Effects of working conditions on intravenous medication errors in a Japanese hospital

YUKIKO SEKI PhD, RN, PHN[1] and YOSHIHIKO YAMAZAKI PhD[2]

[1]*Department of Nursing, Gunma University School of Health Sciences, Gunma and* [2]Associate Professor and Head of Health Sociology, *Graduate School of Health Sciences and Nursing, The University of Tokyo, Tokyo, Japan*

Correspondence
Yukiko Seki
Department of Nursing
Gunma University School of Health Sciences
3-9-15 Showa-Machi Maebashi-shi
Gunma 371-8514
Japan
E-mail: yseki-tky@umin.ac.jp

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Aim The aim of this study was to explore quantitatively which working conditions influence the occurrence of medical near-miss errors related to intravenous medication at a hospital in Japan.

Background Although working conditions such as stress, fatigue and inexperience have been reported to contribute to medical errors, countermeasures to these conditions have been delayed, and working conditions have deteriorated in many Japanese medical sites.

Methods A self-reporting questionnaire analysing working conditions that can lead to near-miss errors relating to intravenous medication was sent to 90 nurses working in four wards of one Japanese hospital in 2001. Eighty-eight subjects responded (response rate: 97.8%). Among 534 person-days in which 88 nurses attended works, 525 person-days of data were used for the analyses.

Results Among 525 person-days, the number of near-miss errors was 94 (17.9%). There was no significant difference in the occurrence of near-miss errors among the three shifts (day shift, 19.2%; evening shift, 19.2%; night shift, 12.5%). During the day shift, errors were reported at a significantly higher frequency when the nursing services were delayed longer due to workload. During the evening shift, errors were reported when the nursing services were delayed longer due to workload and when years of experience at the current ward were shorter. In addition, nurses whose perceived level of fatigue before work was lower during the day shift, and nurses whose years of experience as a nurse were longer and who had longer sleep duration during the evening shift experienced near-miss errors with a significantly higher frequency than other nurses. These latter factors could be important conditions that encourage the detection of errors before they occur.

Conclusions Workload and lack of experience at the current ward are two conditions that can lead to errors. Furthermore, lack of fatigue and long experience as a nurse may help encourage the detection of errors before they occur. It is important to improve working conditions so that health care workers can detect errors before patients are harmed and decrease the number of errors that occur.

Keywords: accident and emergency, nursing errors, workforce issues, working conditions

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Introduction

In recent years, the prevalence of medication errors in hospitals has become a worldwide concern. In some cases, medical errors are caused by specific workers who intend to cause harm, and in most cases, these workers are caught and punished. However, in most cases, medical errors are typically organizational errors, i.e. they result from a problem in the entire process of medical care and not from a single person.

Unsafe acts (errors and procedural violations) committed by workers who are in direct contact with patients or systems are directly related to the occurrence of medical errors, but the unsafe acts alone rarely lead to the occurrence of a medical error. In Reason's (1997, 2000) model, latent conditions (i.e. error-provoking conditions within the workplace that can create long-lasting holes or weaknesses in the defence) exist behind the unsafe acts, and it is these conditions that lead to medical errors. To prevent medical errors, it is important to investigate working conditions to determine if they result in errors or safety violations by health care workers. It is also necessary to improve the medical care system and working conditions so that workers can safely provide medical services.

Working conditions that promote unsafe medical practice include time pressures, understaffing, inappropriate tools and equipment, fatigue and inexperience (Reason 1997, 2000). In addition, inadequate rest because of prolonged surgical times and long working hours, and disturbances in biological rhythms because of shift-work and night work lead to fatigue, shortage of sleep, lower mood and motivation, reduced morale and decreased ability to perform tasks and pay attention (Krueger 1994, O'Shea 1999). These factors all contribute to the incidence of medical errors.

The relation between working conditions and the occurrence of medical errors has been studied at various sites. Studies have reported on the occurrence of errors in relation to stress (Sexton *et al.* 2000, Grasha & Schell 2001, Reilley *et al.* 2002), shortage of sleep (Dinges *et al.* 1985, Cooper 1989, Doran *et al.* 2001), workload (Leape *et al.* 1995, Grasha & Schell 2001, Dean *et al.* 2002, Reilley *et al.* 2002), night work (Roseman & Booker 1995) and fatigue (Williamson *et al.* 1993, Gander *et al.* 2000, Sexton *et al.* 2000). Although all of the above working conditions have been reported to induce errors, countermeasures have been delayed and situations are deteriorating in Japan. For instance, the number of health care workers in Japan is comparable with other countries, but the number of workers per hospitalized patient is lower than in many other places. For example, according to OECD Health Data for the year 2000, the average number of nurses per 100 beds is 221.0 in the United States, 120.0 in the United Kingdom, 99.8 in Germany, 69.7 in France and 43.5 in Japan. In addition, the workload of each worker in Japan is large, as the number of beds is high. Furthermore, medical institutions have been required to streamline medical care because of the recent restrictive health care expenditure policies. Thus, the length of stays in the hospital is shortened and bed turnover rate is increased, but the number of health care workers remains the same. The amount of work performed by an individual worker in a given length of time has increased as well. Under the above conditions, many health care workers are busy, lack sleep, complain of chronic fatigue and think that their working conditions lead to medical errors (Tokyo Medical Worker's Unions Council 2000). According to a report of medical accidents for approximately 10 000 nurses in Japan (Japan Federation of Medical Worker's Unions 2000), factors that were considered to lead to medical accidents included busy units ($n = 9825$, 84.6%), shift work fatigue ($n = 4877$, 42.0%), lack of knowledge and skill ($n = 4404$, 37.9%) and staff shortage ($n = 3553$, 30.6%).

A variety of error prevention measures have been proposed in Japan to reduce the number of human errors in medical care. However, in many of these prevention measures, the focus is on the medical tasks performed by health care workers, such as cross-checks, and working conditions are ignored. Consequently, the workload is increased further in order to prevent errors, which in turn, leads to the occurrence of errors. Therefore, it is necessary to investigate whether the working conditions are causes of the medical errors in the Japanese medical system. However, in contrast to the large amount of qualitative research, quantitative research on the relationship between medical errors and working conditions in Japan is limited (Inoue & Koizumi 2004, Suzuki *et al.* 2004).

The study

Aim

The aim of this study was to explore quantitatively which working conditions influence the occurrence of medical near-miss errors related to intravenous medication at a hospital in Japan.

Sample events

Many more cases of errors in which patients were not actually harmed can be collected than accident cases (Kohn *et al.* 2000). Therefore, the present study included only events in which patients were not harmed. These events, hereafter, referred to as 'near-miss errors', included medical actions that were not actually taken but would have harmed patients if performed (i.e. these actions were discovered before they were undertaken and thus avoided), and errors that were actually made but did not harm patients or require follow-up observation. In addition, events in the present study were limited to near-miss errors concerning intravenous medications (e.g. wrong route, patient, time, drug and dose).

Setting and subjects

The present study was conducted at a public hospital that had approximately 800 beds and 10 departments, practiced advanced and high-tech medical treatments, and performed education and training for medical staff. A safety management committee chaired by an assistant hospital director was inaugurated, and experienced head nurses were appointed as full-time risk managers to deal positively with error prevention by collecting and analysing errors and near-misses. Ninety nurses who worked on four wards (i.e. nephrology, cardiovascular medicine, neurosurgery and haematology) in the hospital were included. All participants were registered nurses (a nurse grading system does not exist in Japan). There was no special relationship between the respondents and us (data collectors and analysts), i.e. our relationship was only that of researcher and subjects.

The nurses worked on a three-shift basis (day shift from 8:00 to 16:30; evening shift from 16:00 to 0:30 and night shift from 0:00 to 8:30 hours). The length of these shifts was 8 hours with 8 consecutive hours of rest between shifts. Most of the night shift consisted of nurses who worked 'the day–night shift' (i.e. they worked the night shift after the day shift, with no days off in between). The number of patients that were taken care of by a single nurse was four to six during the day shift, nine to 13 during the evening shift and 12 to 17 during the night shift.

Ethical considerations

Approval for the study and written consent was obtained from the hospital. Confidentiality of study data and anonymity for the hospital and nurses were assured. Each nurse provided informed consent, and was told that participation was voluntary. In addition, nurses were assured that access to the questionnaires was tightly controlled and that their supervisors would not be able to read them.

Measures

In January 2001, a self-reporting questionnaire was distributed to all 90 nurses and collected through head nurses of subject wards. The survey period was 10 consecutive days, and each nurse was asked to fill out the questionnaire only during working days (2–8 days).

The various working conditions that could affect medical errors were drawn from a report of medical accidents for approximately 10 000 nurses (Japan Federation of Medical Worker's Unions 2000), and a study of the shift work and medical errors (Krueger 1989, 1994). Thus, nurses were asked about the following variables for this analysis: their shifts, work experience, fatigue, sleep duration, workload, busyness and the occurrence of any near-miss medical errors.

Shifts

Data from three shifts, including the day, evening and night, were included in the analysis.

Work experience

The survey measured years of experience as a nurse and years of experience at the current ward.

Fatigue

To investigate the influence of cumulative fatigue, the perceived level of fatigue of each nurse was measured immediately before starting work using a 100-mm visual analogue scale (Philip *et al.* 2003, 2004). The degree of fatigue was expressed by drawing a vertical line on a horizontal line whose left edge indicated 'no fatigue' and right edge indicated 'severe fatigue' (see Appendix).

Sleep duration

Sleep duration before work was assessed. Nap hours were included in sleep duration.

Workload

Although a patient dependency scoring system should be used to determine the level of nursing resources required for each patient, the tool for measuring patient dependency had not yet been validated in Japan in 2001. Instead, we measured and used 'the number of patients per nurse' in the ward as the nurses' workload.

Furthermore, we used 'the number of patients given intravenous medication per nurse' because we were trying to determine which factors affected the occurrence of near-miss errors regarding intravenous medication.

Busyness

Feeling of busyness (absent = 0, present = 1) and delay of nursing services because of busyness (absent = 0, present = 1) at the end of work were used for the analysis (see Appendix).

Occurrence of near-miss errors

At the end of their shift, nurses were asked whether they made a near-miss error in terms of intravenous medication during the working shift. To minimize the number of unreported near-miss errors, various devices were used to remind the nurses of the possibility of near-miss occurrences, including questions about near-misses experienced in the past and reminders of the types and details of near-misses possible during the administration of intravenous medication. In addition, nurses were reminded that their supervisors would never read the questionnaires (see Appendix).

Data analysis

To investigate the working conditions relating to the occurrence of errors, bivariable and a multivariate logistic regression analysis were performed by work shift with regard to the presence of near-miss errors (absent = 0, present = 1) as a dependent variable, and each working condition as an independent variable. The odds ratio and 95% confidence intervals for adjusted wards were calculated for the dependent variable.

Because fatigue was measured subjectively, interindividual differences were observed. Therefore, the z-score (standardization of 'perceived level of fatigue' score for each nurse) was used to compare the relative standings score with different mean values and/or different standard deviations. In addition, to consider the usual perceived level of fatigue of each nurse, the mean values themselves were used for analysis.

Because the data from repeated measurements in which one nurse answered more than once (eight times maximum) were used, parameter estimation in the logistic regression analysis was performed using generalized estimating equations to consider intraindividual correlations in each nurse. The generalized estimating equations approach is an extension of generalized linear models that provides a semiparametric approach to longitudinal data analysis with univariate outcomes for which the quasi-likelihood formulation is possible, for example, normal, Poisson, binomial and γ-response variables (see Liang & Zeger 1986, Zeger & Liang 1986, Horton & Lipsitz 1999, Stokes *et al.* 2001). Analyses were performed using a statistical package (SAS version 8). P-values <0.05 (two-sided) were considered statistically significant.

Results

Among the 90 nurses who replied to the questionnaire, 88 participants [one man and 87 women (male nurses are not common in Japanese hospitals)] were included in the analysis (response rate: 97.8%); two respondents did not fill in their demographic characteristics and were thus excluded. There were 534 person-days in which the 88 nurses attended work during the survey period. Nine were excluded because of incomplete reports; thus 525 person-days were eligible for the analysis. The mean years of experience as a nurse was 10.6 ± 8.0 years, and the mean years of experience at the current ward was 2.4 ± 1.4 years. Among 525 person-days, the number of near-miss errors was 94 (17.9%; Table 1). According to brief descriptions of near-miss errors in questionnaires, examples of errors were misinterpreting doctors' handwritten orders, failing to record that medications had been given, preparing the wrong solvent/diluent but correcting before administration, and giving bolus doses too quickly (see Box). The occurrence of near-miss errors differed, depending on the ward: the highest occurrence rate was 30.6% (nephrology ward) and the lowest was 12.8% (cardiovascular ward). There were significant differences in the degrees of fatigue, workload and busyness among the four wards. There was no difference in sleep duration before work among the wards.

Table 2 shows the working conditions and the occurrence of near-miss errors by work shift. Because most of the night shift workers included those who worked day–night shift, the perceived level of fatigue before work was significantly higher ($F = 19.859$, $P < 0.001$) and mean sleep duration before work was significantly shorter in night shift workers than in other workers ($F = 190.506$, $P < 0.001$). Because the number of nurses was largest during the day shift, followed by the evening shift and the night shift, the number of patients per nurse ($F = 2172.261$, $P < 0.001$) and the number of patients who were given intravenous medication per nurse ($F = 383.168$, $P < 0.001$) was significantly larger during the evening shift than the day shift, and during the night shift than the evening shift.

Table 1
Working conditions and occurrence of near-miss errors in each ward ($N = 525$ person-days)

Ward	*Total* (N = *525)*	*A1* (n = *98)*	*A2* (n = *141)*	*A3* (n = 145)	*A4* (n = 141)	F/χ^2	P-*value*
Shift							
The day shift (person-days)	291	48	81	80	82		
The evening shift (person-days)	130	30	30	36	34		
The night shift (person-days)	104	20	30	29	25		
Perceived level of fatigue before work (mm)*†	61.0 ± 22.3	62.6 ± 20.1	56.5 ± 20.1	57.6 ± 24.2	67.9 ± 22.1	5.378‡	0.001‡
Sleep duration before work (hours)*	6.1 ± 2.7	6.5 ± 3.4	5.9 ± 2.6	6.1 ± 2.6	6.0 ± 2.4	1.081‡	0.357‡
Workload							
Number of patients per nurse*	8.5 ± 4.27	7.8 ± 3.48	9.2 ± 4.54	8.4 ± 4.37	8.3 ± 4.31	0.238‡	0.069‡
Number of patients given intravenous medication per nurse*	3.4 ± 2.1	3.9 ± 2.0	2.4 ± 1.4	3.2 ± 1.9	4.1 ± 2.5	19.779‡	<0.001‡
Busyness							
Feeling of busyness (%)							
Present	332 (63.2)	55 (56.1)	81 (57.4)	92 (63.4)	104 (73.8)	10.885§	0.012§
Absent	193 (36.8)	43 (43.9)	60 (42.6)	53 (36.6)	37 (26.2)		
Delay of nursing service due to busyness (%)							
Present	140 (26.7)	29 (29.6)	24 (17.0)	44 (30.3)	43 (30.5)	9.197§	0.027§
Absent	385 (73.3)	69 (70.4)	117 (83.0)	101 (69.7)	98 (69.5)		
Occurrence of near-miss errors (%)							
Present	94 (17.9)	30 (30.6)	18 (12.8)	19 (13.1)	27 (19.1)	15.722§	0.001§
Absent	431 (82.1)	68 (69.4)	123 (87.2)	126 (86.9)	114 (80.9)		

A1, nephrology; A2, cardiovascular medicine; A3, neurosurgery; A4, haematology.
*Mean ± SD.
†Measured by visual analogue scales (VAS; 0 = no fatigue to 100 = severe fatigue).
‡Results of one-way ANOVA (*F*-value).
§Results of chi-square test (χ^2-value).

Table 2
Working conditions and occurrence of near-miss error in each work shift ($N = 525$ person-days)

Ward	*Day shift* (n = *291*)	*Evening shift* (n = *130*)	*Night shift* (n = *104*)	F/χ^2	P-*value*
Perceived level of fatigue before work (mm)*†	59.7 ± 21.3	54.5 ± 23.5	72.9 ± 18.9	19.859‡	<0.001‡
Sleep duration before work (hours)*	6.1 ± 1.3	8.5 ± 3.0	3.1 ± 2.2	190.506‡	<0.001‡
Workload					
Number of patients per nurse*	5.0 ± 1.25	11.5 ± 1.90	14.5 ± 1.02	2172.261‡	<0.001‡
Number of patients given intravenous medication per nurse*	2.0 ± 0.7	4.6 ± 1.5	5.8 ± 2.2	383.168‡	<0.001‡
Busyness					
Feeling of busyness (%)					
Present	194 (66.7)	67 (51.5)	71 (68.3)	10.258§	0.006§
Absent	97 (33.3)	63 (48.5)	33 (21.7)		
Delay of nursing service due to busyness (%)					
Present	78 (26.8)	24 (18.5)	38 (36.5)	9.661§	0.008§
Absent	213 (73.2)	106 (81.5)	66 (63.5)		
Occurrence of near-miss errors (%)					
Present	56 (19.2)	25 (19.2)	13 (12.5)	2.577§	0.276§
Absent	235 (80.8)	105 (80.8)	91 (87.5)		

*Mean ± SD.
†Measured by visual analogue scales (VAS; 0 = no fatigue to 100 = severe fatigue).
‡Results of one-way ANOVA (*F*-value).
§Results of chi-square test (χ^2-value).

The number of person-days in which nurses felt busyness ($\chi^2 = 10.258$, $P = 0.006$) and that nursing services were delayed due to busyness ($\chi^2 = 9.661$, $P = 0.008$) was largest during the night shift, followed by the day shift and the evening shift. There was no significant difference in the occurrence of near-miss errors per person-days among the three shifts. Because there were significant differences in many independent variables among the four wards and among the three shifts, the results of the following analyses were adjusted for wards and compared among the day, evening and night shifts.

Table 3 shows the results of bivariable logistic regression analyses of the relationship between working conditions and occurrence of near-miss errors. Regarding the working conditions, a near-miss error occurred with a significantly higher frequency during the day shift when busyness was felt (OR = 2.163, 95% CI: 1.079–4.337) and when the nursing service was delayed longer due to busyness (OR = 3.658, 95% CI: 1.992–6.717). A near-miss occurred with a significantly higher frequency during the evening shift when the nursing service was delayed longer due to busyness (OR = 5.649, 95% CI: 1.951–16.357). No variables were associated with the occurrence of near-miss errors during the night shift.

Table 4 shows the results of multiple logistic regression analyses of working condition variables tested for the possible association with the occurrence of near-miss errors by work shift. During the day shift, a near-miss error was thought to occur with a significantly higher frequency when the nursing services were delayed longer due to busyness (OR = 3.289, 95% CI: 1.608–6.726) and when the mean perceived level of fatigue before work was lower (OR = 0.976, 95% CI: 0.952–0.999).

During the evening shift, the occurrence of a near-miss error had a significant relation to the delay of nursing services because of busyness (OR = 7.993, 95% CI: 1.490–42.883). In addition, a near-miss error occurred with a significantly higher frequency when years of experience as a nurse were longer (OR = 1.105, 95% CI: 1.025–1.192), when years of experience at the current ward were shorter (OR = 0.688, 95% CI: 0.488–0.969) and when sleep duration was longer (OR = 1.242, 95% CI: 1.049–1.470).

During the night shift, the occurrence of a near-miss error was not significantly related to experience, fatigue, hours of sleep, or workload.

Discussion

The majority of reported near-miss errors in the present study were events in which an error was found in advance and corrected by nurses themselves. Thus, there is a possibility that conditions that induce near-miss errors and that can be used to detect near-miss errors exist together.

Conditions that induce near-miss errors

During the day shift, a near-miss error was reported at a significantly higher frequency when nursing services

Table 3
Effects of working conditions on occurrence of near-miss errors during the day shift (bivariable logistic regression analysis*)

	Day shift			Evening shift			Night shift		
Occurrence of near-miss errors	*Mean ± SD*	*OR (95% CI)*	P-value	*Mean ± SD*	*OR (95% CI)*	P-value	*Mean ± SD*	*OR (95% CI)*	P-*value*
Work experience									
Years of experience as a nurse (years)									
Absent	10.4 ± 7.9	0.966 (0.932–1.002)	0.065	8.9 ± 7.0	1.040 (0.982–1.102)	0.183	10.6 ± 7.8	0.933 (0.858–1.015)	0.105
Present	8.5 ± 7.4			10.6 ± 6.8			8.6 ± 6.1		
Years of experience at the current ward (years)									
Absent	2.3 ± 1.5	0.996 (0.812–1.223)	0.971	2.6 ± 1.4	0.786 (0.532–1.162)	0.228	2.5 ± 1.5	0.879 (0.646–1.197)	0.413
Present	2.3 ± 1.3			2.2 ± 1.8			2.4 ± 1.0		
Fatigue									
Mean 'perceived level of fatigue before work' (mm)†									
Absent	59.8 ± 14.8	1.278 (0.981–1.664)	0.069	60.0 ± 13.9	0.875 (0.609–1.257)	0.468	59.5 ± 16.2	0.778 (0.470–1.287)	0.328
Present	57.1 ± 13.3			58.7 ± 14.1			60.1 ± 11.3		
Perceived level of fatigue before work (*z*-score)‡									
Absent	0.0 ± 1.3	0.988 (0.967–1.008)	0.238	–0.2 ± 1.4	0.993 (0.966–1.022)	0.643	0.9 ± 1.3	1.004 (0.975–1.033)	0.799
Present	0.4 ± 2.0			–0.5 ± 1.3			0.5 ± 0.9		
Sleep duration before work(hours)									
Absent	6.0 ± 1.4	1.116 (0.926–1.346)	0.248	8.2 ± 3.0	1.179 (0.993–1.400)	0.061	3.0 ± 1.9	1.092 (0.799–1.492)	0.581
Present	6.3 ± 1.2			9.6 ± 3.0			3.3 ± 3.6		
Workload									
Number of patients per nurse									
Absent	5.0 ± 1.3	0.935 (0.696–1.255)	0.654	11.6 ± 1.9	1.247 (0.612–2.542)	0.543	14.5 ± 1.0	0.996 (0.489–2.026)	0.990
Present	4.9 ± 1.0			11.0 ± 1.9			14.4 ± 1.4		
Number of patients given intravenous medication per nurse									
Absent	1.9 ± 0.7	0.729 (0.403–1.318)	0.296	4.5 ± 1.5	1.104 (0.845–1.442)	0.468	5.7 ± 2.2	1.159 (0.879–1.529)	0.295
Present	2.0 ± 0.6			4.9 ± 1.2			6.6 ± 2.4		
Busyness									
Feeling of busyness									
Absent	63.4%§	2.163 (1.079–4.337)	0.030	49.5%§	1.952 (0.731–5.207)	0.182	68.1%§	1.049 (0.306–3.594)	0.940
Present	80.4%§			60.0%§			69.2%§		
Delay of nursing services due to busyness									
Absent	20.9%¶	3.658 (1.992–6.717)	<0.0001	13.3%¶	5.649 (1.951–16.357)	0.001	35.2%¶	1.591 (0.451–5.613)	0.470
Present	51.8%¶			40.0%¶			46.2%¶		

*The generalized estimating equation method was used to estimate model parameters. Every analysis was adjusted for ward. Dependent variable: the occurrence of near-miss (absent = 0 or present = 1).
†Measured by visual analogue scales (VAS; 0 = no fatigue to 100 = severe fatigue).
‡Standardization of 'perceived level of fatigue before work' score for each nurse.
§Percentage of 'feeling of busyness was present'.
¶Percentage of 'delay of nursing services due to busyness was present'.
OR, odds ratio; CI, confidence interval.

Table 4
Effects of working conditions on occurrence of near-miss errors (multiple logistic regression analysis*)

	Day shift		*Evening shift*		*Night shift*	
	OR (95% CI)	P-value	*OR (95% CI)*	P-value	*OR (95% CI)*	P-*value*
Work experience						
Years of experience as a nurse (years)	0.968 (0.928–1.010)	0.135	1.105 (1.025–1.192)	0.009	0.917 (0.814–1.034)	0.157
Years of experience at the current ward (years)	1.061 (0.852–1.320)	0.596	0.688 (0.488–0.969)	0.032	1.089 (0.676–1.757)	0.726
Fatigue						
Mean 'perceived level of fatigue before work'† (mm)	0.976 (0.952–0.999)	0.043	0.963 (0.922–1.005)	0.086	0.986 (0.943–1.031)	0.541
Perceived level of fatigue before work (*z*-core)‡	1.164 (0.906–1.497)	0.236	0.772 (0.476–1.251)	0.293	0.780 (0.515–1.180)	0.239
Sleep duration before work	1.128 (0.924–1.377)	0.239	1.242 (1.049–1.470)	0.012	1.156 (0.843–1.585)	0.541
Workload						
Number of patients per nurse	1.019 (0.734–1.413)	0.912	0.908 (0.384–2.146)	0.825	0.944 (0.390–2.282)	0.898
Number of patients given intravenous medication per nurse	0.691 (0.365–1.414)	0.311	1.182 (0.834–1.674)	0.348	1.248 (0.886–1.758)	0.204
Busyness						
Feeling of busyness§	1.440 (0.640–3.239)	0.378	0.698 (0.149–3.279)	0.649	0.600 (0.114–3.175)	0.548
Delay of nursing services due to busyness¶	3.289 (1.608–6.726)	0.001	7.993 (1.490–42.883)	0.015	1.618 (0.291–8.989)	0.582

*The generalized estimating equation method was used to estimate model parameters. Every analysis was adjusted for ward. Dependent variable: the occurrence of near-miss (absent = 0 or present = 1).
†Measured by visual analogue scales (VAS; 0 = no fatigue to 100 = severe fatigue).
‡Standardization of 'perceived level of fatigue before work' score for each nurse.
§Feeling of busyness (0 = absent or 1 = present).
¶Delay of nursing services due to busyness (0 = absent or 1 = present).
OR, odds ratio; CI, confidence interval.

were delayed longer due to busyness. The reason for this might be that time pressures caused by the delay of services promoted unsafe acts and induced near-miss errors. Time pressure is an important factor in inducing errors (Reason 1997, 2000). Therefore, during the day shift, identification of conditions that induce time pressures and improvement of these conditions might help prevent errors. During the day shift, the number of patients served was small compared with other shifts; however, nurses were also assigned to assist doctors during the day in terms of surgery, examinations, injections and other treatment. These tasks were to be performed along with the regular nursing duties. Many of these additional duties in nursing must be performed at a fixed time; in contrast, other nursing tasks, such as support of toileting, must be performed according to the patients' needs. When these tasks must be performed at the same time, some services are delayed, and time pressures occur. To improve the occurrence of time pressures on nurses and prevent medical errors, it might be necessary to consider work responsibilities and personnel distribution carefully in view of the number of patients, the amount of work one nurse can precisely perform, and the ability of each nurse.

Because of the option in the hospital of working the day–night shift, nurses who work the night shift after completion of the day shift generally like to complete the day shift as promptly as possible to nap or rest between shifts; this results in time pressures on these nurses. This day–night shift is not the forward rotation that was reported to be favourable for the shift system, and induces a disturbance in circadian rhythm, lack of sleep and fatigue (Knauth 1993). In the present study, no particular conditions relating to the occurrence of near-miss errors were seen during the night shift, but the shift system should be carefully devised to improve time pressures during the day shift as well as lack of sleep or fatigue that occur during the night shift.

During the evening shift, a near-miss error was reported at a higher frequency when nursing services were delayed due to busyness and when years of experience at the current ward were shorter. The number of medical treatments performed during the evening shift was smaller than during the day shift. However, as the number of nurses during the evening shift decreased to one-thirds of that during the day shift, the workload per nurse increased. In addition, time pressures may exist during the evening shift, as well as during the day shift, as doctors give many orders for patients. These orders are often urgent, are often changed, and are often delayed if drugs are not dispensed from the pharmacy. These situations force the administration of intravenous medications under time pressure. Furthermore, to deal with these urgent and often-changed orders, it is necessary to apply rules other than those relating to the basic intravenous medication process; many of these rules are unwritten and differ from ward to ward. It is possible that a nurse with less experience at a current ward who is not familiar with the unwritten rules may be working during the evening shift when the number of nurses on duty is small and the number of senior nurses available to answer questions is low; this may result in the occurrence of a near-miss error. According to Reason (1997), unwritten rules, ambiguous standard operating procedures and lack of experience or training are key factors that induce errors. Reconsideration of unwritten rules and careful consideration of the period and roles of training for nurses should be reviewed to prevent errors during the evening shift.

Conditions that encourage detection of near-miss errors

A near-miss error was reported with higher frequency when the mean perceived level of fatigue before work was lower during the day shift and when sleep duration was longer during the evening shift. Under the condition when 'nursing services were delayed longer due to busyness', which can lead to the occurrence of errors, the conditions of lack of fatigue or having gotten enough sleep could be factors that help detect errors before they occur. Workers are often less able to detect errors when their arousal level is low. Fatigue and sleep loss can affect arousal level (Coffey *et al.* 1988, Krueger 1989, 1994, Skipper *et al.* 1990, Smith-Coggins *et al.* 1994, Rollinson *et al.* 2003). Therefore, these results suggest that intravenous medication near-miss errors were detected successfully when nurses had enough sleep and were not tired before work.

To ensure that errors are detected promptly so that they do not have serious consequences, it is important to design a work process that allows an error to be detected (Norman 1998, Kohn *et al.* 2000). Several cues in the work process are available to help detect errors (Reason 1990), as a person who makes an error often does not notice the error himself/herself. Several cues during the recall phase can provide information about the error occurring. These clues include 'humans' other than oneself, 'documents', 'presented information' and 'subjects' (Matsuo 2003), and many medical accident prevention measures use the cue of 'human' cross-check. However, as the ability of humans to work decreases due to sleepiness and fatigue, removing sleepiness or fatigue from the workforce might improve the accuracy of human cross-checking and thus increase the detection of errors.

Long years of experience, which was significantly related to the occurrence of near-miss errors during the evening shift, could be necessary for finding errors. For example, nurses with more experience may have seen a larger number of errors and might know more about when and where errors occur and what is needed to prevent them. Therefore, they might be better able to detect errors than inexperienced nurses. It is important to improve conditions that interfere with the detection of errors, perhaps by having inexperienced nurses work alongside experienced nurses.

Limitations

Subjects of the present study included nurses at four wards in one hospital; results of our survey may differ if it were conducted at other wards or hospitals that had different treatment regimens and work shift systems. To improve working conditions most effectively, the survey and analyses should be performed for each medical institution and for each ward.

The definition of a near-miss error in the present study included medical actions that were not actually taken but would have harmed patients if performed (i.e. these actions were discovered before they were undertaken and thus avoided), and errors that were actually made but did not harm patients or require follow-up observation. Errors that are corrected before actually being made are considered successfully prevented errors, and errors that are actually made considered are unsuccessfully prevented errors. Thus, the 'near-miss' in the present study involved two antithetic events. Many organizations in Japan, including the Health, Labour and Welfare Ministry, define and classify errors based on the presence of an effect on patients. However, to investigate conditions needed to find errors before they occur, errors should have been defined based on whether or not they were corrected before being made on the patients. Furthermore, a self-reporting method in which the subjects reported their near-miss was used in the present study; however, some investigators report limitations in collecting error information through this method (Leape *et al.* 1995, Leape 1997, 2002, Jha *et al.* 1998, Wakefield *et al.* 1999). Thus, some errors may not have been included in the present study. In addition to the self-reporting form used in the present study, analysis of documents such as medical and nurse's records and observation by a third party are better methods to gather information on medication errors. In general, more than one method should be used to understand the occurrence of errors more accurately in further studies.

Conclusions

In the present study, a self-reporting questionnaire was distributed to 90 nurses working in four wards in one hospital in Japan to investigate working conditions that cause errors in intravenous medication administration. A near-miss error was reported significantly more frequently during the day and evening shifts when nursing service was delayed longer due to busyness, and during the evening shift, when years of experience of the nurses at the current ward were shorter. These factors could be conditions that induce errors, and improvement of these conditions might help prevent errors. In addition, a near-miss was reported with a higher frequency during the day shift when the mean perceived level of fatigue before work was lower, and during the evening shift when sleep duration was longer and experience was greater. Workers are often less able to detect errors when their arousal level is low. Therefore, these factors could be important conditions that encourage the detection of errors. To prevent medical errors that cause harm to patients, it is important to identify errors early on; factors that encourage early detection of errors should be investigated further.

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References

Coffey L.C., Skipper J.K. Jr & Jung F.D. (1988) Nurses and shift work: effects on job performance and job-related stress. *Journal of Advanced Nursing* **13**, 245–254.

Cooper J.B. (1989) Do short breaks increase or decrease anesthetic risk? *Journal of Clinical Anesthesia* **1**, 228–231.

Dean B., Schachter M., Vincent C. & Barber N. (2002) Causes of prescribing errors in hospital inpatients: a prospective study. *Lancet* **359** (9315), 1373–1378.

Dinges D.F., Orne M.T. & Orne E.C. (1985) Assessing performance upon abrupt awakening from naps during quasi-continuous operation. *Behavior Research Methods, Instruments and Computers* **17**, 37–45.

Doran S.M., Van Dongen H.P. & Dinges D.F. (2001) Sustained attention performance during sleep deprivation: evidence of state instability. *Archives Italiennes de Biologie* **139**, 253–267.

Gander P.H., Merry A., Millar M.M. & Weller J. (2000) Hours of work and fatigue-related error: a survey of New Zealand anaesthetists. *Anaesthesia and Intensive Care* **28**, 178–183.

Grasha A.F. & Schell K. (2001) Psychosocial factors, workload, and human error in a simulated pharmacy dispensing task. *Perceptual and Motor Skills* **92**, 53–71.

Horton N.J. & Lipsitz S.R. (1999) Review of software to fit generalized estimating equation regression models. *The American Statistician* **53**, 160–169.

Inoue K. & Koizumi A. (2004) Application of human reliability analysis to nursing errors in hospitals. *Risk Analysis* **24**, 1459–1473.

Japan Federation of Medical Worker's Unions (Nihon Iryo Rodo Kumiai Rengokai) (2000) *An Interim Report of 'Actual Condition of Nursing*' (Kango Genba Jittai Chosa: Chukan Hokoku) (in Japanese).

Jha A.K., Kuperman G.J., Teich J.M. *et al.* (1998) Identifying adverse drug events: development of a computer-based monitor and comparison with chart review and stimulated voluntary report. *Journal of the American Medical Informatics Association* **5**, 305–314.

Knauth P. (1993) The design of shift systems. *Ergonomics* **36**, 15–28.

Kohn L.T., Corrigan J.M. & Donaldson M.S. (2000) *To Err is Human: Building a Safer Health System*. National Academy Press, Washington, DC, USA.

Krueger G.P. (1989) Sustained work, fatigue, sleep loss and performance: a review of the issues. *Work and Stress* **3**, 121–141.

Krueger G.P. (1994) Fatigue, performance and medical error. In *Human Error in Medicine* (M.S. Bonger ed.), pp. 311–326. Lawrence Erlbaum Association, New Jersey, USA.

Leape L.L. (1997) A systems analysis approach to medical error. *Journal of Evaluation in Clinical Practice* **3**, 213–222.

Leape L.L. (2002) Reporting of adverse events. *New England Journal of Medicine* **347**, 1633–1638.

Leape L.L., Bates D.W., Cullen D.J. *et al.* (1995) Systems analysis of adverse drug events. ADE Prevention Study Group. *Journal of the American Medical Association* **274**, 35–43.

Liang K.Y. & Zeger S.L. (1986) Longitudinal data analysis using generalized linear models. *Biometrika* **73**, 13–22.

Matsuo T. (2003) The motivation model for prevention of human-error by external cue. *Human Interface Society* **5**, 75–84 (in Japanese).

Norman D.A. (1998) *The Design of Everyday Things*. Basic Books, New York, USA.

O'Shea E. (1999) Factors contributing to medication errors: a literature review. *Journal of Clinical Nursing* **8**, 496–504.

Philip P., Sagaspe P., Taillard J. *et al.* (2003) Fatigue, sleep restriction, and performance in automobile drivers: a controlled study in a natural environment. *Sleep* **26** (3), 277–280.

Philip P., Taillard J., Sagaspe P. *et al.* (2004) Age, performance and sleep deprivation. *Journal of Sleep Research* **13** (2), 105–110.

Reason J. (1990) *Human Error*. Cambridge University Press, New York, NY, USA.

Reason J. (1997) *Managing the Risks of Organizational Accidents*. Aldershot, Ashgate.

Reason J. (2000) Human error: models and management. *British Medical Journal* **320**, 768–770.

Reilley S., Grasha A.F. & Schafer J. (2002) Workload, error detection, and experienced stress in a simulated pharmacy verification task. *Perceptual and Motor Skills* **95**, 27–46.

Rollinson D.C., Rathlev N.K., Moss M. *et al.* (2003) The effects of consecutive night shifts on neuropsychological performance of interns in the emergency department: a pilot study. *Annals of Emergency Medicine* **41**, 400–406.

Roseman C. & Booker J.M. (1995) Workload and environmental factors in hospital medication errors. *Nursing Research* **44**, 226–230.

Sexton J.B., Thomas E.J. & Helmreich R.L. (2000) Error, stress, and teamwork in medicine and aviation: cross sectional surveys. *British Medical Journal* **320**, 745–749.

Skipper J.K. Jr, Jung F.D. & Coffey L.C. (1990) Nurses and shiftwork: effects on physical health and mental depression. *Journal of Advanced Nursing* **15**, 835–842.

Smith-Coggins R., Rosekind M.R., Hurd S. & Buccino K.R. (1994) Relationship of day versus night sleep to physician performance and mood. *Annals of Emergency Medicine* **24**, 928–934.

Stokes M.E., Davis C.S. & Koch G.G. (2000) *Categorical Data Analysis Using the SAS System* (2nd ed.). SAS Institute Inc., Cary, NC, USA.

Suzuki K., Ohida T., Kaneita Y. *et al.* (2004) Mental health status, shift work, and occupational accidents among hospital nurses in Japan. *Journal of Occupational Health* **46**, 448–454.

Tokyo Medical Worker's Unions Council (Tokyo Iryo Kanren Rodo Kumiai Kyogikai) (2000) *An Interim Report of 'Questionnaire Survey of Medical Accident'* (Iryo Jiko Anketo: Chukan Hokoku) (in Japanese).

Wakefield D.S., Wakefield B.J., Borders T., Uden-Holman T., Blegen M. & Vaughn T. (1999) Understanding and comparing differences in reported medication administration error rates. *American Journal of Medical Quality* **14**, 73–80.

Williamson J.A., Webb R.K., Sellen A., Runciman W.B. & Van der Walt J.H. (1993) The Australian Incident Monitoring Study. Human failure: an analysis of 2000 incident reports. *Anaesthesia and Intensive Care* **21**, 678–683.

Zeger S.L. & Liang K.Y. (1986) Longitudinal data analysis for discrete and continuous outcomes. *Biometrics* **42**, 121–130.

Box: Examples of intravenous drug near-miss errors

Misinterpreting doctors' handwritten orders

A nurse was preparing '100 units' of regular insulin when a doctor wrote '10 U' because 'u' looked like zero; this error was corrected due to another nurse's checking the system before the insulin was administered

Failing to record that medications had been given

A nurse gave a patient 500 mL isotonic saline solution intravenously, but no record that it had been given was made. Half a day later, the evening nurse saw the order and gave the patient the same solution again

Preparing the wrong solvent/diluent

A nurse prepared and administrated 100 mL physiological saline instead of 100 mL 5% glucose of antibiotic solution

Giving bolus doses quickly

An anticancer drug bolus dose was set up to be given inappropriately, because a nurse miscalculated the dosage and programmed the infusion pump. However, the nurse corrected the dose before administration because of an alarm sounding on the pump

Appendix: Questionnaire (an excerpt from the original Japanese version)

Before work

Perceived level of fatigue before work

Q How are fatigued you now? (tick along scale below)

No fatigue __________ Severe fatigue _________

After work

Feeling of busyness

Q During this shift, did you feel that today was busy?

1. Yes   2. No

Delay of nursing services due to busyness

Q During this shift, was there any delay in nursing services due to busyness?

1. Yes   2. No (if yes, describe briefly)

Occurrence of near-miss error

Q During this shift, did you make a near-miss error of intravenous medication?

1. Yes   2. No [If yes, describe briefly (please refer to the following example)]

Example of errors

Receiving order

Missed order, misreading order, misinterpreting order, known allergy

Preparation

Wrong drug, wrong dose, wrong time, wrong route, wrong patient, wrong i.v. solution, missed dose, missed order

Administration

Wrong drug, wrong dose, wrong time, wrong route, wrong patient, wrong i.v. rate, wrong i.v. solution, missed dose, missed order, known allergy, expired drug, drug interaction, late medication administration, i.v. infiltrate, wrong administration technique, inadequate monitoring

Recording

Wrong drug, wrong dose, wrong time, wrong route, wrong patient, wrong i.v. rate, wrong i.v. solution, miss recording