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Patient Turnover and the Relationship Between Nurse Staffing and Patient Outcomes

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Abstract: High patient turnover (patient throughput generated by admissions, discharges, and transfers) contributes to increased demands and resources for care. We examined how the relationship between registered nurse (RN) staffing and failure-to-rescue (FTR) varied with patient turnover levels by analyzing quarterly data from the University HealthSystem Consortium. The data included 42 hospitals, representing 759 nursing units and about 1 million inpatients. Higher RN staffing was associated with lower FTR. When patient turnover increased from 48.6% to 60.7% on nonintensive units (non-ICUs), the beneficial effect of non-ICU RN staffing on FTR was reduced by 11.5%. RN staffing should be adjusted according to patient turnover because turnover increases patient care demand beyond that presented by patient count, and outcomes may be adversely affected. © 2012 Wiley Periodicals, Inc. Res Nurs Health 35:277–288, 2012

Keywords: nurse staffing; patient outcomes; patient safety; patient turnover

Acute care hospitals have been challenged by external and internal changes in the health care system. Since the 1980s, Medicare's Prospective Payment System has reimbursed hospitals by diagnosis-related group (DRG) formulas to reduce hospital costs (Shen, 2003). As a result, over several decades, shorter patient stays and sicker patient populations have characterized hospital occupancy (Norrish & Rundall, 2001; Shen, 2003). The average length of stay (LOS) in

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nonfederal acute care hospitals fell from 7.5 days in 1980 to 4.8 days in 2007 (Centers for Disease Control and Prevention, 2004, 2010). More recently, Medicare reimbursement regulations, enacted in October 2008, eliminated payment for hospital-acquired and preventable adverse conditions (Rosenthal, 2007). These external and internal changes have required nursing staffs to provide more complicated and skilled care and, at the same time, to reduce adverse patient outcomes (Page, 2004; Stone et al., 2010).

The shortened LOS indicates that patients are discharged earlier, and the beds are ready for new patients to be admitted (Blankenship & Winslow, 2003; Duffield, Diers, Aisbett, & Roche, 2009). This quick patient throughput increases the number of admissions, discharges, and transfers among units (patient turnover). High patient turnover makes the nursing work environment more crowded and chaotic because nurses must provide concentrated nursing care to an increased number of patients and families within shorter time frames (Unruh & Fottler, 2006). Thus, patient turnover should be considered an important factor in the allocation of nursing personnel and in patient outcomes (Jennings, 2008). Although many researchers have added to our understanding of the relationship between nurse staffing and adverse patient outcomes and mortality, little attention has been paid to patient turnover (Cho, Ketefian, Barkauskas, & Smith, 2003; Mark, Harless, McCue, & Xu, 2004; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). We conducted a study, therefore, to explicitly examine the effect of nurse staffing on patient outcomes based on patient turnover levels.

Literature Review on Patient Turnover

In the literature, there is no consistent definition of patient turnover. Previous researchers have used various terms including patient turnover, census variability, churn, and environmental turbulence to explain the same or similar concepts (Duffield et al., 2009; Jennings, 2008; Wagner, Budreau, & Everett, 2005). The terms patient turnover, census variability, and churn were used interchangeably and represented patient throughput resulting from admissions, discharges, and transfers. Conversely, environmental turbulence was defined as "a loss of control due to simultaneous demands; new, difficult, or unfamiliar work; heavy patient loads; and excessive responsibility" (Jennings, 2008, p. 193). Turbulence indicated the complexity and instability of the work environment based on daily changes in patient acuity and occupancy in addition to the number of admissions, discharges, and transfers on or off the unit (Salyer, 1995). In this study, we chose the term patient turnover to focus on examining variability in patient throughput and its impact on the nurse staffing and outcomes relationship.

Previous researchers measured patient turnover in different ways. In an analysis of 205 acute care hospitals in Pennsylvania, Unruh and Fottler (2006) measured patient turnover as the inverse of LOS. Unruh and Fottler's measure can easily be calculated from hospital LOS data. Their calculation, however, yields only a rough measure of patient turnover because it does not count the actual changes in the numbers of admissions, discharges, and transfers. Norrish (1999) and Lawrenz (1992) measured the average number of admissions, discharges, and transfers divided by patient days generated from the midnight census. In Norrish's study, patient turnover on nursing care units was as high as 50% during a given shift. Lawrenz reported patient turnover rates of 25–70% of the midnight census in 20 medical/ surgical units in five hospitals. The Labor Management Institute (2008) evaluated the measure used by Norrish and Lawrenz and found that nursing care units with higher patient turnover had a higher rate of overtime for nursing staff and more adverse events. In other studies, the ratio of the number of admissions, discharges, and transfers to the total number of treated patients was used to assess patient turnover levels (Jacobson, Seltzer, & Dam, 1999; Wagner et al., 2005). Instead of using the midnight census for the denominator, these researchers counted patients (a) occupying a bed for a 24-hour period, (b) discharged from a unit, (c) admitted to a unit, and (d) admitted to and discharged from a unit on the same day. Although the denominator of the measure can reflect the actual volume of patients treated in a unit, it is impossible to use the measure for a study when the number of full-day patients is not available.

High patient turnover leads to an increased demand for care to complete the processes of the admission, discharge, and transfer of patients (Norrish & Rundall, 2001; Page, 2004). Nurses provide relatively greater amounts of nursing care in short periods for assessments, documentation, patient education, and discharge planning. Despite the importance of patient turnover to the demand for care that nurses experience, previous investigators have examined the nurse staffing and patient outcomes relationship without adjusting or controlling for the effect of patient turnover (Kovner, Jones, Zhan, Gergen, & Basu, 2002; Mark & Harless, 2010; Needleman et al., 2002). Nurse staffing is measured by (a) nurse-to-patient ratios, (b) number of full-time equivalent nursing staff per patient day, or (c) number of hours of nursing care per patient day (Blegen, 2006; Kane, Shamliyan, Mueller, Duval, & Wilt, 2007). For the staffing measures, hospitals traditionally report information on patient volume obtained from the midnight census (Beswick, Hill, & Anderson, 2010; Simon, Yankovskyy, Klaus, Gajewski, & Dunton, 2011). The midnight census, however, does not account for care demands driven by variations in patient turnover (Spetz, Donaldson, Aydin, & Brown, 2008; Wagner et al., 2005). For example, even if there were more admissions, discharges, and transfers before midnight on a given day compared with the previous day, patient volume might be constant at the midnight census over the 2 days. For these reasons, previous researchers as well as typical nurse staffing measures likely underestimated the demand for care. Jennings (2008) speculated that the relationship between nurse staffing and patient outcomes would be different if studies accounted for patient turnover. Little is known, however, about the effect of increased patient turnover on the nurse staffing and patient outcomes relationship.

The purpose of this study, therefore, was to examine how the relationship between nurse staffing and patient outcomes varied with the level of patient turnover. Instead of combining values across all types of units, we used data on nurse staffing and patient turnover specific to adult nonintensive care units (non-ICUs) and adult intensive care units (ICUs), which would affect the outcomes of adult patients, to aid administrators and policy makers in determining adequate staffing levels based on unit needs (Blegen, Goode, Spetz, Vaughn, & Park, 2011). Medical, surgical, and medical/surgical units were included because bed availability allows for medical or surgical patients to be placed on any of these units.

Among patient-centered outcome measures for nursing-sensitive care recommended by the National Quality Forum (2004), failure-to-rescue (FTR) was selected in this study as an indicator measurable from the Agency for Healthcare Research and Quality's (AHRQ) Patient Safety Indicators software. FTR has been used in many studies as a measure of preventable adverse events, specifically deaths that follow adverse events associated with post-surgical complications (Harless & Mark, 2010; Needleman et al., 2002; Silber et al., 2007). Moreover, FTR has been considered to be an indicator showing a strong inverse relationship with nurse staffing (Blegen, 2006; Lang, Hodge, Olson, Romano, & Kravitz, 2004). Needleman et al. (2002) found a significant relationship between FTR and registered nurse (RN) staffing, whereas there was no evidence of a meaningful association between FTR and staffing by either licensed practical nurses (LPNs) or certified nursing assistants (CNAs). Because RNs play a critical role in monitoring patients, detecting complications early, and responding to them appropriately, they contribute to reducing FTR and thus improving patient safety. When patient turnover increases and RN staffing is insufficient, the capability of RNs to reduce FTR may be impeded because they must spend more time in nursing activities associated with patient admissions, discharges, and transfers and less in detecting preventable complications. Based on this background, we examined the effect of patient turnover on the relationship between RN staffing and FTR.

Theoretical Framework

Donabedian's (1988) structure–process–outcomes model provided guidance for conceptually linking nurse staffing and patient turnover to patient outcomes. The model incorporates three components: (a) structure, representing the attributes of environments such as human resources and organizational structure; (b) process, indicating activities of patients who seek care and of health care providers who carry out treatment and care; and (c) outcomes, encompassing patients' knowledge improvement and satisfaction with care as well as clinical outcomes (Donabedian). Donabedian assumed relationships among the three components so that good structure is more likely to affect good process that then affects good outcomes.

Since the publication of the Institute of Medicine report *To Err Is Human* (Kohn, Corrigan, & Donaldson, 2000), increased attention has been paid to good environmental structure to provide safe and high quality care in the health care sector (Page, 2004). Over the past decade, researchers have examined whether high nurse staffing levels, representing good structure, were associated with better patient outcomes (Cho et al., 2003; Mark & Belyea, 2009; Needleman et al., 2002). Those staffing studies added components of patient characteristics and context (separating hospital characteristics from the specific structural factor of nurse staffing); typically hospital characteristics were size, teaching status, technological complexity, and overall patient mix.

Based on Donabedian's (1988) model and previous staffing research, we incorporated components of patient characteristics, hospital characteristics, structure, and outcomes in our theoretical framework. Our primary interest for this study was a link between structure and outcomes, controlling for hospital and patient characteristics. Staffing by unit type was considered a structural factor that would affect patient outcomes (Donabedian; Mark & Belyea, 2009). We considered patient turnover by unit type as another structural factor characterizing the organizational structure in which nurses work. Researchers have concluded that high patient turnover and insufficient nurse staffing levels contribute to an increase in nursing workload (Needleman et al., 2011; Page, 2004; Unruh & Fottler, 2006). We assumed that allocating adequate staffing according to patient turnover levels would result in better patient outcomes. Thus, it was hypothesized that patient turnover would moderate the staffing and patient outcomes relationship instead of directly influencing outcomes.

Hospital characteristics were considered as confounders to the true staffing and patient outcomes relationship and were controlled for in our regression analysis (Mark & Harless, 2010). Hospital size, teaching status, technological complexity, patient case mix, location, and ownership have been commonly identified as hospital characteristics in previous staffing research (Kovner et al., 2002; Mark & Harless, 2010; Needleman et al., 2002). Thus, they were tested in our preliminary analysis. In this study, patient characteristics were controlled using the AHRQ risk adjustment method to determine patient risk for deaths or complications apart from nursing care.

Methods

Data

Our study involved a secondary analysis of the data reported by Blegen et al. (2011) with a focus on the subsample of hospitals and units that included information on patient turnover. Using a descriptive correlational design, we analyzed the University HealthSystem Consortium (UHC) data reported quarterly for the calendar year 2005, the most recent year with complete data when the request was made. The UHC data consisted of three datasets: (a) the hospital facility dataset, which contained information on hospital characteristics such as patient case mix, size, and location; (b) the operational dataset, which contained information on nursing care unit characteristics such as unit type, nurse staffing, and the volume of admissions, discharges, and transfers; and (c) the clinical dataset of patient characteristics, which contained information on age, diagnosis and procedure codes, and complications. Additional data on hospital characteristics were extracted from the American Hospital Association's Annual Survey of Hospitals to calculate a measure of hospital technological complexity.

Sample

The UHC is an organization that represents about 90% of the nonprofit teaching hospitals in the United States (UHC, 2006). Members voluntarily submit data to each of the three data sets. Fifty-seven of the 234 UHC-affiliated hospitals (about 24%) provided data for all three datasets used in this study. To examine nurse staffing and patient outcomes for adult care, we excluded pediatric, obstetric, and psychiatric nursing care units and eliminated data for inpatients younger than 18 years. We checked the data for outliers and excluded unit quarters with RN staffing below the 1st percentile or above the 99th percentile. Moreover, hospital and unit quarters were omitted if they reported no data (zero or missing values) for their patient throughput, a reflection of input (admissions and transfers in) and output (discharges and transfers out). Consequently, in this study we analyzed quarterly data from 42 teaching hospitals comprising 759 nursing care units (512 adult non-ICUs and 247 adult ICUs) and reflecting data for about 1 million inpatients. The UHC removed all hospital and patient identifiers before transmitting the data.

Measures

Nurse staffing. All information on nurse staffing was retrieved from the operational dataset collected at the nursing care unit level. We measured staffing as nursing care hours per patient day (HPPD) for nursing personnel. We calculated RN staffing separate from non-RN staffing because we were interested in the RNs' role in detecting preventable complications and thus reducing FTR. Hours worked by LPNs and CNAs were summed to measure non-RN staffing. In calculating nurse staffing, we used productive nursing care hours, excluding hours paid for sick leave or vacation and those hours worked by unit administrative and management staff. The number of patient days, a denominator of HPPD, was obtained from the midnight census. For regression analysis, the unit-level measures of nurse staffing were aggregated at the hospital/quarter level to be matched with the level of patient outcomes or FTR. In addition, we calculated nurse staffing in adult non-ICUs separately from that in adult ICUs because these units have largely different staffing patterns.

Patient turnover. There is no standard measure for patient turnover in the literature. We therefore developed a measure by modifying the Norrish (1999) and Lawrenz (1992) methods. The UHC data included an indicator of observation or short stays, defined as the number of patients who were (a) undergoing evaluation for admission, (b) waiting for a procedure, or (c) recovering from a procedure. We considered the volume for observation or short stay as one of the contributors to increasing patient throughput. Consequently, we calculated patient turnover as a ratio of patient throughput volume to midnight census volume, where patient throughput volume was the sum of the volume of admissions, discharges, transfers in, transfers out, and observation stays. For the regression equations, patient turnover levels were measured at the nursing care unit level and then aggregated at the hospital/quarter level, separating patient turnover on adult non-ICUs from that on adult ICUs.

Hospital characteristics. Researchers have controlled for differences in system characteristics among hospitals when they examined the relationship between nurse staffing and patient outcomes (Kovner et al., 2002; Mark & Harless, 2010; Needleman et al., 2002). We selected hospital technological complexity and patient case mix as control variables for our multivariate regression analysis. In this study, other hospital characteristics, such as size, location, and ownership, did not show any systematic differences in patient outcomes and thus were excluded from multivariate analysis.

To measure hospital technological complexity levels, we used the Saidin Index of the weighted number of technologies and services in terms of relatively complicated, rare, new, or expensive technology services (Spetz, 1999). Based on the literature review, we hypothesized that hospitals with high technology would yield better patient outcomes, or lower rates of FTR (Blegen et al., 2011; Mark et al., 2004). The Medicare Case Mix Index represents the average DRG relative weight for a given hospital, which was calculated by the sum of the DRG weights for all Medicare patients divided by the number of all discharges (Centers for Medicare and Medicaid Services, 2005). The Case Mix Index was used to control for the average severity of all patients in the hospital during the year these data were collected. The Index might be a confounder to the staffing and outcome relationship because hospitals with more severe patients would need more nursing staff and at the same time have worse patient outcomes (Blegen et al., 2011; Kovner et al., 2002).

Patient outcome measures and risk adjustment. We used FTR to measure patient outcomes. FTR was defined as mortality in surgical patients preceded by a hospital-acquired complication such as pneumonia, deep vein thrombosis or pulmonary embolism, sepsis, acute renal failure, shock or cardiac arrest, and gastrointestinal hemorrhage or acute ulcer (AHRQ, 2007). The algorithms in the AHRQ's Patient Safety Indicators software were used to calculate FTR. Although this outcome is specific to surgical patients, it is used to estimate the effects of nurse staffing and hospital quality in general (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Blegen et al., 2011; Needleman et al., 2002). Based on the findings from these studies, hospitals with higher RN staffing throughout were likely to have lower FTR rates.

We used a standardized ratio: the observed rate divided by the expected rate (*O*/*E*) of FTR. The *O*/*E* ratios for FTR were measured at the hospital/quarter level. To calculate the expected rate for each quarter and each hospital, AHRQ algorithms estimated the likelihood that patients at risk would die after a complication, controlling for differences in patient characteristics such as age, gender, and risk based on the All Patient Refined DRGs (AHRQ, 2007). This calculation performed risk adjustment of this outcome measure at the patient level. Hospitals with FTR *O*/*E* ratios >1.0 were those with more FTR cases than expected; FTR *O*/*E* ratios

<1.0 indicated hospitals with better patient outcomes and fewer FTR events than expected.

Statistical Analysis

Before conducting multivariate regressions, we considered whether multicollinearity might be a concern among the predictor variables (RN staffing, non-RN staffing, patient turnover, the Saidin Index, and the Case Mix Index) by calculating correlations and the variance inflation factor (VIF). Multicollinearity proved not to be a concern. The absolute values of bivariate correlations were <.45, and mean VIF values were 1.25 and 1.11 for adult non-ICUs and ICUs respectively. In general, VIF >10 demonstrates a high degree of multicollinearity (Cohen, Cohen, West, & Aiken, 2003). Using residual analysis, we checked regression diagnostics, such as normality and homoscedasticity, for the models tested in this study.

We estimated mixed-effects linear regression equations that included fixed coefficients for predictor variables and random effects for each hospital. To be specific, the random-intercept model, a type of mixed-effects model, was produced to consider the clustered and unbalanced structure of the data. The model has the advantage of dealing with the correlations of observations within a subject, in this case quarters within a hospital (Rabe-Hesketh & Skrondal, 2008).

For our study, we first estimated the main effects of RN staffing on FTR with and without adjusting for non-RN staffing, hospital technological complexity, and patient case mix (Models 1 and 2). Second, we added patient turnover to the model to determine whether it was a confounding variable to the true relationship between RN staffing levels and FTR (Model 3). Third, we included an interaction term of patient turnover by RN staffing to evaluate whether the effect of RN staffing on FTR differed according to patient turnover (Model 4). Finally, we estimated the slopes and 95% confidence intervals (CIs) of RN staffing at the 25th, 50th, and 75th percentile values of patient turnover based on Model 4.

The Wald Chi-Squared Test was used to evaluate the fit for each model. Based on the Likelihood Ratio Test, we compared models to see whether they were significantly different according to the inclusion of additional predictors. In this study, the analytic procedures for the models were performed for the two unit types (adult non-ICU and adult ICU). All data analyses were conducted using Stata Version 11.0.

Results

In our study, data were analyzed from 159 quarters of adult non-ICUs and 158 quarters of adult ICUs at 42 hospitals. Although five hospitals provided data for only two or three quarters, the other hospitals reported all four quarters of data. Hospital ownership represented universities (47%), local governments (31%), communities (17%), and religious sponsors (5%); all were teaching hospitals. The hospitals had an average of 571 beds in operation, ranging from 211 to 925 beds ($SD = 192.26$); in 2005, U.S. hospitals averaged 157 beds (AHRQ, 2005). Of the hospitals, 81% were located in metropolitan areas; 15% and 4% were in suburban and rural areas, respectively.

Table 1 presents descriptive statistics for nurse staffing, patient turnover rates, hospital characteristics, and FTR. The mean RN hours per patient day were lower on non-ICUs than in ICUs. Non-ICUs had higher and wider-ranging patient turnover rates than ICUs. The hospitals had fewer FTR events than expected, presenting a mean *O*/*E* ratio of 0.93 but showing variability with a range of 0.43 to 1.47.

The results of mixed-effects regression models for non-ICUs and ICUs are presented in Tables 2 and 3, respectively. In Models 1 to 3, we examined the main effect of RN staffing and the effects of other variables on FTR. In Model 4, we examined the interaction between patient turnover and RN staffing. The unadjusted model (Model 1) for non-ICUs (see Table 2) showed there was no statistically significant association between RN staffing and FTR ($p = .132$). After adjusting for non-RN staffing, patient case mix, and hospital technological complexity, higher RN staffing levels on non-ICUs were significantly associated with lower rates of FTR ($p = .036$, see Model 2). A change of 43.1% was noted in the coefficients for RN staffing on non-ICUs before and after the adjustment. A coefficient change over 10% is considered to be substantial (Greenland, 1989; Vittinghoff, Glidden, Shiboski, & McCulloch, 2005). The direct effect of patient turnover on FTR was not statistically significant for non-ICUs (Model 3). When comparing changes before and after the adjustment for patient turnover (Model 2 vs. 3), the change in the coefficients for RN staffing

Table 1. Descriptive Statistics for Measures of Nurse Staffing, Patient Turnover, Hospital Characteristics, and Outcomes ($N = 159$ Quarters From 42 Hospitals)

	Adult Non-ICUs	Adult ICUs*
Variable of Nurse Staffing and Patient Turnover	*M* (*SD*)	*M* (*SD*)
RN hours per patient day	6.74 (1.40)	15.52 (2.03)
Non-RN hours per patient day	2.87 (1.03)	2.27 (1.33)
Patient turnover (%)	56.10 (17.87)	45.41 (14.09)

Variable of Hospital Characteristics and Patient Outcomes	*M* (*SD*)
Hospital characteristics	
Saidin index	27.35 (5.39)
Medicare case mix index	1.82 (0.20)
Patient outcomes	
Failure-to-rescue (*O/E*)	0.93 (0.21)

Note: Standard deviations of the variables are in parentheses. Non-ICUs, nonintensive care unit; ICU, intensive care unit; *M*, mean; *SD*, standard deviation; RN, registered nurse; Non-RN, nonregistered nurse; *O/E*, observed rates/expected rates.
*$N = 158$.

was 11.1% for non-ICUs. According to the Likelihood Ratio Tests, Model 3 did not provide a better fit compared with Model 2 for non-ICUs (LR χ^2 (1) = 0.12, $p = .728$).

We found a statistically significant association between FTR and the interaction of patient turnover and RN staffing in non-ICUs ($p < .01$; see Model 4 in Table 2). Model 4, where the interaction term was included, demonstrated a significantly better fit when compared with Model 3 without the interaction (LR χ^2 (1) = 6.25, $p = .012$). Using the Stata *lincom* command, we estimated the coefficients of RN staffing and their 95% CIs at different levels of patient turnover on non-ICUs (see Table 4). The estimated effects of RN staffing on FTR were statistically significant at the 25th (48.6), 50th (53.5), and 75th (60.7) percentile values of patient turnover. The magnitude of the relationships between RN staffing and FTR decreased as patient turnover levels increased. When patient turnover rates increased from 48.6%

Table 2. Regression Estimation Results on Adult Non-ICUs ($N = 159$)

	Failure-to-Rescue			
Variable	Model 1	Model 2	Model 3	Model 4
RN hours per patient day	−0.019	−0.027*	−0.030*	−0.081*
	[−0.044, 0.006]	[−0.052, −0.002]	[−0.060, −0.0001]	[−0.127, −0.035]
Non-RN hours per patient day		0.012	0.011	0.018
		[−0.032, 0.056]	[−0.033, 0.056]	[−0.024, 0.059]
Saidin index		−0.015*	−0.015*	−0.013*
		[−0.024, −0.005]	[−0.024, −0.005]	[−0.022, −0.005]
Case mix index		0.059	0.067	0.066
		[−0.172, 0.290]	[−0.168, 0.301]	[−0.153, 0.285]
Patient turnover			0.0004	−0.005*
			[−0.002, 0.003]	[−0.010, −0.0004]
RN hours per patient day × patient turnover				0.001*
				[0.0001, 0.001]
Wald χ^2 statistic	2.26	13.55*	13.71*	23.54*
Log likelihood	65.65	70.46	70.52	73.65

Note: 95% confidence intervals are in box brackets. Coefficient estimates were calculated from mixed-effects linear regression equations using random intercepts. Non-ICU, nonintensive care unit; RN = registered nurse; Non-RN, nonregistered nurse.
*$p < .05$.

Table 3. Regression Estimation Results on Adult ICUs ($N = 158$)

Variable	Failure-to-Rescue			
	Model 1	Model 2	Model 3	Model 4
RN hours per patient day	−0.021* [−0.038, −0.004]	−0.023* [−0.040, −0.007]	−0.022* [−0.039, −0.005]	−0.016 [−0.083, 0.051]
Non-RN hours per patient day		0.020 [−0.015, 0.054]	0.019 [−0.015, 0.053]	0.019 [−0.014, 0.053]
Saidin index		−0.013* [−0.022, −0.005]	−0.014* [−0.023, −0.005]	−0.014* [−0.023, −0.005]
Case mix index		0.059 [−0.163, 0.281]	0.042 [−0.179, 0.263]	0.043 [−0.177, 0.264]
Patient turnover			−0.002 [−0.004, 0.001]	0.0004 [−0.020, 0.020]
RN hours per patient day × patient turnover				−0.0001 [−0.001, 0.001]
Wald χ^2 statistic	5.59*	17.69*	19.48*	19.80*
Log likelihood	66.23	70.99	71.55	71.57

Note: 95% confidence intervals are in box brackets. Coefficient estimates were calculated from mixed-effects linear regression equations using random intercepts. ICU, intensive care unit; RN, registered nurse; Non-RN, nonregistered nurse.
$^*p < .05$.

(25th percentile) to 60.7% (75th percentile), the effect of RN staffing on FTR was reduced by 11.5%. At the median value of patient turnover (53.5%), a 1-hour increase in RN staffing per patient day on non-ICUs was associated with a 0.053 decrease in FTR *O/E* ratios ($p = .001$, 95% CI [−0.085, −0.020]).

Unlike the results for non-ICUs, the unadjusted effect of RN staffing on FTR in ICUs was statistically significant ($p = .018$; see Model 1 in Table 3) and remained so in Models 2 and 3. On ICUs, the RN staffing effect changed by 13.7% after adjusting for the control variables used in Model 2. There was no statistically significant direct effect of patient turnover on FTR (Model 3). After the adjustment for patient turnover (Model 2 vs. 3), the change in the coefficients for RN staffing for ICUs was small, representing a change of 7.5%. When comparing the Likelihood Ratio Tests for Models 2 and 3, including the direct effect of patient turnover did not provide a better fit (LR χ^2 (1) = 1.12, $p = .291$). No statistically significant interaction was noted between patient turnover and RN staffing on ICUs (see Model 4). For ICUs, the model without the patient turnover effect, controlling only for non-RN staffing, technological complexity, and patient case mix, showed the best fit according to the results of the Likelihood Ratio Tests (Model 2).

Of the control variables, hospital technological complexity measured by the Saidin Index showed statistically significant associations with

Table 4. The Effects of RN Staffing on Failure-to-Rescue Ratios By Changes in Patient Turnover Levels on Adult Non-ICUs

	Percentile Value for Patient Turnover		
	25th	50th	75th
	48.63	53.49	60.69
RN staffing effect on failure-to-rescue	−0.055* [−0.089, −0.022]	−0.053* [−0.085, −0.020]	−0.049* [−0.080, −0.018]

Note: 95% confidence intervals (in box brackets) beside the coefficients of the nurse staffing effects. Coefficient estimates were calculated from mixed-effects linear regression equations using random intercepts. Non-ICU, nonintensive care unit; RN, registered nurse.
$^*p < .05$.

FTR when considering nurse staffing in non-ICUs as well as in ICUs, holding other predictors constant (Models 2–4 in Tables 2 and 3). As expected, higher technological complexity levels at hospitals were related to lower rates of FTR ($p < .01$).

Discussion

In this study we examined the relationship between RN staffing and FTR and evaluated the effect of patient turnover on that relationship. In general, we found that more RN hours per patient day were associated with lower rates of FTR, controlling for non-RN staffing and hospital characteristics. This finding is consistent with that of previous studies where investigators found an inverse relationship between RN staffing and FTR (Blegen et al., 2011; Harless & Mark, 2010; Needleman et al., 2002). In this sample, patient turnover rates differed by unit type, with higher turnover on non-ICUs (56.1%) than ICUs (45.4%), but our results showed no direct effect of patient turnover on FTR rates on either non-ICUs or ICUs.

We found an interaction effect between patient turnover and RN staffing on non-ICUs, however, indicating that the association between RN staffing and FTR differed significantly depending on the level of patient turnover. Specifically, we found that non-ICUs with higher patient turnover rates require more RN hours per patient day to decrease FTR rates as compared to units with lower levels of patient turnover. When patient turnover (admissions, discharges, and transfers) is high, RNs experience high workload demand because they are providing more concentrated care to a larger number of patients than the unit size might indicate. During high patient turnover, the care must also be accomplished within short time frames to accommodate the needs of the high number of patients moving in and out. Staffing standards limit the maximum number of patients treated by a nurse at each time point, although the total number of patients per nurse during a shift may exceed that limit due to turnover. Hospital and nursing administrators, however, have paid little attention to the additional workload from patient turnover when they project nurse staffing levels necessary for patient care (Needleman et al., 2011). Based on our findings and those linking high patient turnover to increased mortality (Needleman et al., 2011), we suggest that patient turnover is an important factor in determining the RN staffing levels that yield better patient outcomes. By projecting RN staffing by patient turnover levels, hospitals could strengthen their environmental structure to ensure safe and high-quality patient care.

By contrast, the interaction between RN staffing and patient turnover on ICUs was not statistically significant. This inconsistent finding might arise from the differences in the nature of these units. ICUs have higher RN staffing levels but lower patient turnover rates compared with non-ICUs. Nurse staffing levels in ICUs are designed to provide more intensive nursing care for much sicker patients in a complicated environment, which may result in patient turnover having less effect on overall workload. Although adjusting for RN staffing in ICUs by patient turnover had no significant influence on better outcomes, sufficient RN staffing on ICUs remains essential based on our findings that higher ICU RN staffing was associated with lower rates of FTR.

We found that higher technological complexity in hospitals was related to lower FTR ratios; findings from previous studies showed mixed evidence regarding the effect of technology on patient outcomes (Mark & Harless, 2010; Mark et al., 2004). Similar to Needleman et al. (2002), we found no evidence of a meaningful relationship between non-RN staffing and FTR. Furthermore, according to our preliminary analysis, changes in patient turnover had no statistically significant influence on the association between FTR and staffing by either LPNs or CNAs.

Our study is not without its limitations. First, we aggregated unit-level measures of patient turnover and nurse staffing at the hospital level because our patient outcome indicator was obtained from administrative data and calculated at the hospital level. In general, patient turnover and nurse staffing tend to present more variation at the unit level than at the hospital level. We aggregated the staffing and patient turnover to the hospital level by unit types to examine the relationship of nurse staffing and patient turnover with the hospital-level outcomes. The aggregation at the hospital level could bias our estimates of the relationships between patient turnover, nurse staffing, and patient outcomes. Second, our findings might not be generalizable to all hospitals because quarterly data were obtained from 42 teaching hospitals, most of which were relatively large. Although our sample presented a large variation in FTR *O*/*E* ratios ranging from 0.43 to 1.47, the mean FTR *O*/*E* ratio was 0.93, indicating fewer FTR events than expected. This result was supported by Ayanian and Weissman's (2002) literature review in which the authors concluded that teaching hospitals were more likely to have better quality of care than nonteaching hospitals. In this sample, RN staffing levels by unit type were similar as compared with those in other studies using hospital data from a randomly selected nationwide sample (Blegen, Vaughn, & Vojir, 2008) and California (Spetz et al., 2008). U.S. teaching hospitals, however, have higher RN staffing than nonteaching hospitals on average (AHRQ, 2005). Thus, because our findings represent only teaching hospitals, they are limited in regard to their generalizability. Finally, although our analysis included risk-adjustment and variables to control for differences in patient and hospital characteristics, unmeasured factors might yield measurement bias when examining the relationships between patient turnover, nurse staffing, and patient outcomes.

To our knowledge, this is the first study in which investigators examined the relationships between nurse staffing, patient turnover, and FTR using administrative data from multiple hospitals. Our findings should draw the attention of hospital and nursing administrators to the issue of high patient turnover. Further research is needed to explore hospital-based and unit-based efforts to decrease nursing workload related to patient turnover and improve patient throughput processes. Developing a group of nurses who do the work of admissions, discharges, and transfers (ADT) may be useful on nursing care units at peak times with high patient turnover. ADT nurses have demonstrated improved nurse and patient satisfaction (Blankenship & Winslow, 2003; Giangiulio et al., 2008). For future research, it will be critical to collect patient turnover data across unit specialty types at the nursing care unit level to account for the variability in patient turnover according to unit specialties. Future researchers can then provide hospital and nursing administrators with more unit-specific guidance on the allocation of nursing resources needed for quality of care.

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