime			Events Occurring During Nighttime vs Daytime, OR (95% CI)
	No. of Intern-Months	No. of Opportunities	No. of Events	Rate (95% CI) per 1000 Opportunities	No. of Opportunities	No. of Events	Rate (95% CI) per 1000 Opportunities	
All percutaneous injuries	14290	318515	223	0.700 (0.608-0.792)	63309	94	1.48 (1.19-1.79)	2.04 (1.98-2.11)
Injuries reported to OH	14290	318515	101	0.317 (0.255-0.379)	63309	32	0.505 (0.330-0.681)	1.59 (1.46-1.73)
Injuries in the ICU	1430	33680	14	0.416 (0.198-0.633)	9824	14	1.42 (0.70-2.17)	3.11† (2.32-4.19)
Injuries in the operating room	2348	53508	93	1.73 (1.39-2.09)	13262	11	0.829 (0.339-1.319)	0.488‡ (0.401-0.594)
Injuries in the ICU, non-ICU, or ED (excludes pathology, labor, surgery, procedure room)	14290	318515	56	0.176 (0.130-0.222)	63309	56	0.885 (0.653-1.120)	5.13 (4.77-5.54)
Injuries in the labor and delivery room	812	18091	12	0.663 (0.288-1.04)	3934	12	3.05 (1.33-4.77)	4.39§ (3.17-6.07)

Abbreviations: CI, confidence interval; ED, emergency department; ICU, intensive care unit; Non-ICU, hospital ward not including the ICU; OH, occupational health department; OR, odds ratio.
*Includes only months in which interns worked at least 150 hours and at least 7 days. The number of daytime opportunities per month was defined as the number of days in the month minus the number of days off in the month. The number of nighttime opportunities per month was defined as the number of self-reported extended-duration shifts in the month.
†Only interns reporting 3 or more ICU weeks that month.
‡Only obstetrics/gynecology or surgery interns.
§Only obstetrics/gynecology interns.

a mean (SD) of 10.0 (9.6) consecutive work hours; nighttime PIs were preceded by a mean of 17.5 (6.7) consecutive work hours. The rate of PI was twice as high during the nighttime (1.48 [95% CI, 1.19-1.79] per 1000 opportunities) than during the daytime (0.70 [95% CI, 0.61-0.79] per 1000 opportunities) (OR, 2.04; 95% CI, 1.98-2.11). Rates were greater during the night vs the daytime for PIs in all locations other than the operating room.

Percutaneous injuries at night were significantly more likely to be associated with fatigue as a contributing factor. Of the 91 nighttime PIs for which at least 1 contributing factor was reported, 51 (56%) cited fatigue as a contributing factor. Of the 191 PIs in the daytime for which at least 1 contributing factor was reported, 47 (25%) cited fatigue as a factor ($P<.001$). In contrast, the proportion of PIs for which a lapse in concentration was reported as a contributing factor was not significantly different during the night compared with the daytime (57 [62%] vs 120 [63%], respectively; $P=.98$).

Sensitivity Analyses and Post Hoc Analyses

To address the issue of reporting bias (the potential that some participants might have completed a monthly survey only during months in which a reportable event occurred), the preceding analyses were repeated using only participants who completed all 12 surveys (baseline and 11 monthly surveys). The ORs for both extended vs nonextended work hours (OR, 1.52; 95% CI, 1.11-2.07) and nighttime vs daytime (OR, 2.20; 95% CI, 2.05-2.37) were significantly greater than 1 and similar in magnitude to the results with all participants included.

Rates of PI in the first 5 months of internship were significantly greater than in the last 5 months (0.036 vs 0.024 per intern-month; $P=.005$). However, the ORs for PI risk related to extended work duration and to night work were not different between these 2 intervals. Statistically significant positive associations between PI and both extended work duration and nighttime work were found in subgroup analyses of men, women, interns 28 years of age or younger, and interns older than 28 years.

COMMENT

In this study, interns commonly reported PIs, with an increased risk associated with extended work duration and nighttime work. Interns in surgery and obstetrics/gynecology residency programs had the greatest risk, with rates of 0.07 and 0.10 incidents per intern-month, respectively, presumably because they perform more invasive procedures than other specialties.

Fatigue was more commonly reported as a contributing factor to PIs that occurred after extended work than those that occurred after nonextended work. The association of these injuries with extended work duration is likely due to the adverse cognitive effects of the sleep deprivation associated with such extended work, consistent with experimental data.[12] Twenty-four hours of continuous wakefulness causes an impairment of cognitive performance comparable to that induced by a blood alcohol concentration of 100 mg/dL, a level consistent with legal intoxication in most states.[13] Residents working frequent extended-duration shifts committed 40% more errors during simulated driving, with an impairment of their performance comparable to that induced in the same trainees by alcohol consumption that raised their blood alcohol concentration to 40 to 50 mg/dL.[14] Substantial decrements in motor performance and a doubling of errors on a laparoscopic surgery simulator task were found in surgical trainees after a 17-hour night work shift without sleep compared with performance after a non–sleep-deprived night.[7]

In our study, rates of PI were much greater during nighttime hours than during the daytime in all locations other than the operating room, consistent with data from Parks et al,[2] although in that study, exposure was based on estimated work schedules rather than a validated measure of work hours. As with extended work duration, we found that fatigue was reported more often as a contributing factor for nighttime compared with daytime injuries, and some of the excess in the nighttime rates may be reflecting the effects of extended work shifts. In addition, there are prominent circadian performance rhythms that can degrade motor coordination and vigilance at night.[12,15] Also, both acute and chronic sleep deprivation increase the neurobiological drive for sleep, increase the risk of attentional failures, and impair performance and short-term memory.[6,16]

The increased nighttime rate of PI may also be related to sleep inertia, a state of transient cognitive impairment that occurs immediately on awakening from sleep and has been shown to impair cognitive performance substantially.[17] Interns typically attempt to sleep during their overnight extended-duration work shifts but are often awakened during the night when patients need to be immediately evaluated and treated. In this cohort, interns slept an average of 2.6 hours during their extended-duration shifts.[5] Performing complex invasive procedures during times shortly after awakening would make the intern susceptible to the detrimental effects of sleep inertia superimposed on the circadian decrement in reaction time and vigilance.

The nighttime findings could be confounded by differences in hospital activity during the night compared with the day that we were unable to assess. Hospitals may have more phlebotomy and intravenous teams available during the day so that interns would be doing relatively more needlesticks at night. Moreover, admitting and transferring patterns may lead to an increased need for interns to perform needlesticks at night. However, fewer patients are usually admitted at night than during the daytime, and fewer elective procedures are done at night compared with the daytime. Notwithstanding these potential confounders, the results are consistent with previous laboratory and field data.[2,3,16]

Pressure to perform procedures quickly, which may vary with time of day and in different specialties, may have contributed to our findings. Operating rooms tend to be busier in the daytime than during the nighttime, which could account for the increased rate of injuries in the operating room in the daytime. In contrast, house staff on labor and delivery services may be much busier at night when there are fewer house staff present; because the initiation of spontaneous labor usually peaks at night, this may lead to more procedures per house staff.[18]

There are a number of limitations to our study. First, the 2737 interns who volunteered to participate and formed the study cohort represent a small proportion of the approximately 18 447 US interns. However, this enrollment rate is similar to large epidemiologic studies such as the Physicians' Health Study I and Physicians' Health Study II, in which advertisements were sent to a large number of potential research participants nationwide in the expectation that only a small percentage would enroll.[19,20] Nevertheless, it is thus possible that our participants are not representative of the entire population of interns. Interns were aware that the study was designed to examine relationships between work hours and safety outcomes. It is possible that interns who were more interested in this issue or who had a predisposition to be affected by long work hours were more likely to volunteer for the study, potentially biasing our results. Because participants were compared with themselves, the case-crossover study design would reduce but not eliminate this potential bias.

In addition, our study sample was similar to the general population of interns but not identical. Our cohort was slightly younger and had a relatively greater proportion of women than those who applied for internship and had fewer foreign medical graduates and differed slightly in distribution of specialties compared with those who were matched for internship. Although it is possible that our findings would not

hold in a population with a more representative distribution, we think that it is unlikely that these characteristics contributed substantially to the observed risk.

Second, although our documented incidents were based on detailed self-reports, we have not validated these reports by direct observation. We sought to minimize this concern by including only incidents accompanied by corroborating information; we believe it is unlikely that the interns would confabulate detailed injury reports. Nevertheless, it remains possible that there is significant under- or overreporting of injuries; furthermore, we cannot exclude a bias in reporting nocturnal incidents or incidents after a prolonged period of working.

Third, participants may have performed more invasive procedures after an extended duration at work. We doubt that this is a reasonable explanation of our findings, because interns working during the daytime after overnight work are typically transitioning patient-care responsibilities to their colleagues and therefore performing fewer invasive procedures.

Although it is possible that interns returned more surveys when a PI occurred after an extended-duration shift, this is unlikely because the results were similar when only interns who completed all 11 monthly surveys were analyzed. Recall bias could lead interns to misreport systematically their work hours in the setting of a PI, but the validation of work hours in a subset makes this unlikely. Finally, the extent to which these findings generalize to physicians with greater experience cannot be determined from this study.

In conclusion, we found that PIs were commonly reported in interns, although rates varied substantially, depending on the specialty. Greater PI risk was associated with extended work duration and nighttime shifts, adding occupational injury to the hazards related to the extended-duration work of interns.[5,21] Given the potentially serious consequences of such injuries, implementation of safety measures de-

signed to reduce the risk of these occupational injuries should be undertaken. The impact of comprehensive fatigue management programs on the risk of these occupational exposures should be evaluated.

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