The Impact of Hospital Nursing Characteristics on 30-Day Mortality

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► ***Background:*** Evidence indicates that hospital nursing characteristics such as staffing contribute to patient outcomes. Less attention has been given to other hospital nursing characteristics central to optimal professional practice, namely nurse education and skill mix, continuity of care, and quality of the work environment.

► ***Objective:*** To assess the relative effects and importance of nurse education and skill mix, continuity of care, and quality of work environment in predicting 30-day mortality after adjusting for institutional factors and individual patients characteristics.

► ***Method:*** A cross-sectional analysis of outcome data for 18,142 patients discharged from 49 acute care hospitals in Alberta, Canada, for diagnoses of acute myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, pneumonia, or stroke between April 1, 1998, and March 31, 1999, was done. Mortality data were linked to patient demographic and comorbidity factors, institutional characteristics, and hospital nursing characteristics derived from a survey of all registered nurses working in acute care hospitals.

► ***Results:*** Using multilevel analysis, it was determined that the log-odds for 30-day mortality varied significantly across hospitals (variance = .044, $p < .001$). Patient comorbidities and age explained 44.2% of the variance in 30-day mortality. After adjustment for patient comorbidities and demographic factors, and the size, teaching, and urban status of the study hospitals in a fixed-effects model, the odds ratios (95% confidence interval) of the significant hospital nursing characteristics that predict 30-day mortality were as follows: 0.81 (0.68–0.96) for higher nurse education level, 0.83 (0.73–0.96) for richer nurse skill mix, 1.26 (1.09–1.47) for higher proportion of casual or temporary positions, and 0.74 (0.60–0.91) for greater nurse-physician relationships. The institutional and hospital nursing characteristics explained an additional 36.9%.

► ***Discussion:*** Hospital nursing characteristics are an important consideration in efforts to reduce the risk of 30-day mortality of patients.

► ***Key Words:*** nurse staffing · hierarchical models · patient outcomes

In the 1990s, North American hospitals experienced restructuring and downsizing on a scale not witnessed before in the healthcare industry. Nursing job losses were estimated in the tens of thousands in the United States and Canada as a result of widespread hospital closures and mergers, the transfer of inpatient care to ambulatory and home settings, and double-digit percentage reductions in hospital budgets (Blythe, Baumann, & Giovannetti, 2001; Norrish & Rundall, 2001). In addition, in Canada, widespread regionalization of health authority governance structures resulted in major hospital restructuring and subsequent displacement of large numbers of nurses (Blythe et al., 2001; O'Brien-Pallas & Baumann, 2000). The effects that hospital restructuring had on the nurses remaining in the workforce included (a) significant decreases in *job satisfaction*; (b) increases in *staff turnover*; (c) reductions in *professional efficacy* and *ability to provide quality care*; (d) negative physical and psychological health effects; and (e) disruption to *healthcare team* relationships (Cummings & Estabrooks, 2003). A typical Canadian experience was that of the province of Alberta. The second Canadian province to redesign the governance structures for all health sectors within the province, it created 17 health regions (governed by Regional Health Authorities) to replace 283 hospital and community health boards, followed by a complete reorganization of the administrative infrastructure and processes in each of the new regional health authorities. The provincial healthcare budget was reduced by 12.2% over 3 years and 3,100 nurses (12% of the total Alberta nursing workforce) were laid off (Maurier & Northcott, 2000). However, the number of nurses affected escalated beyond this as nurses

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with more seniority exercised displacement rights afforded by the provincial collective bargaining agreement.

Research results in Canada and the United States have shown that the effects of restructuring on nursing are strongly linked to increased adverse patient events, morbidity, and mortality (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Cho, Ketefian, Barkauskas, & Smith, 2003; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002; Tourangeau, Giovannetti, Tu, and Wood, 2002). Recently, Needleman and Buerhaus (2003) argued that despite the difficulties investigators face (e.g., with data limitations and measurement problems), a breadth of studies now exist that provide compelling, if not yet conclusive, evidence of the contribution of nurse staffing on mortality and other important patient outcomes. Aiken, Clarke, Cheung, Sloane, and Silber (2003) recently argued that higher *nurse education* levels lower mortality. Previous studies have also reported that *nursing education* exerted a positive influence on selected nurse and patient outcomes (Blegen, Vaughn, & Goode, 2001; Johnson, 1988; O'Brien-Pallas et al., 2002; Young, Lehrer, & White, 1991) but did not examine its effect on mortality. The positive effect of better *nurse–physician relationships* on patient outcomes has been a consistent finding since the 1986 study by Knaus, Draper, Wagner, and Zimmerman (Shortell et al., 2000; Shortell, Rousseau, Gillies, Devers, & Simons, 1991).

The responding nurses were representative of nurses in the province with respect to age, sex, specialty, level of education, and marital status.

Previous research indicated that hospital-level nursing characteristics would be important to consider when examining the impact of nursing on patient outcomes such as mortality (Silber, Williams, Krakauer, & Schwartz, 1992). Staff expertise, a domain of variables, became an area of interest. Not only have researchers (Aiken et al., 2002; Needleman et al., 2002) suggested a positive association between nurse staffing levels and patient outcomes such as mortality, but Aiken et al. and Elixhauser, Steiner, and Fraser (2003) have suggested that staff expertise (e.g., education) contributed to patient outcomes such as mortality. It was reported that quality of care, as an index of *nursing tasks left undone* was an important predictor of unmet patient needs (Sochalski, 2001). Duncan et al. (2001) argued that *emotional abuse* adversely affects provider (in this case nurse) outcomes. Previous research indicates that patient outcomes, specifically mortality, are adversely affected by lower job satisfaction, higher proportions of casual or temporary staff, higher number of nonnursing tasks done by nurses, lower professional nurse autonomy, and greater floating by nurses. As well, it may be the case that variables such as these are more amenable to managerial interventions (although not necessarily more *easily* changed) than are staffing levels.

The previous studies cited and others have generally been premised on single-level models that predict, for example, that fewer hours of nursing care per patient or lower levels of nursing education contribute to increased mortality, complications and failure to rescue (death due to in-hospital complications). The current researchers argue that such studies may under- or overestimate the contribution of hospital nursing characteristics to patient outcomes, and that if hierarchical or multilevel modeling is used more robust estimates are obtained.

Methods

Setting

The current study is derived from the Alberta arm of the larger International Hospital Outcomes study (Sochalski, Estabrooks, & Humphrey, 1999). Alberta, a western Canadian province, has a population of just over 3 million. Two thirds of the provincial population is concentrated in two major urban centers, and the remaining third is dispersed throughout the province. At the time of data collection there were 17 regional health authorities in the province governing 109 hospitals employing approximately 12,000 registered nurses. Approximately 80% of the residents are served by 20% of the hospitals. The remaining 20% of the people are served by a much larger number of small hospitals.

Patient data and outcomes from hospital discharge abstracts and vital statistics were analyzed. Regional health authorities provided hospital characteristics, and the hospital nursing characteristics were obtained from a survey of all registered nurses working in acute care hospitals in Alberta.

Data Sources and Procedures

Hospitals The sample consisted of all 49 of 109 total acute care hospitals in the province that met two criteria: (a) hospital size of at least 20 beds and (b) hospitals that had responses from at least five registered nurses on staff. While a minimum of five nurse respondents was required for a hospital to be included in the sample, the actual number of respondents per hospital ranged from 8 to 1019. Psychiatric, pediatric, oncology, and long-term care facilities were excluded from the study design. Regional health authorities provided information on hospital characteristics, including location, number of beds, teaching status, and use of high technology, for each hospital. All nurses who responded to the survey from the selected hospitals were included in the analysis. The response rates from the individual hospitals ranged from 18% to 100%.

Hospital Nursing Staff All registered nurses working in acute care hospitals in Alberta (according to Alberta Association of Registered Nurses registry records) were mailed a questionnaire survey between September 1998 and February 1999. There were 6,526 surveys received for a 52.8% response rate of the provincial census of hospital nurses. The responding nurses were representative of nurses in the province with respect to age, sex, specialty, level of education, and marital status. Questions about various facets of the work environment, including nursing skill mix, use of casual and temporary nurses, quality of care, job satisfaction, and their own educational preparation were asked.

While many of the questions were developed specifically for this survey, the revised Nursing Work Index (NWI-R) (Aiken & Patrician, 2000) and the Maslach Burnout Inventory (Maslach, Jackson, & Leiter, 1996) were incorporated into the survey. Several of the questions for this study were items from the NWI-R. The psychometric properties of the NWI-R in this sample were demonstrated earlier (Estabrooks et al., 2002). The responses of nursing staff ($N = 4{,}799$) representing the 49 selected hospitals were aggregated to the hospital level. Five empirical indices were used to assess the psychometric properties of the nurse data at the hospital level.

Patients and Patient Outcomes Discharge abstracts were obtained from the Hospital Inpatient Database, maintained by the Canadian Institute for Health Information (CIHI), for 18,142 patients discharged between April 1, 1998, and March 31, 1999. The patients were admitted for acute myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, pneumonia, or stroke. These medical conditions were selected because they were acute, high-volume, and had high crude death rates. The discharge abstracts included patient information on age, sex, vital status at discharge, and comorbid conditions, as well as most responsible diagnosis. The Charlson index, as modified by Deyo, was used (Charlson, Pompei, Ales, & McKenzie, 1987; Deyo, Cherkin, & Ciol, 1992) to adjust for the risk of comorbidities on mortality.

Deaths of Alberta residents are recorded on the Alberta Health Care Insurance Plan Registry (AHCIPR). The patient data were linked with the registry to identify those persons who died within 30 days of admission, which helped identify deaths that occurred following discharge from the hospital.

Data Analysis

Descriptive statistics (means, *SD*s, and percentages) and significance tests (χ^2 and ANOVA) were used for comparisons of hospital characteristics, hospital nursing characteristics, and patient variables. Nurse data were aggregated for each hospital and reliability measures were assessed for all aggregated variables included in this analysis (Bleise, 2000). One-way analysis of variance (ANOVA) was performed for each variable using the 49 hospitals as groupings. The between-mean-square (BMS) and the within-mean-square (WMS) from the source table of the one-way ANOVA were used to calculate the two intra-class correlations ICC(1) and as: ICC(1) = (BMS − WMS)/(BMS + [K − 1]WMS), where K is the number of participants per group; and ICC(2) = (BMS − WMS)/BMS. The sum of squares between (SSB) and the sum of squares total (SST) from the source table of the one-way ANOVA were used to calculate the eta-squared (η^2) (Hays, 1988) as η^2 = SSB/SST. The omega-squared (ω^2) (Keppel, 1991, p. 66) was calculated as ω^2 = SSB − (K − 1)WMS/(SST + WMS). Since the number of nurses in the sample varied for each hospital, the average hospital size K (calculated = 89, actual = 98) = $(1/[N - 1])(\Sigma K - [\Sigma K^2/\Sigma K])$ as suggested by Tinsley and Weise (1975) for unequal group sizes was used. For each nursing characteristic analyzed, there was strong agreement among nurses in each given hospital when ICC(1) was greater than 0.1. Aggregated nursing data were deemed reliable when the F statistics from the ANOVA table was significant ($p < .05$) and ICC(2) was greater than 0.60. An indicator of effect size was η^2, which was the proportion of variance in the individual factor accounted for by group membership (Rosenthal & Rosnow, 1991), and ω^2 was a measure of the relative strength of the aggregated variable at the group level (Keppel, 1991, p. 66).

Hierarchical generalized linear model (HGLM) techniques in HLM 5.0 were used (Raudenbush & Bryk, 2002) with a logit link function to partition the variance in patient mortality into two components—patient level and hospital level. The dependent variable was the vital status of the patient at 30 days after admission (1 = *dead*, 0 = *alive*). Using an empty model (i.e., a model without an independent variable), the hospital-level variability in log-odds for 30-day mortality (null variance) was calculated first and its significance assessed using the p-value statistic. A variance with a p value less than .05 was considered significant.

To estimate the independent effect of hospital nursing variables, the effect of comorbidities using comorbidity scores, patient age, and gender was adjusted first. These factors were included in the model at the patient level (Level 1). Initially, hospital nursing variables in a random-intercept model (i.e., the effect of patient-level variables was assumed fixed within each hospital), and later in a random coefficient model (i.e., the effect of patient-level variables was assumed random across hospitals) were assessed. This allowed a comparison of the effects of the hospital nursing variables obtained by the fixed-effects model to those obtained by the random-effects model with random coefficients for comorbidity and age variables.

In a subsequent model, the residual variance in log-odds for 30-day mortality at the hospital level, after adjusting for the effect of institutional factors, was modeled as a function of the hospital nursing explanatory variables at the hospital level (Level 2). The means of all hospital nursing variables were incorporated at the hospital level of the hierarchy, and the significance of each was tested before inclusion in the final multivariate risk-adjusted model. To determine the percentage of hospital differences in 30-day mortality that was explained by the adjusted regression model, the percentage of explained hospital-level variance (hospital-level R^2) was calculated, using $(\sigma^2_{\text{null}} - \sigma^2_{\text{regression}})/\sigma^2_{\text{null}}$, where σ^2_{null} was the estimate of the initial (null) variance at the hospital level when no factor had been added to the model and $\sigma^2_{\text{regression}}$ was the hospital-level residual (or adjusted) variance for given sets of predictor variables in the model (Merlo, Ostergren, Broms, Bjorck-Linne, & Liedholm, 2001). The interclass (hospital) correlation (ICC) was calculated using the formula $\sigma^2_{\text{null}}/(\sigma^2_{\text{null}} + \pi^2/3)$, as suggested by Snijders and Bosker (1999). Each model parameter was estimated using the restricted penalized quasi-likelihood (PQL) function. The effects of the estimated hospital nursing variables using both fixed-effects model and random-effects models are presented as an odds ratio (OR) and a 95% confidence interval (95% CI), with corresponding p values (Tables 5 and 6).

Results

Characteristics of the Patient Population and Selected Hospitals

For this study, the focus was on hospital nursing characteristics reflective of the delivery of nursing services. The key variables that were selected and analyzed at the hospital level are displayed in Table 1. The indices for the measures were used to evaluate the reliability of the aggregated mean scores for each nursing characteristic.

The responding nurses were representative of nurses in the province with respect to age, sex, specialty, level of education, and marital status. The reliability and validity properties of the aggregated nursing data at the hospital level are shown in Table 2. These properties supported the reliability of the aggregated data at the hospital level. Significant ($p < .05$) F statistics and ICC(2) values greater than 0.60 indicate greater reliability and justification for aggregating the variables at the hospital level. The ICC(1) values greater than 0.00 indicate some degree of perceptual agreement of nurses about the mean values within each hospital. That is, the nurses' perceptions about their own hospital were highly similar. However, the relative effect sizes for both η^2 and ω^2 values were smaller, suggesting that, as we aggregated data, it was not possible to *carry up* as much information from the individual level to the hospital level as would have been optimal.

Descriptive statistics for the institutional and hospital nursing characteristics for the 49 hospitals (Table 3) show that for institutional factors, 79.6% of the hospitals were classified as small (≤150 beds; small and medium hospitals were collapsed into one category for analysis), and 20.4% as large (>150 beds). All four (8.2%) major teaching hospitals were large hospitals located in larger cities. Only 2 of the 49 hospitals studied (4.1%) were high-technology hospitals; hence this factor was not included in the model. Descriptive statistics for patient age, sex, comorbidities, and mortality across the five selected primary diagnostic groups (Table 4) indicate that of the 18,142 patients in the study population, a total of 1,460 (8.0%) deaths were recorded within 30 days of admission.

Effect of Patient-Level Characteristics

The estimate of 30-day mortality at an average hospital, obtained using a null hierarchical model with no other factors in the model, was 8.21%. The unadjusted variability in the log-odds of 30-day mortality rates among the 49 hospitals was 0.044 ($p < .001$) and the ICC was 0.0132. After adjusting for patient comorbidities, the mean risk-adjusted 30-day mortality rate was 6.97% and the residual variability (or variance) among hospitals was 0.027 ($p = .002$). This was smaller than the unadjusted variance of 0.044. Comparing these two estimates, 39.17% of the between-hospital variance in log-odds for mortality was accounted for by differences in patient comorbidities across hospitals. After further controlling for patient age and sex, the residual variance in log-odds for 30-day mortality reduced to 0.024 ($p = .006$) but still varied significantly across hospitals. Age and sex accounted for a small proportion of the variance (5.04%), after adjusting for comorbidities. At the patient level, patient age and comorbidities were strong determinants, collectively accounting for 44.22% of the observed differences in 30-day mortality across hospitals.

Effect of Institutional and Hospital Nursing Variables

The estimated effect of each institutional and hospital nursing variable after adjusting for comorbidities, patient age at admission, and sex are presented in Table 5. In order to remain in the multivariate model at the hospital level, a variable had to be a statistically significant predictor of mortality in the univariate model and have a nontrivial effect size (i.e., estimated model coefficient >.01). Eleven hospital nursing variables were included that were significant in the univariate analysis, but only four were statistically significant predictors of mortality in the multivariate model: nurse education levels, staff skill mix, nurse–physician relationships, and employment status. An additional 36.93% of the variance in log-odds for 30-day mortality was explained by the collective effect of these variables after risk adjustment and controlling for age and sex. The adjusted effect of the hospital nursing variables on 30-day mortality can be interpreted as follows.

Nurse Education In the current model, hospitals with a higher proportion of baccalaureate-prepared nurses were associated with lower rates of 30-day patient mortality, OR, 0.81 [95% CI (0.68, 0.96)].

Skill Mix Hospitals with a higher proportion of richer skill mix of registered nurses (ie higher RN-to-non-RN ratios) were associated with lower rates of 30-day patient mortality, OR, 0.83 [95% CI (0.73, 0.96)].

Employment Status In the same model, hospitals with a higher proportion of casual and temporary nurses were associated with higher rates of 30-day patient mortality, OR, 1.26 [95% CI (1.09, 1.47)].

Nurse-Physician Relationships In the same model, hospitals with higher scores on collaborative nurse–physician relationships were associated with lower rates of 30-day patient mortality, OR, 0.74 [95% CI (0.60, 0.91)].

These results were premised on the assumption that patient-level effects were the same (nonrandom) across the hospitals in the study. After allowing the patient-level effects to vary in a random-effects model across the hospital, it was noted that the assumption of fixed, nonrandom effects for patient comorbidities was not true. When further adjustments were made in a random-effects model, the variance for the log-odds of mortality was 0.061 ($p = .001$) and for the random effects of patient comorbidities across the hospital level it was 1.030 ($p < .001$). Hence, the effect of institutional and hospital nursing variables was reestimated, allowing the effects of comorbidity factors to vary across hospitals. Comparing the results (Table 6) of the multivariate estimates of hospital nursing factors obtained from the alternative (i.e., random coefficient of the morbidity variable) hierarchical model to the fixed-effects model obtained earlier did not change the current conclusion. However, there were some appreciable differences in the magnitude of the effect size.

TABLE 1. Selected Survey Items and Codes Used for Hospital Nursing Variables

Nursing Characteristics	Survey Sections[a]	Survey Questions and Response Codings
Nurse education level	F	Q5. What is your highest registered nurse credential? (1. Diploma; 2. Baccalaureate; 3. Masters; 4. Otherwise) *Recoded values*: 1 = 0; 2, 3, and 4 = 1.
Skill mix (RN to total nurse staff)	E	Q7. How many of each of the following worked on your unit during your last shift: registered nurses(RNs), licensed practical nurses (LPNs) unlicensed assertive personnel, nursing students? *Derived variable*: Percentage of RNs to total nursing staff, i.e., RNs, LPNs, Nursing Assistive Personnel nursing students)
Employment status: casual or temporary staffs	A	Q2. Is your employment permanent, temporary, or casual? (1. Permanent; 2. Temporary; 3. Casual) *Recoded values*: 1 = 0; 2 and 3 = 1
Perception of staffing adequacy	B	Q12. Enough registered nurses on staff to provide quality patient care. (1. Strongly disagree; 2. Somewhat disagree; 3. Somewhat agree; 4. Strongly agree)
Patient's care needs unmet[b]	E	Q13: Which of the following tasks were necessary but left undone because you lack the time to complete them? *Circle those that apply.* 1. Routine teaching for patients and family; 2. Prepare patients and family for discharge; 3. Comforting/talking with patients; 5. Backrub and skin care; 7. Oral hygiene.
Nonnursing activities performed by nurses[b]	E	Q12. Which, if any, of the following tasks did you perform during your last shift? *Circle those that apply*. 1. Delivering and retrieving food trays; 2. Ordering, coordinating, or performing ancillary services (e.g., Physio, ordering lab work); 3. Starting IVs; 4. Arranging discharge referrals and transportation (including to nursing homes); 5. Performing ECGs; 6. Routine phlebotomy; 7. Transporting of patients; 8. Housekeeping duties (e.g., cleaning patient rooms).
Nurse work satisfaction	D	Q1. On the whole, how satisfied are you with your job? (1. Very dissatisfied; 2. A little dissatisfied; 3. Moderately satisfied; 4. Very satisfied)
Support for nonfloating policy	B	Q46. Staff nurses do not have to float from their designated units. (1. Strongly disagree; 2. Somewhat disagree; 3. Somewhat agree; 4. Strongly agree)
Nurse autonomy	B	Q17. Freedom to make important patient care and work decisions. (1. Strongly disagree; 2. Somewhat disagree; 3. Somewhat agree; 4. Strongly agree)
Nurse–physician relationship[b]	B	Q2. Physicians and nurses have good working relationships. Q24. A lot of teamwork between nurses and physicians. (1. Strongly disagree; 2. Somewhat disagree; 3. Somewhat agree; 4. Strongly agree) *Derived variables*: This variable is the sum of responses to the two items above.
Emotional abuse	D	Q8. Over the past year how often would you say the following incident has occurred involving you or your patient? #6. Incident of verbal abuse directed toward you or your patient. (1. Never; 2. Rarely; 3. Occasionally; 4. Frequently).

Note. The various sections were preceded by the following statements Section A: This section asks questions about your job as an RN. Please circle the number of the appropriate response to each question or, where indicated, fill in the blanks. Section B: For each item in this section, please indicate the extent to which you agree that the following items *are present in your current job*. Indicate your degree of agreement by circling the appropriate number. Section D: This section asks about your job as an RN and asks for your views about the care on your nursing unit in your hospital. Please circle the number of appropriate response to each question or, where indicated, fill in the blank. Section E: This section asks about nursing activities during the *last full shift* that you worked. Please circle the number of the appropriate response to each question or, where indicated, fill in the blanks. Section F: This section asks about you and your background. Please circle the number of the appropriate response to each question, where indicated, fill in the blanks.

[a]http://www.nursing.ualberta.ca/kusp/images/PDFfiles/Alberta%20Nurse%20Survey%20Final%20 Report,%2024july02.pdf

[b]Variable was derived as count of items above circle.

TABLE 2. Reliability and Validity of Nurse Data Aggregated at the Hospital Level

Hospital Nursing Characteristics	Mean (*SD*)[a]	Mean (*SD*)[b]	Range[c]	ANOVA *F* (*df*)	ICC(1)	ICC(2)	η^2	ω^2
Nurse education[d]	0.22 (0.41)	0.15 (0.11)	0.00–0.50	4.28** (48; 4734)	0.035	0.767	0.042	0.024
Skill mix	0.66 (0.42)	0.59 (0.11)	0.29–0.77	8.937** (48; 4378)	0.081	0.888	0.089	0.071
Casual or temporary staff	0.25 (0.44)	0.11 (0.05)	0.01–0.25	1.522* (48; 4750)	0.006	0.344	0.015	0.003
Perception of staffing adequacy	2.19 (0.93)	2.00 (0.47)	1.00–3.06	7.833** (48; 4725)	0.071	0.872	0.074	0.056
Patient care needs unmet	1.29 (1.41)	1.39 (0.59)	0.61–3.17	3.689** (48; 4750)	0.029	0.729	0.036	0.018
Nonnursing activities	3.20 (1.85)	3.81 (0.58)	2.81–5.50	5.192 (48; 4750)	0.045	0.807	0.050	0.032
Nurse job satisfaction	2.85(0.86)	2.73 (0.31)	2.08–3.47	3.21** (48; 4730)	0.024	0.689	0.032	0.013
Support for nonfloating policy	2.98 (1.04)	2.54 (0.52)	1.33–3.39	20.15** (48; 4625)	0.176	0.950	0.173	0.157
Nurse autonomy	2.66 (0.74)	2.43 (0.26)	2.00–3.11	3.94** (48; 4723)	0.032	0.746	0.038	0.020
Nurse–physician relationship	5.73 (1.36)	5.70 (0.56)	4.33–7.18	4.650** (48; 4749)	0.039	0.785	0.045	0.027
Emotional abuse	2.75 (0.93)	2.83 (0.26)	2.44–3.46	2.13** (48; 4750)	0.012	0.532	0.021	0.003

Notes. (a) Analysis of variance (ANOVA): Measure used to compare differences in mean score of nursing characteristics across hospitals; (b) *p* values for ANOVA *F* statistics: *$p < .05$; **$p < .01$. The denominator, degree of freedom, differs for some nursing variable owing to missing values. (c) Measures of intraclass correlation (ICC): ICC(1) measures the perceptual agreement of individual nurse score about the group mean for each hospital. ICC(2) measures the likelihood of obtaining similar mean scores if more subgroups were drawn repeatedly from the same population within each hospital. Values for ICC(2) greater than 0.60 justify aggregation of the nursing data at the hospital level. (d) η^2: Proportion of total information in a given factor at the individual level, which is captured by the aggregated data. (e) ω^2: provides a relative measure of strength of a factor used as an independent variable–small effect, <0.06; medium effect, 0.06–0.15; large effect, >0.15.

[a]Overall sample means.

[b]Between-group means.

[c]Range of aggregated mean values across hospitals.

[d]Nurse education variable in the ANOVA was coded as 1 (*diploma*), 2 (*baccalaureate*), 3 (*masters*), 4 (*otherwise*), but was recoded as 1 = 0; and 2, 3, and 4 = 1 for the hospital-level analysis.

Discussion

Hierarchical modeling was used to analyze hospital nursing characteristics and other institutional characteristics that determine patient outcomes across Alberta hospitals, thus accounting for the inherent hierarchical structure of the data. This approach untangles sources of variation in patient outcomes and partitions it into two distinct levels: variation attributable to patient and institutional characteristics and variation attributable to hospital nursing characteristics. Hierarchical linear modeling has been used widely by social scientists for the last two decades, particularly in the field of education (Raudenbush & Bryk, 2002). These models are also known as random-coefficient regression models, mixed-effects and random-effects models, and covariance component models (Witte, 1997). Recently, these models have been used in health services research to analyze data involving intercluster units (Longford, Bentham, & McDonald, 1998; Merlo et al., 2001).

In this analysis it has been demonstrated that variations in log-odds for 30-day mortality across hospitals can be explained by patient and institutional characteristics, and hospital nursing variables. The initial analysis indicated a significant variance (*p* values) of .044 (.001) across hospitals. On further analysis, the residual or unexplained variance was .027 (.002) after adjusting for comorbidities; .025 (.005) with the addition of patient age and sex; and .008 (.030) when institutional and hospital nursing characteristics were added. The *p* value for unexplained variance after the final model was .03, which was less than the .05 conventional cutoff, hence other factors at the hospital level need to be explored further to explain the variability in 30-day mortality across hospitals. Novel features of this study are the partitioning of variance in patient mortality into patient and hospital levels, and the simultaneous modeling of variables at the patient and hospital levels that explain this variation.

Significant interhospital differences were found by comparing variations in mortality among hospitals. In particular, after adjusting for important individual patient characteristics and comorbidities, and other institutional characteristics, significant hospital nursing variables, which

TABLE 3. Descriptive Information on the Institutional Characteristics for the 49 Hospitals

Institutional Factors	Hospitals (*N* = 49)	Patients (*N* =18,142)	Nurses (*N* = 4,799)
Hospital volume, No. of beds[a]			
Small (≤150 beds)	39 (19.6)	6,900 (38.1)	870 (18.1)
Large (>50 beds)	10 (20.4)	11,242 (61.9)	3,929 (81.9)
Teaching status[b]			
None	41 (83.6)	9,259 (51.1)	1,633 (34.0)
Minor	4 (8.2)	3,143 (17.3)	759 (15.8)
Major	4 (8.2)	5,740 (31.6)	2,407 (50.2)
High-technology[c]			
No	47 (95.9)	14,741 (81.3)	3,082 (64.2)
Yes	2 (4.1)	3,401 (18.7)	1,717 (35.8)
Location[d]			
Small cities	39 (79.6)	6,714 (37.0)	898 (18.7)
Large cities	10 (20.4)	11,428 (63.0)	3,901 (81.3)

Note. Values in parentheses are percentages.
[a]Total number of staffed and operating beds available (excluding newborn nursery).
[b]Resident per bed ratio: *major*, one or more medical residents per four beds; *minor*, less than one resident per four beds; *none*, no residents.
[c]High-technology: if cardiac surgery or major organ transplant services, or both, were available.
[d]Geographic location of hospital: Large cities/towns with populations >50,000. Small cities/towns with populations of <50,000.

were associated with *lower* patient mortality among hospitals were as follows: higher nurse education levels, a richer skill mix of nursing staff, better nurse–physician relationships, and lower casual and temporary employment.

Physician board certification, an important variable in other analyses (Aiken et al., 2003; Silber, Rosenbaum, & Ross, 1995) was not available to us. However, a related variable "responsible physician specialization" reflected whether the responsible physician had a specialty designation. When examined in the univariate model, it was not a significant predictor of mortality and was not included in the multivariate model.

In this analysis, each of the seven nonsignificant predictors (e.g., perceived adequate staffing, unmet patient care needs, time spent on nonnursing tasks, etc.) in this final model had been a significant predictor and had a nontrivial effect size in the univariate analyses. This suggests that their failure to reach statistically significant levels in the final model does not render them irrelevant. They are important variables requiring assessment in ongoing studies. Several

TABLE 4. Comparison of Low- and High-Volume Hospital by Age, Gender, and Mean Number of Comorbidities for the 49 Hospitals

	Mean Age (Years)		Male Sex (%)		Mean Number of Comorbidities		30-Day Mortality Percent Unadjusted	
Diagnosis	Low	High	Low	High	Low	High	Low	High
Acute myocardial infarction	65	65	71	69	4	7	8	11
Congestive heart failure	73	72	56	55	6	8	7	9
Obstructive pulmonary disease	69	70	52	52	4	5	4	5
Pneumonia	62	62	51	53	5	8	5	6
Stroke	73	70	55	53	6	8	15	16

Note. Comorbidities – 1. Previous AMI; 2. Previous CHF; 3. Peripheral vascular diseases; 4. Cerebrovascular disease; 5. Dementia; 6. COPD and other respiratory diseases; 7. Rheumatic-like diseases; 8. Ulcer of the digestive system; 9. Mild liver disease; 10. Diabetes with chronic complications; 11. Hemiplegia or paraplegia; 12. Renal disease; 13. Moderate/severe liver disease; 14. Hyponatremia; 15. Pulmonary edema; 16. Hemorrhage; 17. Cardiac dysrhythmias.

TABLE 5. Results of Fixed-Effects Hierarchical Model: Effects of Institutional and Hospital Nursing Characteristics Adjusted for Patient's Comorbidity Factors (Fixed and Nonrandom Across Hospitals), Age, and Sex

Institutional and Hospital Nursing Characteristics	Separately[a] (Univariate Analyses)		Jointly[a] (Multivariate Analysis)	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Hospitals with bed size >151	0.97 (0.94–1.00)	.044	1.45 (1.19–1.76)	.001
Major teaching hospitals	0.92 (0.90–0.95)	<.001	0.88 (0.79–0.99)	.038
Hospital located in large cities	0.96 (0.93–0.99)	.012	0.66 (0.49–0.88)	.009
Nurse education level	0.62 (0.51–0.74)	<.001	0.81 (0.68–0.96)	.021
Skill mix	0.78 (0.67–0.90)	.001	0.83 (0.73–0.96)	.013
Casual or temporary staffs	2.75 (1.26–6.00)	.014	1.26 (1.09–1.47)	.004
Perception of staffing adequacy	0.87 (0.81–0.94)	.001	0.93 (0.59–1.47)	.765
Patient care needs unattended	1.08 (1.02–1.14)	.010	0.84 (0.55–1.28)	.416
Nonnursing activities performed	1.04 (1.02–1.07)	.003	0.85 (0.66–1.11)	.235
Nurse job satisfaction	0.90 (0.80–1.01)	.079	0.85 (0.47–1.55)	.604
Support for nonfloating policy	0.95 (0.92–0.98)	.001	1.15 (0.90–1.46)	.262
Nurse autonomy	0.82 (0.70–0.95)	.001	0.79 (0.37–1.66)	.535
Nurse–physician relationship	0.90 (0.84–0.98)	.013	0.74 (0.60–0.91)	.007
Emotional abuse	1.15 (1.01–1.32)	.039	0.97 (0.56–1.70)	.929

[a]Effects of characteristics estimated on adjusted 30-day motality.

TABLE 6. Results of Random-Effects Hierarchical Model: Effect of Institutional and Hospital Nursing Characteristics Adjusted for Patient's Comorbidity Factors (Random Across Hospitals), Age, and Sex

Institutional and Hospital Nursing characteristics	Separately[a] (Univariate Analysis)		Jointly[a] (Multivariate Analysis)	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Hospitals with bed size >151	1.05 (1.02–1.09)	.003	1.49 (1.25–1.76)	<.001
Major teaching hospitals	1.05 (1.01–1.09)	.020	0.87 (0.78–0.96)	.010
Hospital located in large cities	1.05 (1.02–1.09)	.005	0.58 (0.44–0.77)	.001
Nurse education level	0.69 (0.54–0.88)	<.001	0.65 (0.60–0.71)	<.001
Skill mix	0.92 (0.76–1.12)	.412	0.76 (0.66–0.87)	<.001
Casual or temporary staffs	9.77 (2.41–39.66)	.003	1.47 (1.21–1.79)	.001
Perception of staffing adequacy	0.89 (0.81–0.98)	.018	1.02 (0.66–1.56)	.935
Patient care needs unattended	1.03 (0.96–1.10)	.382	0.79 (0.56–1.13)	.211
Nonnursing activities performed	1.00 (0.97–1.04)	.956	0.91 (0.72–1.15)	.432
Nurse job satisfaction	0.99 (0.86–1.15)	.937	0.74 (0.41–1.36)	.341
Support for nonfloating policy	0.99 (0.95–1.03)	.508	1.15 (0.91–1.45)	.244
Nurse autonomy	0.83 (0.68–1.00)	.056	0.80 (0.41–1.58)	.524
Nurse–physician relationship	0.96 (0.88–1.05)	.390	0.72 (0.58–0.88)	.003
Emotional abuse	1.03 (0.87–1.21)	.767	0.87 (0.50–1.53)	.636

[a]Effects of characteristics estimated on adjusted 30-day mortality.

explanations may provide insight into their performance in this model. As demonstrated previously, nursing specialty (and by extension, the unit of the hospital on which a nurse worked) interacted with other variables that predicted the occurrence of emotional abuse (Duncan et al., 2001). Given the extent to which other work environment characteristics varied across specialties in this sample (http://www.nursing.ualberta.ca/kusp/ Research_Products.htm#techreps), it seemed reasonable to expect that the within-hospital variation would nullify their significance between hospitals. In addition, with only 49 hospitals in the sample and 14 explanatory variables, it is possible that these analyses were underpowered to find significant effects with these variables. The failure to retain adeque staffing in the final model was unexpected. Two explanations may be applicable. First, the measure of staffing was indirect and perceptual; and second, patient assignment models varied considerably across hospitals owing to differences in assignment practices and models of care delivery such as team or primary nursing.

A number of limitations are recognized. First, this study is vulnerable, as are previous studies, to the quality of the administrative data on which they are based. Findings from recent Canadian Institutes for Health Information (CIHI) on meta-evaluation of data quality in terms of theoretical robustness found that, overall, administrative health data across Canadian institutions are reasonably well-defined and coded (http://secure.cihi.ca/cihiweb/en/downloads/quality_e_Meta-Eval_Study.pdf). While the quality of the entire AHCIPR database is not indicated, there is confidence in the accuracy of this study's 30-day mortality data because each case was linked to the CIHI database by a unique patient identifier. Nearly all of the in-hospital deaths (91.75%) that occurred within 30 days of admission to the CIHI database were linked, demonstrating the quality of the overall AHCIPR database. Similarly, the potential for response bias on the nurse survey with a 52% response rate should be considered. When this sample was compared to the population, differences in demographics or speciality composition were not detected, indicating that a detectable response bias was not present.

Second, one of the criticisms of aggregating data collected at one level to a higher level is that the relationship among the variables is typically different at each level. In econometric literature, this aggregation bias has been described as a negative artifact of the loss of information that occurs during aggregation. However, in the educational psychology literature investigators argue that aggregation bias is not a statistical byproduct, but rather a legitimate consequence of contextual effects that make the group performance on outcome variables different than individual performances. In essence, the difference between the individual and aggregated analyses is that the individual-level analysis fails to account for the group or organizational effects that a group-level analysis captures (Sellin, 1990). This argument is also the basis for using hierarchical linear modeling (Raudenbush & Bryk, 2002). In addition, as shown earlier in Table 2, aggregation of nursing data to the hospital level is defensible, as indicated by significant ($p < .05$) F and high ICC(2) values. There is a high level of internal agreement in nurse perceptions *within* each hospital as indicated by ICC(1) values, but with minimal hospital-level effects. That is, whether the aggregated data for each of the nursing variables reflect valid hospital phenomena is open to question on the basis of the relatively small effect size of η^2 and ω^2. Furthermore, some of the hospitals in this sample had less than the recommended 50% response rate for group opinion by the nursing staff participating in the data collection (Ferketich & Verran, 1991).

Third, the selected sample involved only patients with a primary diagnosis of acute myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, stroke, or pneumonia. Patients in these diagnostic categories may differ from the general population of patients in Alberta hospitals. Also, the criteria used to select the 49 hospitals in this study may not have given a representative sample of all patients in Alberta hospitals. While we believe our method of analysis is more robust than previously reported single-level analyses, it does not overcome the need to exercise caution in interpreting and generalizing these findings.

The nature of a *fitting* multivariate model, such as the one presented here, implies the highest level of internal validity—*construct validity.* The current model is explicitly defined by the level at which the variables were entered. By accounting for the effects of variables at the patient level first, then simultaneously testing the effects of all of the hospital nursing variables of interest, it is possible to see how these variables explain variance in light of their relationship to the other variables. In essence, we are testing the construct of nursing care as it relates to mortality as completely as possible, given our data and current working theory. This enables us to exert our findings with some confidence. To establish generalizability we require a greater breadth of cross-sectional comparisons and longitudinal designs. However, much of our report confirms or extends previous findings and does so with a robust modeling approach, suggesting that we may be nearing the ability to converge on better explanatory models when considering mortality at the hospital level.

There have been recent reports (Sochalski, 2002) and recent calls (http://www.hc-sc.gc.ca/english/pdf/Office-of-NursingPolicy.pdf) for greater attention to healthy workplaces focusing on the impact of the workplace on outcomes such as workforce retention. The integration of these foci permits the complex interrelationships among provider, patient, and system outcomes to be understood thoroughly. Failing to do so will allow the propagation of a research agenda that does not account for systemic characteristics that reach deeper than supply and demand issues.

The fact that several significant institutional and hospital nursing characteristics at the hospital level explain a considerable amount of variation in 30-day mortality across hospitals indicates that these factors deserve serious consideration. Attention to the improvement of modifiable conditions that influence 30-day mortality has the potential to improve the prognosis for patients with these medical diagnoses. These findings support policies that improve the work environment for providers, in this case, nurses. Deliberately focusing on the work environment should improve patient and system outcomes. Each of the four hospital nursing characteristics—higher nurse education levels, a richer skill mix of nursing staff, better nurse–physician relationships, and lower casual and temporary employment—are modifiable conditions. ▼

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