Nurse Working Conditions and Patient Safety Outcomes

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Background: System approaches, such as improving working conditions, have been advocated to improve patient safety. However, the independent effect of many working condition variables on patient outcomes is unknown.

Objective: To examine effects of a comprehensive set of working conditions on elderly patient safety outcomes in intensive care units.

Design: Observational study, with patient outcome data collected using the National Nosocomial Infection Surveillance system protocols and Medicare files. Several measures of health status and fixed setting characteristics were used to capture distinct dimensions of patient severity of illness and risk for disease. Working condition variables included organizational climate measured by nurse survey; objective measures of staffing, overtime, and wages (derived from payroll data); and hospital profitability and magnet accreditation.

Setting and Patients: The sample comprised 15,846 patients in 51 adult intensive care units in 31 hospitals depending on the outcome analyzed; 1095 nurses were surveyed.

Main Outcome Measures: Central line associated bloodstream infections (CLBSI), ventilator-associated pneumonia, catheter-associated urinary tract infections, 30-day mortality, and decubiti.

Results: Units with higher staffing had lower incidence of CLBSI, ventilator-associated pneumonia, 30-day mortality, and decubiti ($P \leq 0.05$). Increased overtime was associated with higher rates of catheter-associated urinary tract infections and decubiti, but slightly lower rates of CLBSI ($P \leq 0.05$). The effects of organizational climate and profitability were not consistent.

Conclusions: Nurse working conditions were associated with all outcomes measured. Improving working conditions will most likely promote patient safety. Future researchers and policymakers should consider a broad set of working condition variables.

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Reports on errors have resulted in a paradigm that shifts attention to systems necessary for improvement.[1] Important systems components are working conditions.[2] Within the context of the ongoing healthcare worker shortage (especially associated with nurses), clinicians, hospital administrators, and policymakers are looking for ways to improve working conditions while providing high quality, safe care, efficiently. Nurse shortages have been found to be concentrated in specialty care areas, particularly intensive care units (ICUs).[3] Understanding how ICU nurse working conditions impact patient safety is important.[4]

Previous researchers have found nurse staffing to be associated with patients' probability of survival,[5,6] decubiti,[6,7] infections,[8–11] and other patient safety outcomes.[12] Fatigue of nurses related to overtime has been correlated with nurses' self-reporting errors.[13] Although the use of overtime may satisfy minimum nurse to patient ratios, no research was found directly measuring its effects on patient outcomes.

Other important working condition components are organizational climate and wages, both of which have predicted nurse turnover.[14] Organizational climate is defined as employees' shared perceptions about the norms, including decision making and collaboration.[15] Shortell et al found that positive culture in ICUs was significantly associated with lower rates of risk-adjusted length of stay, nurse turnover, and provider-rated quality of care.[16] Similarly, Baggs et al found providers' perceptions of interdisciplinary collaboration to be significantly related to readmission and mortality.[17] The effect of nurses' wages on patient outcomes has not been directly studied, although it is debated in the literature.[18,19] Human resource decisions related to staffing, overtime, and wages, as well as the nurses' perceptions of the work environment are important aspects of working conditions that may be associated with patient safety outcomes.

Two hospital characteristics, profitability and magnet accreditation, may be directly related to the organization of nursing services. Nurses are the hospital's largest workforce; therefore, profitability may be associated with human resource decisions, which may impact patient safety. No research was found directly measuring relationships between profitability and patient safety. Magnet accreditation, which

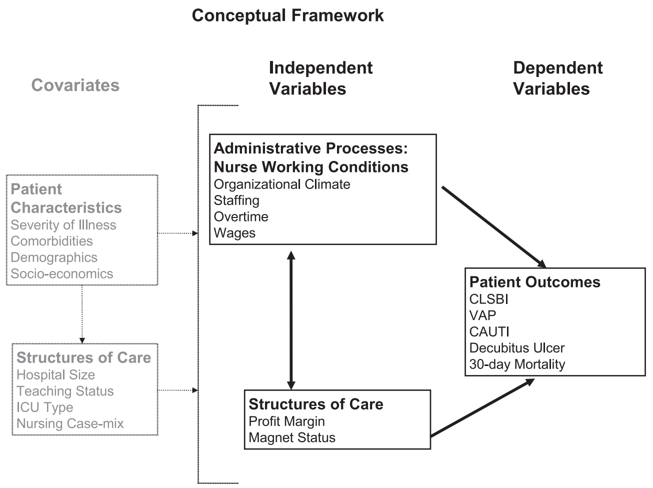

FIGURE 1. This figure guided the empirical analyses. The covariates on the left impact both the independent and dependent variables shown on the right. The covariates were controlled for in all analyses. The extent to which individual clinicians performed specific technical processes (eg, catheter care) was not measured in this study.

is based on the excellence in nursing services, has been noted to promote positive organizational climates and be associated with positive patient outcomes.[20] The independent contribution of magnet accreditation on patient outcomes, given other indicators of working conditions, is not known.

Conceptual Framework

Donabedian defined quality healthcare along 3 basic dimensions: structure, process, and outcomes of care.[21] The structures of care include the adequacy of facilities and equipment, and the administrative structure and operations related to programs providing care. The processes of care are actions/services involved with direct care. The outcomes are consequences that can be attributed to the structure and processes of care. Patient characteristics affect these relationships.

Based on this theoretical framework and previous research evidence, we developed a conceptual model (Fig. 1). The structures of care included both covariates and characteristics that may be directly related to organization of nursing services (ie, profit margin and magnet status). Administrative processes related to nurse working conditions included organizational climate, staffing, overtime, and wages. We examined outcomes thought to be sensitive to nursing care. Three of these relate to patients' probability of acquiring healthcare-associated infections in ICU settings (ie, central line associated bloodstream infection [CLBSI], ventilator-associated pneumonia [VAP], and catheter-associated urinary tract infection [CAUTI]). Decubiti and 30-day mortality were also considered. We adjusted for patients' underlying risk for disease using comprehensive sets of variables to decrease selection bias. We hypothesized that elderly patients being cared for in ICUs with better working conditions would have better safety outcomes.

METHODS

Sample

Recruitment of hospitals was through the Association for Professionals in Infection Control and Epidemiology, Inc., Listserve, and invitations sent to hospitals participating in the Centers for Disease Control and Prevention's (CDC) Nosocomial Infections Surveillance (NNIS) system.[22] Hospitals were eligible to enroll adult ICUs that (1) had a minimum of 500 patient days; (2) conducted device-associated infection surveillance using NNIS's protocols; and (3) had electronic databases or other infrastructure necessary for data collection.[22] Human subject approvals were obtained from the institutional review boards at each participating hospital and the primary investigators' institutions.

Elderly Medicare ICU patients were the population of interest. Although there are pragmatic reasons for studying the elderly (ie, availability of claims data, which is helpful in developing risk-adjustment variables) there are also important physiologic and demographic reasons. Elderly persons are at higher risk for many adverse patient outcomes, including infections.[23] Furthermore, the number of elderly patients is growing, making understanding patient safety issues in this population extremely important.

Data Collection Procedures

Data were collected from a variety of sources for the year 2002: (1) Medicare files, (2) NNIS infection data, (3) administrative data, (4) the American Hospital Association's (AHA) annual survey data, and (5) registered nurse (RN) survey. Site coordinators at each hospital were trained and assisted with institutional review board approvals and data collection at their institution. Using standardized data collection forms, site coordinators submitted all data electronically.

Dependent Variables: Patient Safety Outcomes

The NNIS's system of infection surveillance was used to identify patients with CLBSI, VAP, and CAUTI. These infections are identified using standard protocols implemented by infection control professionals, which include accurate case finding based on both clinical and laboratory criteria.[24] The full NNIS protocols and handbook are available on the CDC's website (http://www.cdc.gov/ncidod/dhqp/nhsn__members.html). These protocols were developed and tested by epidemiologists.[25] Using chart abstraction as the gold standard, the sensitivity of infection identification using these protocols was found to range from 68% to 86% and the specificity from 98% to 99%, depending on the infection.[26] This method for identification of infections is recognized worldwide as reliable and valid.[27]

Site coordinators provided lists of all elderly Medicare patients receiving care in each ICU in 2002 cross referenced with NNIS infection data. Although each ICU conducted NNIS infection surveillance, the number of months surveillance was conducted and the type of infections that were measured varied across settings.

Thirty-day mortality and decubiti were ascertained using Medicare files. Thirty-day mortality was identified by cross referencing the date of the index admission in the inpatient standard analytic file to the date of death in the denominator file. The Agency for Healthcare Research and Quality's Patient Safety Indicator protocol was used to identify decubiti.[28] This method identifies decubiti based on discharge codes and excludes patients without a length of stay of 5 or more days, patients with paralysis, obstetrical patients, and those admitted from a long-term care facility.

Independent Variables: Administrative Processes Related to Nurse Working Conditions and Other Structures of Care

A wide range of administrative processes were measured, including staffing (RN hours per patient day), ratio of overtime to regular time hours for RN, and average RN wage per ICU (adjusted by average RN wages per metropolitan statistical area). These variables were derived from monthly payroll data, monthly total ICU patient census data (ie, not just Medicare patients), and Bureau of Labor Statistics regional estimates of RN salary. We considered analyzing skillmix (the proportion of RN hours to total nursing staff hours); however, from the payroll data we found little variation in skillmix across ICUs with almost 100% of the care being provided by RNs; therefore, this was not used in the analyses.

Because different institutions offer employees different benefits and use various categories in payroll files, these data were standardized into 2 direct care working hours and wages categories: regular (which included working on holidays) and overtime. Compensation for nondirect care (such as administrators), paid time off, sick time, or educational benefits were not included.

Organizational climate was measured by surveying RNs using the Perceptions of Nurse Work Environment scale, which is a validated 42-item instrument. The respondent is asked to rate the extent a specific organizational trait is present using a Likert scale from 1 to 4 which includes items such as staff nurses are involved in the internal governance of the hospital, enough staff to get the work done, and a lot of teamwork between nurse and doctors. We chose to use the composite measure because of interest in identifying the importance of organizational climate, in general. The scale was internally consistent (Cronbach's $\alpha = 0.95$). Full reporting on the development and psychometric properties has been published elsewhere.[29] Each ICU was assigned an average score constructed by aggregating individual scores.

Profit margin was estimated from 2002 Medicare cost reports from each hospital and defined as the ratio of profit (ie, revenue minus expenses) to revenue. The hospitals' magnet accreditation status as of December 2002 was determined using the credentialing body's website and validated by each site coordinator.

Covariates

Comparisons of outcomes across settings are valid only if patients' underlying risks of illness are similar and/or adjustments are made. There are a number of severity of illness scores that have been developed to adjust for critical care patients' underlying illness using clinical data, such as the Acute Physiology and Chronic Health Evaluation.[30,31] However, these approaches have been found to have limited usefulness in benchmarking across ICUs, especially for infections.[32,33] Therefore, 2 state-of-the art measures of health status were used to capture distinct dimensions of patient severity of illness and risk for disease.

The diagnostic cost group hierarchical coexisting conditions (DCG/HCC) risk-adjustment method is based on the patient's hospitalizations over the 12-month time period, including the index hospitalization, and is an indicator of overall severity of illness.[34] For each outcome, the DCG/HCC was tailored for optimal risk adjustment with the minimal numbers of covariates. Three clinician investigators (P.S., C.K., and L.G.) reviewed the 184 condition categories; and, using clinical knowledge and the findings of exploratory analyses, they selected those that were likely to be associated with the outcome of interest, and then collapsed the categories into broad diagnostic groups. For example, for infections, categories such as drug/alcohol psychosis (which is not likely to be related to an increased risk for infection) were dropped. Categories that are associated with increased risk for infection, such as type I diabetes mellitus, were retained. The 60 retained categories were aggregated into 15 broad categories: infection, cancer, diabetes, liver conditions, gastrointestinal conditions, disorders of immunity, paralysis, coma, cardiac arrest, cerebrovascular injury, peripheral vascular disease, lung conditions, renal failure, transplant recipient, and chemotherapy recipient.

Second, to control for comorbid conditions upon admission, the Elixhauser et al method was used, which is based on the primary and secondary diagnoses of the index hospitalization.[35] Because this measure has only 30 categories it was not tailored. For a full discussion of this measure, see article by Elixahauser et al.[35]

Other patient characteristics that we controlled for in all analyses were gender, age, and socioeconomic status.[36] These variables were ascertained using the Medicare files and 2002 US census data.

Two hospital and 2 ICU-level variables, which have been found to be related to patients' risk for disease, were used as covariates. Hospital size and teaching status were obtained from AHA data. Teaching status was defined by membership (yes/no) in the Council of Teaching Hospitals. The ICU-level variables were nursing case-mix and unit type (eg, medical vs. surgical). Nursing case-mix was estimated using unit-specific nurse intensity weights, which has been used by other researchers.[11] These weights are a set of values ranging from 1 to 5 that measure the relative degree of nursing service provided to different types of patients based on diagnostic-related groups. A "peak" weight for ICU care is available. For example, an ICU patient with the diagnosis of extensive third-degree burns was assigned a weight of 4.73 compared with an ICU patient with an uncomplicated peptic ulcer who was assigned a weight of 1.91. An average monthly nursing case-mix was computed for each unit.

Statistical Analysis

When possible, variables were computed on a monthly basis. Individual patients were analyzed based on the month they were in the ICU. If a patient's stay covered more than 1 month, they were assigned to the period in which they had the longest stay. Patients were excluded from an analysis if: (1) infection surveillance was not conducted that month, (2) the risk adjustment perfectly predicted an outcome (eg, there was no variance in an outcome for a specific DCG/HCC category), or (3) the patient did not meet the defined inclusion criteria for decubiti.

Descriptive statistics were examined and multivariate logistic regressions were constructed for each outcome. Robust variance estimators (Huber–White)[37] were calculated and analyses were clustered at the hospital level to allow for an arbitrary variance–covariance matrix, adjusted odds ratios (OR) and 95% confidence intervals (CI) were examined. Psuedo R^2 were calculated for each model to examine the strength of the association of all variables with the outcome. To test the sensitivity of the results, we examined multiple other random and fixed effect models.

To explore the generalizability of results, hospital characteristics of the sample were compared with the national AHA data. Infection rates by ICU type were compared with the published rates for all NNIS ICUs.[38] For the latter, NNIS data are reported in infections per 1000 device days; therefore, we converted our results into a comparable metric using the 2002 reported average device utilization ratio per ICU type. To understand how the ICU might vary by the RN survey response rate, we regressed the hospital and ICU characteristics on the response rate. Furthermore, to examine representativeness of the nurse respondents, we compared demographics of our sample to critical care nurse respondents in the National Sample Survey of Registered Nurses 2000.[39] All statistical analyses were conducted in Stata 9.0. All statistical tests were 2-sided and $P \leq 0.05$ was considered significant.

RESULTS

The study sample comprised 15,902 patients from 51 ICUs in 31 hospitals. Patients were dropped from each multivariate analysis and the final sample sizes ranged from 15,846 for 30-day mortality to 5462 for VAP (Table 1); 1095 RN surveys were analyzed with an average response rate of 60% (range, 44% to 100%). There were no significant relationships between response rates and setting characteristics ($P > 0.05$). The respondents were of similar age and gender as the national sample of nurses ($P > 0.05$). Table 2 lists the summary statistics for the covariates and the independent variables. Although participating hospitals had the same geographic distribution as the national sample of hospitals ($P > 0.05$), they were larger and more likely to be affiliated with an academic institution ($P < 0.05$). The ICU infection rates were similar to the majority of NNIS participants.

The overall rates of the infections were low (CLBSI 0.95% [n = 61 of 6385], CAUTI 1.7% [n = 102 of 6031], VAP 1.5% [n = 81 of 5462]). The average 30-day mortality rate was 22% (3185 of 15,846) and the percentage of patients acquiring a decubitus ulcer was 2.0% (191 of 9554).

Results of the logistic regressions examining independent predictors of the patient safety outcomes clustered at the hospital level are reported in Table 3. In all models, various aspects of working conditions processes were found to be associated with each outcome measured and the pseudo R^2 indicated that the overall strength of the associations were significant. There were no substantive differences in the random and fixed effect models examined.

Patients admitted to ICUs in which the nurses' perceived a more positive organizational climate had a slightly higher odds of developing a CLBSI (adjusted OR 1.19; 95% CI, 1.05–1.36), but were 39% less likely to develop a CAUTI (adjusted OR 0.61; 95% CI, 0.44–0.83). Patients admitted to an ICU with more RN hours per patient day had significantly lower incidence of CLBSI, VAP, 30-day mortality, and decubiti ($P \leq 0.05$ for either the third or fourth quartile compared with the first). Staffing level was not significant in the CAUTI model, but the point estimates were in the same direction. In settings where nurses worked less overtime, patients experienced less CLSBI (third quartile compared with first quartile: adjusted OR 0.33; 95% CI, 0.15–0.72). Conversely, in settings where nurses worked more overtime, patients had increased odds of acquiring CAUTI ($P < 0.001$ across quartiles) and higher rates of decubiti (fourth quartile compared with first quartile: adjusted OR 1.91; 95% CI, 1.17–3.11). Nurses' wages were not associated with any of the patient safety outcomes.

The associations found between hospital profitability and patient outcomes were mixed. In the CAUTI, VAP, and decubiti models there were significant positive relationships; hospitals with the lowest profit margin had less adverse outcomes than those more profitable ($P \leq 0.05$). However, the results were in the opposite direction in the CLBSI model ($P < 0.001$). Magnet accreditation was not independently related to any of the patient safety outcomes measured.

TABLE 1. Number of Patients Excluded From Each Regression

	Infection Surveillance Not Conducted	Risk Factor Completely Predictive of Outcome	Did Not Meet Patient Safety Denominator	Total No. Patients Excluded From Analysis	Sample Size Analyzed
CLBSI	8931	586	N/A	9517	6385
CAUTI	9441	430	N/A	9871	6031
VAP	10,132	308	N/A	10,440	5462
30-d mortality		56	N/A	56	15,846
Decubitus ulcer		0	6384	6348	9554

N/A indicates not applicable.

TABLE 2. Operational Definitions and Summary Statistics of Covariates and Independent Variables

Variable	Operational Definition	Summary Statistic
Covariates		
Hospital level (N = 31)		
Size	Below median; ≤420 beds	279 (84)
	Above median; >420 beds	634 (289)
Teaching status	Yes	24 (78%)
ICU level (N = 51)		
Type	Surgical or cardiothoracic	10 (20%)
	Medical or coronary	12 (24%)
	Neurosurgical	3 (6%)
	Medical/surgical	26 (50%)
Nursing case-mix	Average nursing intensity weight	3.08 (0.15)
Patient level (N = 15,846)		
Age (yr)	65–74	6625 (41%)
	75–79	4025 (25%)
	80–84	3046 (19%)
	85 or older	2238 (14%)
Gender	Female	7502 (47.3%)
Socioeconomic status	Median income of patient's zipcode	$30,000 (13,900)
	Percentage of population living in poverty in patient's zip code	8 (7.7)
Independent Variables		
ICU-level administrative processes related to nurse working conditions (N = 51)		
Staffing	Registered nurse hours per patient day	17.0 (5.1)
Overtime	Proportion of overtime hours to regular hours	5.6 (3.1)
Wages	Average nurse wage per ICU adjusted by overall nurse wages per metropolitan statistical area	1.2 (0.16)
Organizational climate	Perception of nurse work environment	2.9 (0.25)
Hospital level structures of care (N = 31)		
Magnet	Yes magnet accreditation	4 (14%)
Profit	(Revenue-Expenses)/Revenue	0.04 (0.05)

Summary statistics are reported as means with standard deviations in parentheses for continuous variables and sample sizes with percentages in parentheses for categorical variables.

DISCUSSION

This study is the first to link NNIS infection surveillance data and other patient outcomes to nurse working conditions and may be one of the most comprehensive examinations of nurse working conditions to date. We found that aspects of administrative processes related to nurse working conditions are associated with all outcomes measured.

The relationships between the nurses' perceived organizational climate and outcomes were not consistent. These findings may be due to the roles of the ICU team members. For example, urinary catheter insertion and care are routinely performed by staff nurses, whereas subclavian catheter insertion (a major risk factor in CLBSI) is usually performed by medical staff.[40] This does not imply that nursing care is not important in preventing CLBSI. Clearly, it is the nurses' role to care for these lines, participate in the surveillance of patients for early signs of infection, and assess the continuing need for line placement on daily basis, all of which are vital in the prevention of these serious infections. However, care of urinary catheters primarily is the responsibility of nurses, and CAUTI may be more sensitive to nursing care. As previously reported, we found organizational climate to be an important factor in nurses' intention to leave.[41]

Previous researchers have found that nurse-to-patient ratios and the composition of the nursing skillmix are associated with various patient outcomes. We found the level of RN staffing per patient to be significantly associated with CLBSI, VAP, 30-day mortality, and decubiti; additionally there were similar (albeit nonsignificant) point estimates in CAUTI. Although nursing skillmix may be an important staffing variable in some settings, we did not find enough use of nurse's aides or licensed vocational nurses in the ICU to examine skillmix in this setting.

To our knowledge, no previous studies have estimated effects of overtime on patient safety outcomes. We found that increased overtime was associated with the patients' risk of CAUTI and decubitus ulcer. Interestingly, less overtime was associated with lower incidence of CLBSI. This may again be related to the importance of interdisciplinary care in prevention of CLBSI and/or other nonmeasured factors.

Other researchers have found that overtime varies dramatically across hospitals,[42] and nurses' working overtime

TABLE 3. Adjusted Odds Ratios Indicating the Effects of Nurse Working Conditions on Patient Safety Outcomes

	CLBSI (n = 6385)		CAUTI (n = 6031)		VAP (n = 5462)		30-d Mortality (n = 15846)		Decubitus Ulcer (n = 9554)	
Variable	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Administrative processes: nurse working conditions										
Organizational climate	1.19†	1.05–1.36	0.61†	0.44–0.83	1.03	0.79–1.34	0.97	0.90–1.02	1.06	0.83–1.37
Staffing										
Second quartile	0.97	0.55–1.17	0.79	0.50–1.25	0.71	0.43–1.19	0.89	0.77–1.02	0.94	0.64–1.39
Third quartile	0.32†	0.15–0.70	0.96	0.44–2.07	0.68	0.39–1.21	0.81†	0.69–0.95	0.69*	0.49–0.98
Fourth quartile	0.57	0.20–1.67	0.86	0.37–1.98	0.21†	0.08–0.53	0.89	0.76–1.05	1.01	0.63–1.61
Overtime										
Second quartile	0.67	0.24–1.88	2.53‡	1.66–3.86	0.76	0.24–2.39	0.99	0.80–1.21	1.39	0.82–2.34
Third quartile	0.69	0.33–1.44	3.54‡	1.95–6.40	0.88	0.39–1.95	1.03	0.80–1.32	1.16	0.67–2.03
Fourth quartile	0.33†	0.15–0.72	4.72‡	2.21–10.05	1.26	0.53–2.96	1.06	0.91–1.31	1.91*	1.17–3.11
Nurses' wages	0.91	0.73–1.13	1.15	0.96–1.36	1.16	0.91–1.48	0.97	0.90–1.02	0.98	0.83–1.23
Structures of care										
Profit										
Second quartile	0.68	0.25–1.81	1.85*	1.04–3.31	4.47‡	2.42–8.27	1.04	0.90–1.21	1.76*	1.21–2.78
Third quartile	0.85	0.31–2.31	1.48	0.58–3.74	1.51	0.55–4.08	0.85	0.67–1.06	0.80	0.44–1.44
Fourth quartile	0.11‡	0.04–0.30	1.11	0.56–2.17	2.55†	1.20–5.43	0.85	0.71–1.03	0.81	0.41–1.57
Magnet	0.67	0.30–1.50	0.74	0.23–2.29	1.04	0.23–4.71	0.92	0.73–1.17	1.57	0.93–2.65
Pseudo R^2	0.19‡		0.15‡		0.15‡		0.18‡		0.14‡	

All models are estimated with robust standard errors clustering for intensive care unit. All models are adjusted for a comprehensive set of (1) patient characteristics, including severity of illness, comorbidities, demographics, and socioeconomic status, and (2) setting characteristics, including hospital size and teaching status and ICU type and case-mix.

$^{*}P \leq 0.01$; $^{\dagger}P \leq 0.05$; $^{\ddagger}P \leq 0.001$.

self-report making errors more frequently.[13] Overtime is one of the staffing effectiveness, human resource indicators put fourth by the Joint Commission of Accreditation of Hospitals Organization[43]; however, overtime has not been endorsed by the National Quality Forum (NQF) or the American Nurses' Association as a nursing-sensitive performance measure.[44,45] Overtime may be an important indicator of the work environment.

Wages were not found to be independently associated with any of the outcomes measured. Hospitals' profitability was associated with outcomes, but not in a consistent manner: more profitable hospitals had better CLBSI outcomes but worse CAUTI, VAP, and decubiti outcomes. The reason for these opposing findings is not clear and further research is warranted examining the relationships between hospital profitability, nurse working conditions, other organizational factors, and patient outcomes.

In the development of Agency for Healthcare Research and Quality's patient safety indicators, 4 measures (decubiti, failure to rescue, postoperative pulmonary emboli or deep vein thrombosis, and postoperative respiratory failure) were identified as potentially being sensitive to levels of hospital staffing.[28] In our sample, because of the small number of surgical ICUs, there were limited number of cases identified for failure to rescue, postoperative pulmonary emboli or deep vein thrombosis, and postoperative respiratory failure, and these outcomes could not be analyzed.

In 2004, NQF published consensus standards to measure nursing-sensitive care and this study uses many similar measures.[45] Three of NQF's patient-centered outcome measures relate to patients' probability of acquiring CLBSI, VAP, and UTI in ICUs using CDC NNIS definitions (ie, device-associated infection/number of device days $\times$ 1000). To control for individual-level patient characteristics we did not use the same aggregate unit level reporting mechanism. Nevertheless, the protocols for identifying an infection followed the CDC NNIS standards. NQF endorsed pressure ulcer prevalence as a patient-centered outcome measure; however, their definition is not based on discharge diagnoses as was the measure used in this study. Last, 2 of NQF's system-centered measures (ie, nursing care hours per patient day and the Practice Environment scale) are similar to measures used in this study. Our staffing measure was based on payroll data, and therefore, does not include contract nurses as recommended by NQF. Our measure of organizational climate, the Perceptions of Nurse Work Environment and the Practice Environment scale, both were developed from the Nursing Work Index-revised and have many similarities.[29]

Strengths and Limitations of Analysis

A strength of this study is the comprehensiveness of the dataset used, which included information on clinical infection surveillance, patient risk factors and outcomes, hospital and ICU demographics, organizational climate, and other nurse working conditions. However, there were still variables that were not measured, such as presence of an intensivist, measures of climate from non-nursing personnel, other human capital variables, such as team stability and specific clinical processes (eg, use of evidence-based protocols).

The use of payroll data is both a strength and limitation. Unit-level payroll data is an improvement over use of datasets that do not distinguish between staffing for inpatient and outpatient settings[46]; however, there are limitations. Nurses may float between units, which results in measurement error. Furthermore, payroll data does not capture whether overtime is mandatory or voluntary or the use of contract nurses.

Although the dataset decreases some measurement error found in many previous studies, the infrastructure needed to allow participation limited the sample size. Congruent with NNIS protocols, hospitals chose the number of months and the type of device-associated infection surveillance they conducted, which further limited the sample sizes. Furthermore, most NNIS hospitals are large academic institutions and the ICU participants were representative of those in NNIS.[47] However, the results may not be generalizable to smaller, nonacademic, non-ICU settings.

Although the most rigorous design is a prospective randomized control trial, such design is not feasible for our specific aims and comparability of groups needs to be addressed. We used comprehensive sets of patient and setting characteristics to help ensure comparability; however, as with all observational studies there are many unmeasured variables and selection bias cannot be ignored.

Future researchers, managers, and policymakers should consider a broad set of working condition variables, including overtime and other aspects of human capital (eg, educational preparation and staffing stability). Larger sample sizes and longitudinal data would be beneficial. Exploration of human capital variables (ie, experience and education) as a possible moderator of the relationship between organizational climate, staffing, and patient outcomes may add further clarity to these issues.

These results support the systems approach and that improving nurse working conditions can improve patient safety. Substitutes for overtime, such as availability of increased qualified float nurses through cross training, should be explored to meet fluctuating staffing needs.

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