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Nurse Staffing, Patient Turnover, and Patient Outcomes in Acute Care Hospitals

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Nurse Staffing, Patient Turnover, and Patient Outcomes in Acute Care Hospitals

by

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DISSERTATION

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When I look back on my time at UCSF, I am reminded of a quote that I read before. In his autobiography, Bertrand Russell said "*Three passions, simple but overwhelmingly strong, have governed my life: the longing for love, the search for knowledge, and unbearable pity for the suffering of mankind."* During my doctoral studies, while focusing on these passions, especially *"the search for knowledge"* in nursing, I have undergone many challenges and achievements. The past five years were the toughest periods of my life. I could never have made my journey without the many great people who have supported me.

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NURSE STAFFING, PATIENT TURNOVER, AND PATIENT OUTCOMES

IN ACUTE CARE HOSPITALS

Shin Hye Park

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ABSTRACT

Background: Registered nurses (RNs) take care of patients at the bedside and play a critical role in protecting them from adverse events through monitoring and surveillance. Researchers have examined the effect of nurse staffing on patient outcomes, but studies have produced inconsistent findings. The mixed findings might have resulted from various staffing measurements and insufficient adjustment for the effect of high patient turnover on nursing workload.

Purpose: This dissertation was to refine evidence of the relationship between nurse staffing and patient outcomes while minimizing measurement errors. The specific aims were: (1) to compare various staffing measures and select the best methods; (2) to examine the association of nurse staffing with patient outcomes for surgical care; and (3) to evaluate the effect of patient turnover on the relationship between nurse staffing and patient outcomes.

Methods: Three studies were performed using data obtained from the University HealthSystem Consortium (UHC) for the year 2005. Multivariate regressions were conducted while controlling for patient and hospital characteristics. For the first aim, the Akaike Information Criterion (AIC) was used to determine which nurse staffing measure performed the best. For the second aim, surgical intensive care unit (ICU) and non-ICU staffing levels were included in the regression models to examine the association with surgical patient outcomes. The interaction between patient turnover and RN staffing was examined for the third aim.

Findings: Measuring nurse staffing as productive hours by both direct and indirect patient care providers was best. Higher RN staffing in surgical non-ICUs was related to lower rates of failure to rescue and post-operative sepsis. We found that there was a significant interaction between patient turnover and RN staffing on general units.

Conclusions: The findings show that higher RN staffing contributes to patient safety by decreasing failure to rescue. However, using only surgical staffing did not reveal more different effects on surgical patient outcomes than previous work. While productive hours of direct and indirect providers were better than other measures of nurse staffing, the differences were small. Further work is needed to determine the reasons for the inconsistency in research findings.

Table of Contents

List of Tables

Chapter 1

Introduction

Background of the Dissertation

Since the 1980s, acute care hospitals have struggled with cost containment due to regulatory changes in the health care system. These include the growth of health maintenance organizations (HMOs) and the Medicare prospective payment system (PPS) based on diagnosis-related groups (DRGs) (Rosenthal, 2007; Shen, 2003). To survive these regulatory changes and cost containment policies, hospitals shortened lengths of inpatient stays and increased patient turnover. As a result, hospitals take care of sicker patient populations than in the past.

The number of hours of care per patient day provided by registered nurses increased through the mid-1990s (Spetz, 1998). The question arises whether nurse staffing has increased rapidly enough to keep pace with the increasing severity of illness of patients and patient turnover rates in the health care system (Page, 2004). In addition, hospitals have continued to strive to improve operational efficiency by replacing high-cost registered nurses with lower-cost licensed practical nurses and unlicensed assistive staff. This has resulted in a reduction in the skill mix of registered nurses (Norrish & Rundall, 2001). Whether the restructured skill mixes of nursing personnel are appropriate for the changed health care system is questionable.

In 2000, the Institute of Medicine (IOM) increased public awareness of the problem of hospital medical errors, which result in more than one million injuries and 44,000 to 98,000 deaths annually (Kohn, Corrigan, & Donaldson, 2000). The IOM report also estimated that national costs (including lost income, lost household production, disability and healthcare costs) of preventable adverse events (medical errors resulting in injury) are between $17 billion and $29 billion, representing one half of all healthcare costs

(Kohn, et al., 2000). The Centers for Medicare and Medicaid Services (CMS) announced new regulations for nonpayment of preventable adverse complications (Rosenthal, 2007). For these reasons, in recent years, hospitals have been forced to pay much more attention to patient outcomes in addition to hospital financial outcomes.

With this background, adequate nurse staffing and the contribution of nurses in improving patient outcomes have become a central issue in healthcare delivery, research, and health policy. Over the past decade, studies have provided evidence that higher nurse staffing levels are associated with reductions in adverse events and mortality (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Blegen, Goode, & Reed, 1998; Cho, Ketefian, Barkauskas, & Smith, 2003; Kovner, 2001; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). However, evidence of the effect of nurse staffing on patient outcomes is still weak due to the inconsistent findings from previous studies (Blegen, 2006; Kane, Shamliyan, Mueller, Duval, & Wilt, 2007; Lang, Hodge, Olson, Romano, & Kravitz, 2004). The mixed findings may create problems when politicians and nursing administrators make decisions about nurse staffing levels in acute care hospital settings.

To establish definite evidence of the relationship between nurse staffing and patient outcomes, it is necessary to explore the factors that led to the inconclusive findings. The complexity of the nature of nursing practice and patient outcomes makes it difficult to find strong evidence of the relationships among them (Needleman, Kurtzman, & Kizer, 2007). The inconsistent findings may result from the following issues: inaccurate or different measures of nurse staffing, inappropriate nurse staffing allocation methods, different inpatient outcome indicators sensitive to nursing care, or diverse risk-adjustment strategies used with existing databases (Blegen, 2006; Mark, 2006). Furthermore, nurse staffing measures used in previous studies may not sufficiently reflect nursing workloads, such as increasing patient turnover rates, in the current context of health care (Jacobson, Seltzer, & Dam, 1999). Of these potential reasons for the inconsistent findings, this dissertation focused on reducing measurement errors by (1) selecting the best method to measure nurse staffing, (2) using the allocation method of nurse staffing matched to patient outcomes, and (3) adjusting for nursing workloads resulting from patient turnover.

Any measurement includes some measurement error. Measurement error refers to the difference between an abstract concept or the true score being measured and the observed measurement (Higgins & Straub, 2006; Nunnally & Bernstein, 1994). The equation used in classical measurement theory is: $X = t + e$, where X is the observed score, t is the true score, and e is the error of measurement (Higgins & Straub, 2006). The "e," indicating measurement error, can result from both systematic and random processes (Nunnally & Bernstein, 1994). Validity can be obtained by using methods which reduce systematic error, and reliability can be ensured by using those methods which reduce random error (Higgins & Straub, 2006).

The degree of scientific utility of a measure can be determined by its validity, "how well it measures what it purports to measure" (Nunnally & Bernstein, 1994, p. 83). A clear definition of nurse staffing is critical for attaining validity, especially construct validity (Mark, 2006). Nurse staffing can be conceptually defined as the process of determining the appropriate number and mix of nursing resources necessary to meet the workload demands for nursing care at the departmental level (Dunn, et al., 1995). Although previous studies have operationally defined nurse staffing in various ways

(Mark, 2006), they have used a common conceptual definition, namely the number of nursing personnel allocated to provide patient care.

Nurse staffing has been operationally defined as patient-to-nurse ratios, full-time equivalent (FTE) employees per patient day, hours of nursing care per patient day (HPPD), or share of registered nurses in total nurse staffing (Kane, et al., 2007; Mark, 2006). The use of different methods of measuring nurse staffing has been considered to be one of the most important factors producing inconsistent findings in the relationship between nurse staffing and patient care outcomes (Spetz, Donaldson, Aydin, & Brown, 2008). Moreover, the identification of the type of nursing hours differed from study to study when calculating nurse staffing. Researchers should decide whether or not they would include hours of indirect patient care providers and non-productive hours of patient care in measuring nurse staffing. Depending on the inclusion or exclusion of indirect patient care providers and non-productive hours of patient care, the level of nurse staffing in a study differs (Spetz, et al., 2008).

Several studies measured nurse staffing by identifying the productive hours of those nurses that provided patient care at the bedside (Blegen, et al., 1998; Blegen & Vaughn, 1998; Donaldson, et al., 2005). None of them compared their nurse staffing measures with other staffing measures including non-productive hours and indirect patient care providers. Thus, little is known about whether or not the productive hours of direct patient care providers are more directly related to the occurrence of adverse events than all nursing hours. By comparing the impact on patient outcomes according to diverse measures of nurse staffing, it may be possible to answer the question of whether diverse measures of nurse staffing estimate “the same thing, several different things, or many different things" (Nunnally & Bernstein, 1994, p. 86). Therefore, this dissertation compared diverse candidate sets of nurse staffing measures when examining their associations with adverse patient outcomes. After that, the best methods to use to measure nurse staffing were selected using model selection statistics.

Another methodological issue presented in previous studies was measurement error resulting from the allocation method of nurse staffing (Harless & Mark, 2006). When examining the effect of nurse staffing on patient outcomes, the measured level of nurse staffing has to be matched to the patients who received nursing care. However, multi-institutional databases, such as the American Hospital Association (AHA) Annual Survey of Hospitals, can not distinguish in-patient staffing from out-patient staffing (Jiang, Stocks, & Wong, 2006). Therefore, previous studies have used different allocation strategies to estimate nurse staffing levels for in-patient care based on those for all services including both in-patient and out-patient care. In general, studies using the AHA data have estimated in-patient nurse staffing using the ratio of inpatient to outpatient gross revenues (Kovner, Jones, Zhan, Gergen, & Basu, 2002; Mark, Harless, McCue, & Xu, 2004). Although previous studies using hospital administrative data selected patients with specific surgical ICD-9-CM codes, they could not identify nurse staffing according to the specific types of nursing care units and thus included nursing staff across all types of units as well as surgical units (Cho, et al., 2003; Kovner, et al., 2002; Mark, et al., 2004; Needleman, et al., 2002). To overcome the measurement error led by these imprecise allocation methods, this dissertation examined the association with surgical patient outcomes while measuring only surgical nurse staffing levels.

Nurse staffing measures used in previous studies did not consider patient care demand resulting from increased patient turnover in acute care hospitals. Nurse staffing measures such as patient-to-nurse ratios, FTEs per patient day, and HPPD have typically estimated demands for patient care from patient volume determined by using the midnight census (Budreau, Balakrishnan, Titler, & Hafner, 1999; Jacobson, et al., 1999). However, nurse staffing measures based on patient volume at midnight do not accurately reflect the actual workload because the midnight census can not delineate increased census variability or patient turnover that results from the increased number of admissions, discharges, transfers, or short-stay observations (Jacobson, et al., 1999). For this reason, nurse staffing measures commonly used in previous studies have limitations with regard to the increase in nursing workload caused by rapid patient turnover.

Patient turnover may be a critical factor because examining it can make it possible to reduce gaps in existing nurse staffing measures that have failed to explain nursing demands resulting from fluctuations in patient volume (Jacobson, et al., 1999; Jennings, 2008). The adjustment for patient turnover can account for the greater demands for nursing care, which are induced by the increased fluctuation in patient volume. Moreover, this adjustment would yield different research findings about the effect of nurse staffing on patient outcomes when compared to not adjusting for patient turnover (Jennings, 2008). However, little is known about how to factor in patient turnover in nurse staffing research. Therefore, this dissertation evaluated the effects of patient turnover on nurse staffing and patient outcomes and determined to what extent nurse staffing affects patient outcomes varying by changes in patient turnover levels.

Purpose of the Dissertation

The goal of this dissertation is to refine the evidence on the relationship between nurse staffing and patient outcomes by reducing measurement error bias. The main body of the dissertation is organized into three chapters. Each chapter contains a manuscript that has been submitted for publication. The three chapters attempted to decrease measurement errors by determining the best method to use to measure nurse staffing, identifying nurse staffing levels more directly related to specific patient outcome indicators, and including the factor of patient turnover affecting nurse staffing as well as patient outcomes. This dissertation is divided into five chapters.

This first chapter includes an introduction to this dissertation and provides a brief background, review of the current literature, and an overview of the dissertation.

The second chapter is titled "Comparison of Nurse Staffing Measures by Akaike Information Criterion (AIC)." This chapter presents the findings from a correlational-descriptive study. It compared diverse nurse staffing measures and selected the best methods based on the AIC statistic by analyzing 208 quarterly data obtained from 54 UHC affiliated hospitals. The findings from this study endorse the use of productive hours for nurse staffing measures and also suggest conducting additional studies using diverse datasets.

The third chapter is titled "Surgical Nurse Staffing Effects on Patient Outcomes." This chapter presents the findings from this study that identified surgical nurse staffing levels in order to examine the association with surgical patient outcomes. Previous studies have included all nursing staff across all types of patient care units. By using this more refined identification method, this study matched the type of patients cared for by nursing staff with patient outcomes and thus attempted to reduce measurement error.

The fourth chapter of the dissertation is titled "Patient Turnover as a Moderator of the Relationship between Nurse Staffing and Patient Outcomes." This chapter presents the research findings of this study examining how the relationship between nurse staffing and patient outcomes differed depending on patient turnover levels. This study found that adult general units with high patient turnover levels required more RN hours for patient care in order to reduce adverse patient outcomes. Based on the findings, this study emphasizes how important it is for hospital administrators to consider patient turnover when making decisions about nursing resource allocations.

The fifth chapter summarizes the findings of the research studies examined in this dissertation. Moreover, this chapter provides implications for policy makers and hospital administrators, and suggestions for future nurse staffing research.

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Chapter 2

Comparison of Nurse Staffing Measures by Akaike Information Criterion (AIC)

Abstract

Objective. To determine the best method to use to measure nurse staffing when describing the relationship between nurse staffing and patient outcomes.

Data Sources/Study Setting. The hospital administrative data collected by the University HealthSystem Consortium (UHC) were used. The sample comprised 54 hospitals, including information on 971 units for adult patient care.

Study Design. A descriptive-correlational design.

Data Collection/Extraction Methods. The UHC provided three datasets (facility, nursing care unit, and patient) for four quarters for the year 2005. These datasets were analyzed at the hospital/quarter level. Regression models based on Akaike Information Criterion (AIC) were used to determine which nurse staffing measure performed the best.

Principal Findings. This study found only small AIC differences between candidate staffing measures for each patient outcome, indicating that the staffing measurements did not provide substantial differentiations for selecting the best way to calculate staffing. The results showed that, in general, the models measuring nurse staffing as productive hours by both direct and indirect patient care providers were best.

Conclusions. This study is the first to evaluate the various measures of nurse staffing using AIC. Repeated studies based on different datasets would provide more enriched knowledge on the best way to measure nurse staffing.

Key Words. Nurse Staffing (measurement), quality, patient outcomes, adverse events

Nurse Staffing Measurement Issues

Since the publication of the Institute of Medicine (IOM) report *To Err Is Human* (Kohn, Corrigan, & Donaldson, 2000), adequate nurse staffing and quality of care have become central issues in healthcare delivery, research, and policy. A number of studies over the past decade have examined the associations between nurse staffing and quality of care while addressing the critical role of nurses in improving patient safety in hospital settings. Previous studies found that higher nurse staffing levels are associated with decreases in adverse events and mortality (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Cho, Ketefian, Barkauskas, & Smith, 2003; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). However, the inverse relationship between nurse staffing and adverse patient outcomes has been debatable because of the mixed findings from previous studies (Blegen, 2006; Kane, Shamliyan, Mueller, Duval, & Wilt, 2007; Lang, Hodge, Olson, Romano, & Kravitz, 2004).

Previous studies commonly measured nurse staffing as: (1) patient-to-nurse ratios, number of patients usually assigned to each nurse (Aiken, et al., 2002; Halm, et al., 2005), (2) number of full-time equivalent nursing staff per patient day (Kovner & Gergen, 1998; Mark, Harless, McCue, & Xu, 2004), (3) number of hours of nursing care per patient day (HPPD) (Blegen, Goode, & Reed, 1998; Kovner, Jones, Zhan, Gergen, & Basu, 2002; Needleman, et al., 2002), and/or (4) the skill mixes of nursing personnel, especially the registered nurse (RN) skill mix measured by the proportion of hours provided by RNs in the total nursing staff (Blegen, et al., 1998; Cho, et al., 2003; Needleman, et al., 2002). Which of those measures is best for measuring nurse staffing is uncertain. The diverse nurse staffing measures used in previous studies have resulted from the lack of a clear operational definition for nurse staffing and have contributed to the mixed findings in previous studies (Kane, et al., 2007; Mark & Harless, 2010; Spetz, Donaldson, Aydin, & Brown, 2008).

Previous studies using hospital administrative data have frequently measured nurse staffing using HPPD and skill mix (Blegen, et al., 1998; Cho, et al., 2003; Kovner, et al., 2002; Needleman, et al., 2002). Both HPPD and skill mix are measured by computing nursing care hours and/or patient days. Different data collection methods for nursing care hours and/or patient days may produce dissimilar results for the two measures of nurse staffing. A recent study, which compared diverse patient day measurements, found that patient day measurement adjusting for short stay patients was more reliable than that without short stay patient adjustment (Simon, Yankovskyy, Klaus, Gajewski, & Dunton, 2010). However, previous studies have paid little attention to measurements of nursing care hours used as a numerator in measuring HPPD and skill mix. These various methods of identifying the type of nursing care hours may also contribute to mixed findings in staffing research.

We can classify nursing hours for patient care as hours provided by indirect or direct patient care providers and nursing hours as productive or non-productive hours. Indirect patient care providers are those who are in supervisory roles or who coordinate patient care; whereas, direct patient care providers carry out nursing activities with patients and/or families directly (Blegen, et al., 1998). Non-productive hours of patient care can be defined as hours spent not providing patient care even though the hours are paid (Spetz, et al., 2008). For example, hours for continuing education, vacation, or sick time are considered as non-productive hours.

Using only the productive hours of providers with direct patient care responsibilities is logically the best choice and has been used to calculate accurate nurse staffing in relation to patient outcomes (Donaldson, et al., 2005). However, little is known about whether or not, among all the types of nursing hours, the inclusion of productive hours of direct patient care providers yields the most sensitive approach to nurse staffing measurements. How differently the inclusion or exclusion of non-direct patient care related time affects the relationship with patient outcomes has been infrequently addressed in previous studies.

The purpose of this study was to determine the best method to use to measure nurse staffing when describing the relationship between nurse staffing and patient outcomes. For this purpose, this study modeled the effect of nurse staffing on adverse patient outcomes while using diverse measures generated from different nurse staffing operational definitions. After that, we compared the estimated models based on Akaike Information Criterion (AIC) to determine which nurse staffing measure performed the best for the data used in this study.

Methods

Study Design and Data Sources

A descriptive-correlational design was used for this study. We analyzed existing datasets from the University HealthSystem Consortium (UHC), a voluntary alliance involving over 90% of the nation's non-profit academic medical centers in the U.S. For this study, the UHC provided data for four quarters in the calendar year 2005. The UHC data included three datasets: facility, operational, and clinical. The facility dataset contained hospital characteristics, such as ownership, location, and bed size. The operational datset provided information related to characteristics and nurse staffing for nursing care units. The clinical dataset consisted of patient data, which included information on patient diagnosis and procedure, demographics, discharge and admission status, and number of complications. Data from the American Hospital Association (AHA) Annual Survey of Hospitals were used to compute a measure of hospital technological complexity, and the variable was matched to the UHC file before removing the hospital identities. For the analyses, all datasets were merged at the hospital/quarter level.

Study Sample

Of 234 hospitals having UHC membership in 2005, this study examined the 57 hospitals that had provided all the data on hospital characteristics, nurse staffing, and patient outcomes. From the hospitals, nursing care units for adult patients were selected, excluding those for pediatric, obstetric, and psychiatric patient care. We excluded the adult units having extreme outliers—below the 1st percentile or above the 99th percentile of RN staffing. Consequently, this study analyzed data from 54 teaching, short-term acute care hospitals, including a total of 971 adult units that consisted of 655 adult general units and 316 adult intensive care units (ICUs). Moreover, the sample reflected data from about one million patients from the hospitals.

The hospitals analyzed for the study maintained on average 555 operating beds (*SD* = 189.38). They are mostly large when compared to U.S. hospitals in 2006 having an average of 159 beds (Department of Health and Human Services, 2006). There were no privately owned facilities in the sample. Universities or local governments owned most of the hospitals, 54% and 26% respectively. The others were owned by a community (15%)

or religious sponsor (5%). The hospitals were located in metropolitan (81%), suburban (15%), and rural (4%) areas. All identifiers for hospitals and patients were stripped from the data by the UHC.

Measures

Hospital characteristics. We included two hospital characteristics as control variables: hospital technological complexity and patient severity of illness. The technological complexity was measured by the "Saidin Index," the weighted sum of the number of technologies and services available in a hospital (Spetz, 1999). Hospitals with higher index values indicate those with relatively rare services, which are typically new, expensive, or complicated. In this study, the Saidin Index was measured annually for each hospital. Medicare case-mix index (CMI) is a measure of the average diagnosis-related group (DRG) relative weight for all of a hospital's Medicare discharges (Centers for Medicare and Medicaid Services, 2005). The CMI was used to control for overall patient severity of illness in a hospital.

Nurse staffing measures. In general, nurse staffing levels differ according to the type of nursing care unit. ICUs had much higher nurse staffing than general units. To deal with this issue of aggregating values with various ranges, this study calculated nurse staffing measures for adult general units and ICUs separately for each quarter in each hospital.

Of the various nurse staffing measures, we focused on a comparison between RN skill mix and RN HPPD, which have been frequently used in previous studies and were available for the UHC data. Two approaches were used to compare these two types of staffing measures. One included nurse staffing measured by RN skill mix, controlling for total nursing staff HPPD (Approach A in Table 1). Total nursing staff HPPD was calculated by the number of total hours of RNs, licensed practical nurses (LPNs), and clinical nursing assistants (CNAs) divided by the number of patient days. RN skill mix was measured as the proportion of RN hours among the total nursing hours. The other approach used nurse staffing measures calculated by RN HPPD, controlling for non-RN HPPD (Approach B). RN HPPD was defined as the number of hours of RNs per patient day. Non-RN HPPD was measured by the number of hours of LPNs and CNAs per patient day.

For the measures used in the two approaches (Approaches A and B), the number of nursing hours was calculated in four ways: (1) all hours (productive and non-productive hours) worked by all providers (direct and indirect care providers) were used for Method 1; (2) all hours by direct providers were used for Method 2; (3) productive hours by all providers were used for Method 3; and (4) only productive hours from direct providers were used for Method 4. A total of eight candidate models with different staffing measures were examined for each patient outcome. Definitions of the staffing measures used for this study are described in Table 1. Productive hours were measured as the number of worked hours of providers. Non-productive hours, such as for sick call or vacation, were calculated from proportions of worked to paid hours. In the UHC data, the proportion of worked to paid hours for all nursing staff were reported at the nursing care unit level, and we used this proportion for all nursing providers. Continuing education hours of providers were counted among worked hours. Indirect care providers were identified as unit management, administrative, or support staff in the nursing care unit; all other hours were assumed to be for direct providers.

For all the Approaches and Methods, the number of patient days was used as a denominator in calculating HPPDs. Patient days are commonly obtained from the midnight census. Because increasing numbers of patients are admitted for short-stay observations during the daytime, the midnight census tends to underestimate the number of patients cared for by nursing staff. Thus, this study used patient days adjusted for short-stay patient days. For the adjustment, we converted the short-stay patient hours into number of patient days, assuming 24 short-stay hours equal one patient day.

Patient outcomes measures. The Agency for Healthcare Research and Quality (AHRQ) developed the Patient Safety Indicators (PSIs) to measure health care quality of care and potentially preventable adverse events from hospital administrative data (Elixhauser, Pancholi, & Clancy, 2005). Among patient-centered outcome measures for nursing-sensitive care, which were recommended by the National Quality Forum (NQF) (2004), this study selected three outcome indicators measurable from the AHRQ PSIs: failure to rescue, decubitus ulcers, and infections (Savitz, Jones, & Bernard, 2005).

The three PSIs were calculated from the AHRQ algorithms. The algorithms identified cases of DRGs or ICD-9-CM codes with failure to rescue, decubitus ulcers, or infections (Agency for Healthcare Research and Quality, 2007). Failure to rescue was defined as death rates for patients who developed specific complications, such as pneumonia, deep vein thrombosis or pulmonary embolism, sepsis, acute renal failure, shock or cardiac arrest, and gastrointestinal hemorrhage or acute ulcer, during hospitalization. Infections were identified for hospital-acquired bloodstream infections associated with intravenous devices and catheters.

The AHRQ algorithms estimated expected rates of adverse events by grouping the populations according to age, gender, and risk based on the All Patient Refined (APR) DRGs. Based on the AHRQ risk adjustment method, this study calculated the ratio of the observed rate to the expected rate (O/E) for the selected three PSIs. O/E ratios greater than 1.0 indicated hospitals with more adverse events than expected. Hospitals with O/E ratios less than 1.0 represented those with fewer adverse events than expected. Only outcomes with more than or equal to 30 patients at risk for each PSI at the hospital/quarter level were included to minimize unstable estimates (AHRQ, 2007).

Data Analysis

Model Estimation

This study modeled the effects of nurse staffing on patient outcomes adjusting for hospital technological complexity and patient severity of illness while using different sets of nurse staffing measures. All analyses were conducted using Stata version 11.0. Mixed-effects regressions, incorporating the fixed effects for predictors in addition to random effects for each subject, were conducted using the Stata *xtmixed* command. To be specific, the random-intercept model, a type of the 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 occasions within a subject, in this case, the four quarters within a hospital (Rabe-Hesketh & Skrondal, 2008). Moreover, the data for this study had an unbalanced structure over four quarters. For example, several hospitals provided data only for two quarters, whereas most of the hospitals had four quarters of data.

Model Selection

This study estimated eight regression models with different nurse staffing measures for each patient outcome indicator. The eight candidate models for each patient outcome indicator were evaluated in two ways. First, we compared models using RN skill mix (Approach A) with those using RN HPPD (Approach B). Second, we evaluated models with four types of nursing hours according to the inclusion or exclusion of non-productive hours and indirect patient care hours (Methods 1 to 4). To compare the eight models, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were examined to select the model that best explained the effect of nurse staffing on patient outcomes.

AIC and BIC are information criteria used to select a “best approximating model” based on the log likelihood statistic. The AIC and BIC can compare the relative goodness-of-fit of two or more competing models with different sets of predictors (Dayton, 2003; Gagne & Dayton, 2002). Along with AIC and BIC, null hypothesis testing based on p-values, stepwise methods, and the adjusted R^2 statistic can be used for comparing estimated models. The use of null hypothesis testing has weaknesses for model selection when several or many different models would be acceptable and thus would produce different interpretations (Burnham & Anderson, 1998; Raftery, 1995). The use of stepwise methods is problematic when used for comparison of non-nested models. The adjusted R^2 statistic is good for descriptive purposes, but is weak when used for model selection (Raftery, 1995). However, AIC and BIC can overcome these limitations.

Both AIC and BIC have an advantage for model selection because they can compare a variety of competing models with a simple, single rule (Dayton, 2003). The rule is that, of the competing models, the best approximating model has the smallest information criterion statistic. Both AIC and BIC can be used for either nested or non-nested models. This study compared various non-nested models using different sets of nurse staffing predictors; thus, AIC and BIC were useful for this study. In the calculation, AIC considers the number of model parameters, whereas BIC is based on that number weighted by the scale factor, half the log of the sample size. For multi-level or clustered data, it is not clear which of the sample sizes should be utilized for the BIC scale factor, either the number of subjects or the number of all cases (Singer & Willett, 2003). Therefore, this study using clustered data focused on and reported the findings derived from AIC.

AIC is computed as $AIC = -2(LL - p)$, where LL is the log-likelihood for the model and p is the number of parameters estimated from the model. The log likelihood for the regression model can be calculated as $-0.5\ N \times (\ln(2\pi) + \ln(SS_e/N) + 1)$, where N is the sample size and SS_e is the sum of squared residuals. AIC is fundamentally based on Kullback-Leibler (K-L) information, which assumes that a good model from the empirical data approximates full reality or truth (Burnham & Anderson, 1998). According to the K-L information theory, the distance from a candidate model to full reality or truth can be calculated and can be minimized by selecting a best approximating model closest to f (truth) (Burnham & Anderson, 1998).

AIC estimates a relative distance between the unknown truth and the model fitted from the data. Thus, AIC values, which are calculated on the basis of logarithm functions, can be either positive or negative. According to Burnham and Anderson (1998), AIC values obtained from regression statistics are negative in many cases. AIC values of models, given the data, can be ranked from smallest to largest; after that, the model with the smallest AIC value is selected as the best approximating model. An AIC value is not interpretable by itself because it is on a relative or interval scale; thus, comparing AIC values across models is more important and useful.

When comparing the AIC differences between the model g_i and the best model g_{min}, calculated by $\Delta_i = AIC_i - AIC_{min}$, larger AIC differences indicate that there is less evidence to support the model g_i, and thus the minimum AIC model g_{min} is plausible as the best model. Although how large AIC differences need to be to favor the best model has been controversial, Burnham and Anderson (1998) suggested rough guidelines. In comparison with the AIC of the best model, models with an AIC difference of over 10 have "essentially no support," and those with a difference of 4 to 7 have "considerably less" support; thus, the model with the minimum AIC value has strong evidence of being the best. However, models with a difference of 0 to 2 have "substantial" support and thus are reasonable as second best models. This study determined models with the smallest AIC values as being best and then examined AIC differences across candidate models for each patient outcome.

Results

Overall, data for 208 quarters from 54 hospitals were analyzed. Table 2 presents descriptive statistics for the nurse staffing measures, hospital characteristics, and patient outcomes. The mean productive RN HPPD for direct care providers was 6.50 (*SD* = 1.24) in general units, whereas ICUs had a mean of 15.45 (*SD* = 2.17). Average productive HPPD for indirect care providers in ICUs (*M* = 0.50, *SD* = 0.35) was greater than that in general units (*M* = 0.27, *SD* = 0.19). Average percentages of worked to paid hours in general units and ICUs were similar, 88.55 % and 87.59 %, respectively. Different nurse staffing measures (Methods 1 to 4 for Approaches A and B) were summarized in Table 2.

Average patient severity of illness measured by Medicare CMI was 1.82 (*SD* = 0.20). The Saidin index for hospital technological complexity was 27.18 on average (*SD* = 5.58). Hospitals had higher observed than expected rates for decubitus ulcers (*M* = 1.28, *SD* = 0.49) and infections due to medical care (*M* = 1.81, *SD* = 0.78), and lower observed than expected FTR rates (*M* = 0.94, *SD* = 0.21).

The results of model selection based on AIC values were described by nursing care unit types, general units and ICUs (see Table 3). After that, we reported the findings of multivariate mixed-effects regressions for the best models (see Table 4).

Model Selection in General Units

Table 3 shows the findings of the AIC values and AIC differences for eight models for each patient outcome. For failure to rescue, Model 3 using nurse staffing measured by RN skill mix (Approach A) generated from productive hours by all providers (Method 3) was best. The AIC differences between the best model (Model 3) and the other Approach A models for failure to rescue had values of less than 0.5. They were smaller than those for Approach B (using RN HPPD) models, which were all greater than three.

Model 4 including nurse staffing measures of RN skill mix (Approach A) based on productive hours by direct care providers (Method 4) was best for the patient outcome of decubitus ulcers. Similar to the finding for failure to rescue, the models for decubitus ulcer showed smaller AIC differences for Approach A than those for Approach B.

For infections, this study selected Model 7 as being best. The patient outcome for infections selected the model using RN HPPD (Approach B) as a nurse staffing measure, whereas the patient outcomes for failure to rescue and decubitus ulcers chose the models using RN skill mix (Approach A). However, according to the AIC findings for three patient outcomes, the best approximating models selected in this study were those using nurse staffing measures calculated from productive hours by either all or direct care providers (Method 3 or Method 4).

Model Selection in ICUs

Model 6 using RN HPPD (Approach B) calculated from all hours by direct care providers (Method 2) showed the smallest AIC value for failure to rescue. Model 7 was selected as being best for decubitus ulcers. Model 7 included a nurse staffing measure of RN HPPD (Approach B) using productive hours by all providers (Method 3). The models using RN HPPD (Approach B) rather than RN skill mix (Approach A) were best for failure to rescue and decubitus ulcers in ICUs. For infections, Model 3, which included RN skill mix (Approach A) based on productive hours by all providers (Method 3), was best. However, the AIC differences among the eight models for infections were less than one, indicating that the models were likely to have very similar goodness of fit.

The Effects of Nurse Staffing on Patient Outcomes

Table 4 presents the multivariate regression results of the best models with the smallest AIC values for each patient outcome. The Wald chi-squared tests for evaluating the fit of the model showed that the models for failure to rescue were significant at the 0.05 significance level for general units (Wald $\chi^2(4, \text{N} = 206) = 27.13, p < .001$) and ICUs (Wald $\chi^2(4, N = 206) = 16.04, p < .001$). The models for decubitus ulcers or infections were not significant.

For both types of nursing care units, higher hospital technological levels were associated with lower rates of failure to rescue, controlling for staffing and patient severity of illness ($p < .05$). Higher RN skill mix and greater total HPPD on general units were associated with lower rates of failure to rescue ($p < .001$). Greater RN HPPD on ICUs was related to lower failure to rescue ($p = .02$).

Discussion

Based on the AIC statistics and differences, this study compared candidate sets of nurse staffing measures for three patient outcomes (failure to rescue, decubitus ulcers, and infections) and for staffing on general units and ICUs. The results demonstrated that the best models were different according to patient outcome indicators and nursing care unit types. Furthermore, we found small AIC differences between candidate models for each patient outcome. These small AIC differences indicated that the diverse nurse staffing measurements did not yield substantial differentiations for selecting the best approximating models when examining the relationship between nurse staffing and patient outcomes.

Evidence for choosing a best nurse staffing measurement is weak due to the divergent model selections and small AIC differences in this study. However, we found that, in general, the models including nurse staffing measured as productive hours by both direct and indirect care providers (Method 3) were best. Similar with our findings, previous studies suggested that the use of productive hours by nursing staff might be ideal in measuring nurse staffing (Donaldson, et al., 2005; Spetz, et al., 2008). However, unlike the previous studies, we demonstrate that it may be important to include productive hours provided by indirect providers as well as by direct providers. Along with the roles of nursing staff providing patient care at the bedside, the contribution of nursing administrators to patient outcomes may need to be considered in nurse staffing research.

AIC selects a best approximating model given the data, regardless of “significance” or “p-values” of all the candidate models. However, Burnham and Anderson (1998) recommended that all candidate models should be well structured because if the models are poor, the best model selected by the AIC statistic would be poor as well and would be not close to *f* (truth). For this reason, it may be more important to look into the results of model selection for failure to rescue, showing significant p-values for the Wald chi-squared tests.

With regard to the models for failure to rescue, relatively larger AIC differences were produced between RN skill mix and RN HPPD (Approaches A and B) than among the types of nursing hours (Methods 1 to 4). Thus, we suggest that the decision to use either RN skill mix or RN HPPD, rather than the type of nursing hours, is more likely to affect the approximation of the relationship between nurse staffing and patient outcomes. The model selection of failure to rescue for the two Approaches A and B was different according to the nursing care unit types. The model selection for failure to rescue for “general units” presented more consistent AIC differences between Approaches A and B. To be specific, the models using RN skill mix and total HPPD (Approach A) showed consistently lower AIC values than those using RN HPPD and non-RN HPPD (Approach B) for failure to rescue on general units. Therefore, these findings support using RN skill mix and total HPPD to determine the effect of nurse staffing on failure to rescue for general units.

Findings from this study have several limitations. First, the sample best represents large teaching hospitals. Second, the poor fit of the models for decubitus ulcers and infections might lead to inconsistent model selections. For this reason, it might be difficult to determine the best nurse staffing measures for these outcomes. Third, control variables and risk adjustment from the AHRQ algorithms used in this study might not be sufficient to control for differences in hospital or patient characteristics. Finally, each type of nursing staff might have different proportions of worked to paid hours. Because of the limitations of the data source, this study had to calculate non-productive hours for RNs and non-RNs using the same proportion of worked to paid hours in a hospital. Nonetheless, based on California's Office of Statewide Health Planning and Development (OSHPD) data for 279 general acute care hospitals from 1996 to 2001, Harless and Mark (2006) reported a proportion of worked to paid hours for RNs as 87.5%, which was similar to our findings of 88.6% and 87.6% for general units and ICUs respectively.

Previous studies have suggested that diverse nurse staffing measurements might yield inconsistent findings on the relationship between nurse staffing and patient outcomes (Mark, 2006; Spetz, et al., 2008). This is the first study to evaluate the various measures of nurse staffing using the information criterion, AIC. This study suggests that, based on AIC statistics, future nurse staffing research should pay attention to the identification of the types of nursing hours for measurement and the determination of either RN skill mix or RN HPPD according to nursing care unit types. Furthermore, repeated studies based on different data are needed to provide more enriched knowledge of the best measurements of nurse staffing.

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Table 1

Definition of Nurse Staffing Measures

	Approach A	Approach B
Method 1: All hours by all providers	RN skill mix = Proportion of RN hours among total hours including Unit management hours Total HPPD = Productive and non-productive hours of direct care providers (RNs, LPNs, and CNAs) and indirect care providers (Unit managers)/Adjusted patient days	RN HPPD = Productive and non-productive RN hours and unit management hours / Adjusted patient days Non-RN HPPD = Productive and non-productive hours of LPNs and CNAs / Adjusted patient days
Method 2: All hours by direct care providers	RN skill mix = Proportion of RN hours among total hours excluding Unit management hours Total HPPD = Productive and non-productive hours of direct care providers (RNs, LPNs, and CNAs) / Adjusted patient days	RN HPPD = Productive and non-productive RN hours / Adjusted patient days Non-RN HPPD = Productive and non-productive hours of LPNs and CNAs / Adjusted patient days
Method 3: Productive hours by all providers	RN skill mix = Proportion of RN hours among total productive hours including Unit management hours Total HPPD = Productive hours of direct care providers (RNs, LPNs, and CNAs) and indirect care providers (Unit managers) / Adjusted patient days	RN HPPD = Productive RN hours and unit management hours / Adjusted patient days Non-RN HPPD = Productive hours of LPNs and CNAs / Adjusted patient days
Method 4: Productive hours by direct care providers	RN skill mix = Proportion of RN hours among total productive hours excluding Unit management hours Total HPPD = Productive hours of direct care providers (RNs, LPNs, and CNAs) / Adjusted patient days	RN HPPD = Productive RN hours / Adjusted patient days Non-RN HPPD = Productive hours of LPNs and CNAs / Adjusted patient days

Note. Approach A measures nurse staffing as RN skill mix, controlling for total nurse staffing HPPD.
Approach B measures nurse staffing as RN HPPD, controlling for non-RN HPPD.
HPPD, Hours per patient day; RN, Registered nurse; LPN, Licensed practical nurse; CNA, Clinical nursing assistant.
Adjusted patient days = number of patient days from the midnight census + observation hours converted to days (assuming that 24 observation hours are equal to 1 patient day).
Productive hours = worked hours of care provider.
Non-productive hours = paid hours of care provider – worked hours of care provider.

Table 2

Descriptive Statistics of Variables in 54 Hospitals over Four Quarters (N = 208)

Nurse Staffing Variable		*General*	*ICU*
		Mean (SD)	*Mean (SD)*
Elements for Nurse Staffing Measures	Productive RN HPPD	6.50 (1.24)	15.45 (2.17)
	Productive indirect care HPPD	0.27 (0.19)	0.50 (0.35)
	Productive LPN HPPD	0.29 (0.47)	0.14 (0.43)
	Productive CNA HPPD	2.50 (1.07)	2.17 (1.32)
	RN skill mix including management hours (%)	68.08 (8.62)	84.63 (6.41)
	RN skill mix excluding management hours (%)	70.06 (8.46)	87.03 (6.29)
	Proportion of worked hours to paid hours (%)	88.55 (2.87)	87.59 (3.21)
Approach A	Total HPPD (Method1)	10.80 (1.88)	20.88 (3.05)
	Total HPPD (Method2)	10.50 (1.85)	20.31 (3.06)
	Total HPPD (Method3)	9.60 (1.73)	18.25 (2.64)
	Total HPPD (Method4)	9.29 (1.69)	17.76 (2.65)
	RN skill mix (Method 1 and 3)	68.08 (8.62)	84.63 (6.41)
	RN skill mix (Method 2 and 4)	70.06 (8.46)	87.03 (6.29)
Approach B	RN HPPD (Method1)	7.66 (1.39)	18.24 (2.42)
	RN HPPD (Method2)	7.35 (1.37)	17.67 (2.46)
	RN HPPD (Method3)	6.78 (1.26)	15.94 (2.13)
	RN HPPD (Method4)	6.50 (1.24)	15.45 (2.17)
	Non-RN HPPD (Method 1 and 3)	3.14 (1.10)	3.15 (1.10)
	Non-RN HPPD (Method 2 and 4)	2.79 (0.98)	2.31 (1.31)

Variable of Hospital Characteristics and Patient Outcomes		*Mean (SD)*
Hospital characteristics	Patient severity of illness	1.82 (0.20)
	Technological complexity	27.18 (5.58)
Patient outcomes	Failure to rescue (O/E)[a]	0.94 (0.21)
	Decubitus ulcers (O/E)	1.28 (0.49)
	Infections due to medical care (O/E)	1.81 (0.78)

Note. HPPD, Hours of care per patient day; RN, Registered nurse; LPN, Licensed practical nurse; CNA, Clinical nursing assistant; O/E, Observed to expected rate; ICU, Intensive care unit.
[a]n = 206.

Table 3

Comparison of AIC Statistics for Adult General Units and ICUs

		Model	Failure to Rescue (N = 206)		Decubitus Ulcers (N = 208)		Infections (N = 208)	
			AIC	Δ	AIC	Δ	AIC	Δ
Adult General Units								
Approach A	Method 1	1	-164.04	0.33	136.26	0.81	458.44	2.04
	Method 2	2	-163.93	0.44	135.64	0.19	456.69	0.29
	Method 3	3	***-164.37***	***0***	136.08	0.63	458.34	1.94
	Method 4	4	-164.25	0.12	***135.45***	***0***	456.47	0.07
Approach B	Method 1	5	-161.19	3.18	138.11	2.66	456.59	0.19
	Method 2	6	-161.1	3.27	137.79	2.34	457.17	0.77
	Method 3	7	-161.01	3.36	138.08	2.63	***456.4***	***0***
	Method 4	8	-160.85	3.52	137.79	2.34	456.8	0.4
Adult ICUs								
Approach A	Method 1	1	-152.93	1.72	140.1	2.23	458.71	0.33
	Method 2	2	-152.21	2.44	139.93	2.06	459.26	0.88
	Method 3	3	-152.88	1.77	139.27	1.4	***458.38***	***0***
	Method 4	4	-152.19	2.46	139.17	1.3	458.82	0.44
Approach B	Method 1	5	-153.61	1.04	138.78	0.91	459.33	0.95
	Method 2	6	***-154.65***	***0***	139.03	1.16	459.2	0.82
	Method 3	7	-153	1.65	***137.87***	***0***	459.11	0.73
	Method 4	8	-153.94	0.71	138.24	0.37	458.76	0.38

Note. AIC, Akaike Information Criterion; Δ, AIC difference; ICU, Intensive care unit.
The number in bold and italicized indicates the smallest AIC that is selected as the best model for each patient outcome.
Each model included different nurse staffing measures, controlling for hospital technological complexity and patient severity of illness.

Table 4

Multivariate Regression Results of the Best Models

Outcome	General			ICUs		
	Variable	*Coefficients*	*95% CI*	*Variable*	*Coefficients*	*95% CI*
Failure to Rescue (N = 206)	Total HPPD	-0.025 ***	-0.042 to -0.008	RN HPPD	-0.015 **	-0.028 to -0.003
	RN skill mix	-0.008 ***	-0.012 to -0.003	Non-RN HPPD	0.020	-0.005 to 0.045
	Technology	-0.009 **	-0.017 to -0.001	Technology	-0.010 **	-0.018 to -0.002
	Patient severity	-0.044	-0.232 to 0.144	Patient severity	-0.072	-0.266 to 0.122
	Wald χ^2	27.13***		Wald χ^2	16.04***	
Decubitus Ulcers (N = 208)	Total HPPD	-0.018	-0.054 to 0.018	RN HPPD	-0.026 *	-0.056 to 0.003
	RN skill mix	-0.012 **	-0.023 to -0.001	Non-RN HPPD	0.020	-0.045 to 0.085
	Technology	0.006	-0.014 to 0.027	Technology	0.005	-0.015 to 0.025
	Patient severity	-0.416 *	-0.866 to 0.035	Patient severity	-0.437 *	-0.886 to 0.012
	Wald χ^2	9.26 *		Wald χ^2	7.00	
Infections (N = 208)	RN HPPD	0.039	-0.060 to 0.139	Total HPPD	-0.005	-0.050 to 0.041
	Non-RN HPPD	-0.137	-0.296 to 0.023	RN skill mix	-0.010	-0.033 to 0.014
	Technology	-0.008	-0.038 to 0.023	Technology	-0.003	-0.034 to 0.028
	Patient severity	0.310	-0.462 to 1.083	Patient severity	0.265	-0.515 to 1.045
	Wald χ^2	3.52		Wald χ^2	1.21	

Note. HPPD, Hours of care per patient day; RN, Registered nurse; ICU, Intensive care unit; CI, Confidence interval.
* p-value < .10 ; ** p-value < 0.05 ; *** p-value < 0.01

Chapter 3

Surgical Nurse Staffing Effects on Patient Outcomes

Abstract

Background: Patient Safety Indicators (PSIs) developed by the Agency for Healthcare Research and Quality (AHRQ) identify potentially preventable adverse patient outcomes. Although the AHRQ PSIs specifically include surgical patient outcomes, no research has examined the surgical PSIs associated only with surgical nurse staffing.

Objective: The purpose of this study was to determine the relationships between surgical nurse staffing levels and surgical patient outcomes.

Methods: Using the University HealthSystem Consortium (UHC) data for four quarters in 2005, the study analyzed 38 acute care hospitals reflecting data for about one million inpatients and a total of 168 surgical nursing care units. Mixed-effects models and marginal panel-data models using generalized estimating equations were conducted for the purpose of this study.

Results: This study found significant relationships between surgical non-ICU RN staffing and two patient outcomes: failure to rescue and post-operative sepsis. A greater number of RN hours per patient day in surgical non-ICUs was associated with lower rates of failure to rescue and post-operative sepsis, holding surgical ICU RN staffing, non-RN staffing, and hospital characteristics constant. However, RN staffing levels in surgical ICUs did not affect the decrease in the adverse surgical patient outcomes.

Discussion: Based on the finding that higher RN staffing in surgical non-ICUs was related to lower rates of failure to rescue and post-operative sepsis, hospital administrators should make more efforts to increase levels of RN staffing in surgical non-ICUs in order to decrease preventable adverse events.

Key Words: nursing, surgery, staffing, quality, patient safety

Introduction

The Institute of Medicine (IOM) report *To Error Is Human* published in 2000 brought increased attention to medical errors and patient safety in the health care sector (Kohn, Corrigan, & Donaldson, 2000; Page, 2004). The critical role of nurses in contributing to patient safety has been emphasized by health care administrators, researchers, and policy makers. Ensuring adequate nurse staffing levels has been considered an important way to improve patient safety. Previous studies have examined the effects of nurse staffing levels on adverse surgical patient outcomes.

Evidence of a relationship between nurse staffing and surgical patient outcomes is still weak because of inconsistent findings from previous studies. Some studies reported that higher registered nurse (RN) staffing levels were related to lower rates of pneumonia for surgical patients (Cho, Ketefian, Barkauskas, & Smith, 2003; Kovner, Jones, Zhan, Gergen, & Basu, 2002), whereas other studies did not find an inverse relationship (Mark & Harless, 2010; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). Needleman et al. (2002) found an inverse relationship between RN staffing and failure to rescue and urinary tract infections for surgical patients. However, several studies showed a non-significant relationship with urinary tract infections (Cho, et al., 2003; Kovner, et al., 2002; Mark & Harless, 2010). In one study of surgical patients, failure to rescue was not inversely related to nurse staffing taking into consideration within-hospital variation over time (Sochalski, Konetzka, Zhu, & Volpp, 2008). With regard to these mixed findings, it is necessary to look at the data sources and nurse staffing measurements used in previous studies.

Previous studies examined the relationships between nurse staffing and surgical patient outcomes while analyzing hospital administrative data. Although there are concerns about the inaccuracy and inconsistency of data coding across hospitals, the data have been used as a source because they are readily accessible and inexpensive compared to clinical data (Iezzoni, 1997). Previous studies using administrative data, however, have revealed limitations with regard to measurements of nurse staffing. The American Hospital Association (AHA) Annual Survey of Hospitals, which has been widely used in previous studies, does not provide a distinction between inpatient and outpatient staffing (Jiang, Stocks, & Wong, 2006). Thus, previous studies using the AHA data have approximated nurse staffing levels based on the ratio of inpatient to outpatient gross revenues (Kovner, et al., 2002; Mark, Harless, McCue, & Xu, 2004). Moreover, administrative data commonly used in previous studies provided information on nurse staffing at the hospital level and therefore could not identify nurse staffing according to the specific types of nursing care units (Cho, et al., 2003; Mark & Harless, 2010; Needleman, et al., 2002). For this reason, although they examined the effects on surgical patient outcomes, the researchers had to use measures of nurse staffing that included the entire hospital rather than only the surgical units.

The Agency for Healthcare Research and Quality (AHRQ) developed the Patient Safety Indicators (PSIs) to identify potentially preventable adverse patient outcomes (Elixhauser, Pancholi, & Clancy, 2005). The AHRQ PSIs are valuable indicators that can be easily used to measure patient outcomes. The AHRQ algorithms can be downloaded from the AHRQ web at no charge and calculate PSIs using hospital administrative data. The AHRQ PSIs specifically include surgical patient outcomes; however, little is known about the effect of nurse staffing on surgical patient outcomes measured by the AHRQ PSIs. Although one study evaluated one of the AHRQ surgical PSIs, failure to rescue, it did not find a significant association with nurse staffing levels when measured in both medical and surgical units (Sochalski, et al., 2008). Therefore, failure to examine staffing only on surgical units might have led to the insignificant as well as inconsistent findings of earlier studies.

The purpose of this study was to determine the relationships between nurse staffing and patient outcomes for surgical care. The AHRQ PSIs were used to measure surgical patient outcomes. The University HealthSystem Consortium (UHC) provided nurse staffing information at the level of nursing care units; thus, staffing could be specifically calculated for surgical intensive care units (ICUs) and surgical non-ICUs.

The theoretical basis for this study was drawn from a model, developed by Aiken, Clarke, and Sloane (2002), that was influenced by Donabedian's theoretical framework of structure, process, and outcome (Donabedian, 1988). The Aiken, Clarke, and Sloane model (2002) also reflected previous research that examined how hospital characteristics affected outcomes for hospitalized patients (Aiken, Lake, Sochalski, & Sloane, 1997; Aiken & Sloane, 1997; Aiken, Sloane, Lake, Sochalski, & Weber, 1999; Aiken, Sochalski, & Lake, 1997). The model explained the relationships between structure, process of care, and outcomes from a micro organizational perspective, while stressing nurses' roles in providing high quality patient care. According to this model, RNs contribute to patient care while playing a role in the ongoing surveillance/early detection for preventing adverse events, complications, or medical errors. The model hypothesized that higher nurse staffing levels might be associated with nurses' early detection of adverse occurrences and thus might produce better patient outcomes. The model provided a good theoretical framework for this study while explaining the underlying process linking structure and outcomes.

Methods

Data Sources and Design

This study analyzed hospital administrative data collected by the UHC for four quarters in the calendar year 2005. The UHC data included information on patients, nursing care units, and facilities obtained at three different levels. The patient-level data included patient diagnosis and procedure codes, number of complications, age, and gender. The UHC provided information on nurse staffing and other unit characteristics at the level of nursing care units; from these data, only surgical nursing care units were selected for analysis in this study. The facility-level data consisted of hospital characteristics, such as ownership, bed size, and patient severity mix. Additional facility information was obtained from the AHA Annual Survey of Hospitals to measure hospital technological complexity. For data analysis, this study merged all the data sets at the hospital/quarter level.

Sample

More than 90% of non-profit teaching hospitals in the U.S. are voluntarily affiliated with the University HealthSystem Consortium (UHC) (2006). Fifty-seven acute care hospitals of the 234 UHC member hospitals provided complete data on hospital characteristics and patient outcomes, in addition to nurse staffing. Only surgical intensive care units (ICUs) and surgical care units (non-ICUs) were selected from the hospitals. To exclude extreme outliers, this study identified the surgical units having RN staffing levels below the 1st percentile or above the 99th percentile, and then omitted them. Therefore, the final sample reflected data for about one million inpatients and a total of 168 surgical nursing care units, including 60 surgical ICUs and 108 surgical non-ICUs, from 38 hospitals. Staffing and patient outcome variables were calculated at the hospital level for each quarter of the calendar year 2005.

The sample included teaching hospitals with an average capacity of 586 operating beds, ranging from 211 to 903 beds. Hospitals in the sample were large compared to the average U.S. hospital beds of 159 in 2006 (Department of Health and Human Services, 2006). The hospitals analyzed in this study were mostly owned by universities (52%) or local governments (24%); followed by a community or religious sponsors, 16% and 8% respectively. They were predominantly located in metropolitan (79%) areas; the other hospitals were suburban (18%) or rural (3%). In the sample, there were no privately owned hospitals.

Measures

Patient outcomes measures. Among the PSIs calculated by the AHRQ algorithms, this study examined eight PSIs related to surgical patient care: failure to rescue and post-operative sepsis, hemorrhage or hematoma, physiologic and metabolic derangements, respiratory failure, pulmonary embolism or deep vein thrombosis, hip fracture, and wound dehiscence. For data analysis, this study excluded post-operative hip fracture and wound dehiscence because hospitals had very small numbers of cases of post-operative hip fracture, and the patient outcome of post-operative wound dehiscence might be more affected by issues in the operating rooms than by staffing on surgical nursing care units.

However, information on nurse staffing levels in operating rooms was not available from the UHC data.

The AHRQ algorithms identified inpatient cases having DRGs or ICD-9-CM codes related to surgical patient care. The algorithms used a risk adjustment method to control for differences in patient population characteristics across hospitals. Based on the AHRQ risk adjustment method, the expected rate for each PSI for each hospital was calculated by grouping the populations according to age, gender, and risk based on the All Patient Refined (APR) DRGs. We used the ratios of the observed to the expected rates (O/E) for each hospital for the six surgical PSIs as the outcome variables. For each PSI, to omit unstable estimates, this study excluded observations with less than 30 patients at risk at the hospital/quarter level (AHRQ, 2007).

Nurse staffing measures. To examine the association with the surgical PSIs, the study extracted information about nurse staffing only from surgical nursing care units in the hospitals, assuming that patients who needed surgical care would be admitted to and be taken care of in surgical units. Nurse staffing was calculated quarterly for each hospital to be matched to hospital-level patient outcomes. Nurse staffing levels largely differ according to the type of nursing care unit, non-ICUs versus ICUs. For this reason, this study measured nurse staffing for surgical non-ICUs separately from surgical ICUs at the hospital/quarter level.

Nurse staffing was measured as nursing care hours per patient day (HPPD). We evaluated a total of four staffing measures, which were RN HPPD and non-RN HPPD for surgical non-ICUs and for surgical ICUs. RN HPPD was calculated as the number of hours of RNs divided by the number of patient days. Non-RN HPPD was measured as the number of hours of licensed practical nurses (LPNs) and clinical nursing assistants (CNAs) per patient day. When computing nursing hours by RNs and non-RNs, this study used only the productive hours of direct care providers, excluding non-productive hours, such as sick call or vacation, and management hours.

Patient days, which are used as a denominator of the measure of HPPD, are commonly obtained from the midnight census. However, they underestimate the actual patient volume cared for by nursing staff because increasing numbers of patients are admitted to nursing care units for short-stay observations during the daytime. Therefore, this study used the number of patient days adjusted for short-stay patient days instead of using the patient volume obtained from the midnight census. We converted the short-stay patient hours into the number of patient days, assuming that 24 short-stay patient hours are equivalent to one patient day.

Hospital characteristics. Previous studies have commonly included control variables, such as hospital bed size, teaching status, technology, and patient case mix, to adjust for variations derived from differences in system characteristics among hospitals (Kovner, et al., 2002; Mark, et al., 2004; Needleman, et al., 2002). This sample was homogenous in terms of the bed size and teaching status as it comprised all teaching hospitals with large bed sizes. Therefore, the other two variables, patient case mix and hospital technological complexity, were used for data analysis. To control for case mixes with regard to patient severity of illness, we measured Medicare Case-Mix Index (CMI), which is an index of the average diagnosis-related group (DRG) relative weight for all of a hospital's Medicare discharges (Centers for Medicare and Medicaid Services, 2005). Technological complexity, measured by the Saidin Index, indicates that hospitals with higher values are those with high and relatively rare technology services which are new, expensive, or complicated (Spetz, 1999).

Data Analysis

This study examined the effects of surgical nurse staffing on surgical patient outcomes, controlling for patient severity of illness and hospital technological complexity, at the hospital/quarter level. Before conducting data analysis, we checked multicollinearity among predictors, which were the four nurse staffing variables (RN HPPDs and non-RN HPPDs for surgical non-ICUs and for surgical ICUs) and two hospital characteristics variables (Medicare CMI and Saidin Index), by using correlations and the variance inflation factor (VIF). There was no multicollinearity concern among the predictors with a mean VIF value of 1.29 (VIF greater than 10 indicates a high degree of multicollinearity). In addition, the absolute values of correlation coefficients among the predictors were less than 0.6. Thus, we included four nurse staffing predictors simultaneously in the regression model for each patient outcome. By doing that, this study was able to examine the effects of surgical non-ICU RN staffing on surgical patient outcomes while controlling for surgical ICU RN staffing levels, and vice versa.

After checking multicollinearity and model diagnostics, we estimated multivariate regression equations to examine the relationships between surgical nurse staffing and patient outcomes controlling for hospital characteristics. For the patient outcomes of failure to rescue and post-operative hemorrhage or hematoma, respiratory failure, and pulmonary embolism or deep vein thrombosis, mixed-effects linear regressions were conducted with the random intercepts. By using the random-intercept models, we could consider the clustered structure of the data, in this study, the multiple quarters within a hospital (Rabe-Hesketh & Skrondal, 2008). However, using mixed-effects linear regressions is not appropriate for non-normally distributed outcome variables. Thus, this study conducted marginal panel-data models using generalized estimating equations for two non-normally distributed patient outcomes: post-operative sepsis and physiologic and metabolic derangements. We performed data analyses using Stata commands of "xtmixed" for random-intercept models and "xtgee" for marginal panel-data models (Rabe-Hesketh & Skrondal, 2008). Stata version 11.0 was used for all the analyses of this study.

Results

Overall, this study analyzed data from 38 hospitals over four quarters (*N* = 144). Table 1 contains descriptive statistics for nurse staffing and hospital characteristics. As we expected, on average, surgical non-ICUs had much lower RN staffing levels than surgical ICUs. The mean hours provided by RNs per patient day was 5.72 (*SD* = 1.07) for surgical non-ICUs and 16.97 (*SD* = 2.84) for surgical ICUs. Surgical non-ICUs showed a slightly greater average number of LPN and CNA hours per patient day (*M* = 2.84, *SD* = 0.82) than surgical ICUs (*M* = 2.10, *SD* = 1.27). Descriptive statistics for surgical patient outcomes are presented in Table 2. The six patient outcomes were measured by the observed to expected ratios (O/E). Thus, mean O/E ratios of greater than 1.0 indicate that the hospitals had, on average, more preventable adverse events than expected; whereas, mean O/E ratios of less than 1.0 suggest that the hospitals had better performance of patient care, fewer preventable adverse events than expected. The descriptive findings showed that, for most surgical patient outcome indicators, the hospitals had poor performance of patient care, indicating more adverse events than expected. Only for failure to rescue did the hospitals have better performance of patient care with a mean O/E ratio of 0.97 (*SD* = 0.21).

Effects of RN Staffing on Patient Outcomes

Among six surgical patient outcomes, this study found significant relationships between surgical non-ICU RN staffing and two patient outcomes: failure to rescue and post-operative sepsis (see Table 3). A greater number of RN hours per patient day in surgical non-ICUs was associated with lower O/E ratios for failure to rescue and post-operative sepsis, holding surgical ICU RN staffing, non-RN staffing, and hospital characteristics constant. However, RN staffing levels in surgical ICUs did not affect the decrease in the two surgical adverse patient outcomes.

RN staffing levels for surgical non-ICUs were not related to the four other surgical patient outcomes: post-operative hemorrhage or hematoma, physiologic and metabolic derangements, respiratory failure, and pulmonary embolism or deep vein thrombosis. Unexpectedly, this study found that a greater number of surgical ICU RN hours per patient day was associated with higher O/E ratios for post-operative hemorrhage or hematoma.

Effects of Non-RN Staffing and Hospital Characteristics

Non-RN staffing levels for either surgical non-ICUs or ICUs were not associated with most of the surgical patient outcomes, except for post-operative pulmonary embolism or deep vein thrombosis and failure to rescue. Higher non-RN staffing levels in surgical ICUs were significantly related to lower O/E ratios of post-operative pulmonary embolism or deep vein thrombosis, controlling for the other staffing levels and hospital characteristics. We found a positive relationship between surgical ICU non-

RN staffing and failure to rescue. In all the regression models, there were no significant relationships between hospital characteristics (patient severity of illness and hospital technological complexity) and surgical patient outcomes.

Discussion

This study is unique in the examination of the effects of surgical nurse staffing on surgical patient outcomes measured by the AHRQ PSIs while using hospital administrative data collected by the UHC. We found a significant relationship between surgical non-ICU RN staffing and two surgical patient outcomes: failure to rescue and post-operative sepsis. The findings showed that a greater number of RN hours per patient day in surgical non-ICUs was associated with lower rates of failure to rescue and post-operative sepsis, controlling for hospital characteristics and other staffing levels (surgical non-RN staffing and ICU RN staffing). Several previous studies supported our findings for the inverse relationship between RN staffing and failure to rescue (Harless & Mark, 2010; Needleman, et al., 2002; Silber, et al., 2000); however, the similar relationship was not found in another study (Sochalski, et al., 2008). Whereas these earlier studies identified nurse staffing for all inpatient acute care, we focused on staffing for surgical care. In this respect, the findings from this study might explain the actual contribution of RNs, caring for surgical patients, to the prevention of surgical failure to rescue. Although previous studies found no association between nurse staffing levels and sepsis (Cho, et al., 2003; Mark & Harless, 2010; Needleman, et al., 2002), this study showed a significant inverse relationship between surgical non-ICU RN staffing and post-operative sepsis. Our finding may represent the importance of RNs' activities, such as early detection of adverse occurrences and surveillance, in the reduction in post-operative sepsis rates.

Unlike the findings for surgical non-ICU staffing, we did not find any inverse relationships between surgical ICU RN staffing and patient outcomes, holding hospital characteristics and other staffing levels constant. Hospitals may already have adequate levels of RN staffing on surgical ICUs, and thus there may be little effect on patient outcomes as surgical ICU RN staffing levels increase. However, surgical non-ICU RN staffing levels may vary across hospitals and should be increased to reduce adverse surgical patient outcomes.

This study found some unexpected results, such as the positive relationship between surgical RN staffing and post-operative hemorrhage or hematoma. It is likely that post-operative hemorrhage or hematoma may result from events in the operating room rather than in surgical ICUs or non-ICUs. In terms of non-RN staffing, we found inconsistent associations with surgical patient outcomes. It is possible that the surgical patient outcomes examined in this study may be sensitive to surveillance, early detection, and prompt interventions performed by RNs rather than by less skilled LPNs and CNAs.

Compared to previous studies, this study has several strengths especially with regard to nurse staffing measurement. First, this study examined nurse staffing effects more relevant to surgical patient care. When evaluating the relationships between nurse staffing and surgical patient outcomes, previous studies measured nurse staffing levels including all types of nursing care units (Cho, et al., 2003; Harless & Mark, 2010; Kovner, et al., 2002; Mark & Harless, 2010; Needleman, et al., 2002). To overcome this limitation of previous studies, we identified only surgical nurse staffing levels when examining the effect on surgical patient outcomes. Second, this study accounted for variation in the effects of nurse staffing on patient outcomes between surgical non-ICUs and ICUs with different levels of nurse staffing. Instead of aggregating nurse staffing for the two types of nursing care units at the hospital level, this study measured nurse staffing levels separately according to the type of nursing care units. By doing that, this study found that hospitals with average levels of surgical ICU RN staffing could decrease failure to rescue and sepsis when they increase RN staffing in surgical non-ICUs. Third, when measuring nurse staffing levels, this study only counted the number of productive hours of nursing staff, excluding paid but non-productive hours. Finally, this study attempted to capture more accurately the number of patients cared for by nursing staff while adjusting for the number of patients admitted for short-stay observations.

This study has several limitations. First, the sample was mostly large teaching hospitals; thus, the findings from this study might not be representative of small and non-teaching hospital settings. Second, we assumed that all surgical patients would be admitted to surgical nursing care units; however, they might be admitted to medical units due to the unavailability of surgical beds. Third, two hospital characteristics variables might not sufficiently adjust for differences among hospitals. Patient characteristics might not be adequately controlled by the risk adjustment method used in this study; therefore, it might be difficult to detect the association between nurse staffing and patient outcomes. Moreover, unmeasured factors may be related to nurse staffing levels or patient outcomes and might yield measurement bias. Another limitation of this study might result from the weaknesses of the patient outcome indicators measured by the AHRQ PSIs. Although researchers have endeavored to improve their validity and reliability, the AHRQ PSIs should be continuously examined in further research with regards to their validity and methods of detecting preventable complications (Bahl, Thompson, Kau, Hu, & Campbell, 2008; Romano, et al., 2009). When calculating PSIs, recent studies have emphasized the importance of using the present-on-admission (POA) indicator to differentiate preventable adverse events from pre-existing conditions (Bahl, et al., 2008; Mark & Harless, 2010). However, the data used in this study did not include the POA indicator.

Based on the finding that higher RN staffing in surgical non-ICUs was related to lower rates of failure to rescue and post-operative sepsis, hospital administrators should make more efforts to increase levels of RN staffing in surgical non-ICUs in order to decrease preventable adverse events. Moreover, further research is needed to examine nurse staffing levels and patient outcomes for surgical care while using the POA indicator.

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Table 1

Descriptive Statistics of Nurse Staffing and Hospital Characteristics (N=144)

Variables	Mean (SD)
RN HPPD for surgical general units	5.72 (1.07)
RN HPPD for surgical ICUs	16.97 (2.84)
Non-RN HPPD for surgical general units	2.84 (0.82)
Non-RN HPPD for surgical ICUs	2.10 (1.27)
Patient severity of illness (CMI)	1.82 (0.20)
Hospital technological complexity	27.00 (4.86)

Note. RN = registered nurse; HPPD = hours per adjusted patient day; ICU = intensive care unit; CMI = case-mix index.

Table 2

Descriptive Statistics of Patient Outcomes (N=144)

Variables (O/E)	Mean (SD)
Surgical failure to rescue	0.97 (0.21)
Post-operative sepsis [a]	1.53 (1.27)
Post-op hemorrhage or hematoma	1.37 (0.56)
Post-op physiologic and metabolic derangements	1.00 (0.67)
Post-op respiratory failure	1.77 (0.75)
Post-op pulmonary embolism or deep vein thrombosis	1.74 (0.46)

Note. O/E = observed rates/expected rates.
[a]n = 143.

Table 3

Regression Estimation Results

	Failure to rescue[a]	Post-op sepsis[b]	Post-op hemorrhage or hematoma[a]	Post-op physiologic and metabolic derangements[b]	Post-op respiratory failure[a]	Post-op pulmonary embolism or deep vein thrombosis[a]
	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)
RN HPPD for non-ICUs	− 0.082 *** (−0.121 to −0.043)	−0.200 *** (−0.337 to −0.062)	0.027 (-0.073 to 0.128)	-0.037 (-0.164 to 0.091)	0.069 (-0.086 to 0.223)	0.016 (-0.071 to 0.102)
RN HPPD for ICUs	0.003 (−0.010 to 0.017)	0.036 (−0.023 to 0.095)	0.040 ** (0.004 to 0.075)	0.018 (-0.026 to 0.062)	0.008 (-0.046 to 0.062)	0.014 (-0.016 to 0.044)
Non-RN HPPD for non-ICUs	0.005 (−0.051 to 0.060)	−0.043 (−0.211 to 0.125)	0.131 * (-0.012 to 0.274)	-0.018 (-0.225 to 0.189)	-0.243 ** (-0.465 to -0.021)	0.017 (-0.108 to 0.141)
Non-RN HPPD for ICUs	0.044 ** (0.005 to 0.082)	−0.037 (−0.150 to 0.077)	-0.023 (-0.120 to 0.074)	-0.001 (-0.171 to 0.169)	0.006 (-0.147 to 0.159)	-0.113 ** (-0.199 to -0.028)
Patient severity of illness	0.013 (−0.198 to 0.225)	0.306 (−0.429 to 1.041)	0.160 (-0.342 to 0.661)	-0.117 (-0.883 to 0.650)	-0.275 (-1.093 to 0.543)	-0.372 (-0.835 to 0.090)
Hospital technological complexity	−0.007 (−0.017 to 0.003)	0.003 (−0.022 to 0.029)	0.005 (-0.017 to 0.027)	-0.015 (-0.052 to 0.022)	-0.002 (-0.039 to 0.034)	0.019 * (-0.002 to 0.040)
Number of observations	144	143	144	144	144	144
Wald Chi-squared statistic	24.32 ***	12.61 **	12.78 **	2.94	7.35	12.97 **

Note. RN = registered nurse; HPPD = hours per adjusted patient day; ICU = intensive care unit; CI = confidence interval; Post-op = post-operative.
a = estimates from mixed-effects linear regression.
b = estimates from marginal panel-data model using generalized estimating equation.
* $p < .10$. ** $p < .05$. *** $p < .01$.

Chapter 4

Patient Turnover and the Relationship between Nurse Staffing and Patient Outcomes

Abstract

Background: High patient turnover contributes to an increase in demands and resources for nursing care related to the procedures of admission, discharge, and transfer. Therefore, it may influence patient outcomes as well as allocation of nursing personnel resources. Previous studies exploring the relationships between nurse staffing and patient outcomes have not examined differences in nursing workload driven by the increase in patient turnover.

Objective: To determine how the relationship between registered nurse (RN) staffing and failure-to-rescue (FTR) rates differs depending on patient turnover levels.

Methods: This descriptive-correlational study analyzed quarterly data from the University HealthSystem Consortium (UHC) for 2005. The data included 42 teaching hospitals, with a total of 759 nursing care units and about one million inpatient discharges. Mixed-effects linear regressions were conducted using random-intercept models.

Results: A greater number of RN hours per patient day was associated with lower rates of FTR. There was a significant interaction between RN staffing and patient turnover on adult general units. The inverse relationships between RN staffing and FTR diminished as patient turnover levels increased. When patient turnover rates increased from 48.6% (25th percentile) to 60.7% (75th), the effects of RN staffing on FTR were reduced by 11%. There was no significant interaction between RN staffing and patient turnover in adult ICUs.

Conclusion: Nurses experience different workloads depending on patient turnover rates in hospitals. Nursing personnel resources, especially RNs, should be allocated according to patient turnover levels because patient outcomes differ in relation to nurse staffing levels as well as patient turnover levels.

Key Words: Nurse staffing, patient turnover, patient outcomes, patient safety

Introduction

Acute care hospitals have confronted challenges as a result of external and internal changes in the health care system. Since the 1980s, the Medicare prospective payment system (PPS) has reimbursed hospitals by diagnosis-related group (DRG) formulas to reduce hospital costs (Shen, 2003). As a result, over several decades, hospitals have been reshaped with shorter patient stays, higher patient turnover rates, and sicker patient populations (Norrish & Rundall, 2001; Shen, 2003). The average length of stay in non-federal short-stay hospitals fell from 7.5 days in 1980 to 4.8 days in 2007 (Centers for Disease Control and Prevention, 2004, 2010). The complexity of care for sicker patients has accelerated transfers of patients between nursing care units and hospitals, and technological improvements in patient care have increased the number of discharges after daytime observation (Jacobson, Seltzer, & Dam, 1999). More recently, new Medicare reimbursement regulations enacted in October 2008 eliminated payments for hospital-acquired and preventable adverse conditions (Rosenthal, 2007). These external and internal changes have required nursing staff to provide more complicated and skilled care and, at the same time, to reduce preventable adverse patient outcomes (Page, 2004; Stone, et al., 2010).

Previous studies have demonstrated that higher nurse staffing levels are associated with reduced adverse patient outcomes. However, this evidence is still weak because the findings of previous studies were inconsistent (Kane, Shamliyan, Mueller, Duval, & Wilt, 2007; Unruh, 2008). Some studies found an inverse relationship between nurse staffing and adverse patient outcomes, whereas others did not find any relationship. The mixed findings from previous studies might be due from the lack of analysis of the changes in health care context, such as increased nursing workloads resulting from higher patient turnover rates. Therefore, this project explored patient turnover as a component of nursing workloads that may affect the association between nurse staffing and patient outcomes.

Patient turnover can be defined as occurring when "a given hospital bed may be occupied by more than one patient in a 24-hour period" (Page, 2004, p. 42). In a study of 19 inpatient medical, surgical, and pediatric specialty units with 8 to 34 beds in a university general hospital, the range of the number of admissions and discharges per 24 hours was from 0.82 to 15.48 (mean=7.38), indicating that there is substantial variation in patient turnover in hospitals (Salyer, 1995).

Previous studies have measured patient turnover in different ways. In an analysis of 205 acute care hospitals in Pennsylvania, Unruh and Fottler (2006) measured patient turnover by the square root of the inverse of the length of patient stay and reported increases in mean rates of patient turnover over 8 years, ranging from 0.17 in 1994 to 0.22 in 2001. However, the study did not consider the total number of admissions, discharges, and transfers at the unit level that contributes to the actual fluctuating patient volume. As a result, the patient turnover measure based on the inverse relationship with the length of patient stay might not adequately measure the total fluctuation in patient volume and nursing care needs.

Norrish (1999) and Lawrenz (1992) measured the average number of admissions, discharges, and transfers divided by patient days generated from the midnight census. In the study by Norrish (1999), patient turnover on nursing care units was as high as 50% during 8 to 12 hour periods of the day. Lawrenz (1992) reported turnover rates of 25 to

70% of the midnight census in 20 medical-surgical care units in 5 hospitals. To identify work intensity, the Labor Management Institute (2008) evaluated the measure used by Norrish (1999) and Lawrenz (1992) and found that nursing care units with higher patient turnover had higher overtime of nursing staff and more adverse events. Similarly, Jacobson and colleagues (1999) calculated a ratio of the number of admissions, discharges, and transfers to the total number of treated patients in order to assess workload in relation to the fluctuation in patient volume. Instead of using the midnight census, for its denominator, they counted patients (1) occupying a bed for a 24-hour period, (2) discharged from the unit, (3) admitted to the unit, and (4) admitted to/discharged from the unit on the same day. Although the denominator of the measure can reflect the actual volume of patients treated in the unit, it is impossible to use the measure for a study when the number of full-day patients is not available from data.

Patient turnover rates increase when the numbers of patient admissions, discharges, and transfers increase. High rates of patient turnover on nursing care units contribute to an increase in nursing care needs and resources relevant to the procedures of admission, discharge, and transfer (Norrish & Rundall, 2001; Page, 2004). Nurses provide relatively intensive care in short periods of time for assessments, documentation, patient education, and discharge planning for patients admitted to, transferred in/out, and discharged from nursing care units and hospitals. Therefore, patient turnover should be considered as an important factor affecting nursing workload and patient outcomes (Budreau, Balakrishnan, Titler, & Hafner, 1999; Jennings, 2008).

Previous research has typically estimated demands for patient care from patient volume determined by using the midnight census (Jacobson, et al., 1999). However, the midnight census ignores nursing activities related to patient turnover and cannot reflect actual nursing workload because it does not account for the fluctuation in patient volume driven by admissions, discharges, and transfers during the day (Budreau, et al., 1999; Jacobson, et al., 1999; Norrish & Rundall, 2001). Moreover, the use of the midnight census has a weakness in that the total patient volume in the nursing unit might be constant at the midnight census over two days, even if there were more admissions, discharges, and transfers before midnight on a given day compared to the previous day (Budreau, et al., 1999; Jacobson, et al., 1999). For these reasons, previous studies using the midnight census have failed to reflect nursing workload driven by variations in patient turnover (Jennings, 2008).

Researchers have addressed the importance of exploring patient turnover for accurate nurse staffing while criticizing the problem of using midnight census (Budreau, et al., 1999; Jacobson, et al., 1999; Page, 2004; Wagner, Budreau, & Everett, 2005). Jennings (2008) speculated that the relationship between nurse staffing and patient outcomes would be different depending on whether or not patient turnover is accounted for in the study. Investigating patient turnover is important in regard to effectiveness and efficiency because it relates to the need for greater intensity of nursing care, and thus to required personnel resources (Page, 2004; Unruh & Fottler, 2006). However, little is known about how increased patient turnover functions as a factor affecting nurse staffing levels and patient outcomes.

The purpose of this study was to determine how the relationship between nurse staffing and patient outcomes differs depending on patient turnover levels using data from the University HealthSystem Consortium (UHC). The UHC data allowed us to assess patient turnover rates and nurse staffing at the nursing care unit level. In addition, they provided a more specific measure of nurse staffing while recording information on direct nursing care providers' productive hours (as distinguished from non-productive and administrative hours). Failure to rescue (FTR), calculated using the Agency for Healthcare Research and Quality's (AHRQ) Patient Safety Indicators (PSI) software, was the measure of patient outcomes in this study. FTR measure 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; Silber, et al., 2007; Sochalski, Konetzka, Zhu, & Volpp, 2008; Thornlow & Stukenborg, 2006). FTR is based on the assumption that good hospitals will detect complications quickly and provide aggressive patient care treatment (Silber, et al., 2007), thus preventing deaths associated with complications. Patient turnover rates may affect nurses' ability to reduce FTR rates because nurses may spend more time in nursing activities required for admissions, discharges, and transfers than in surveillance of patients.

Methods

Data

This was a descriptive, correlational study. For this study, we analyzed UHC data, which were reported quarterly for the calendar year 2005. The UHC data included three datasets at different levels: (1) the hospital facility dataset containing information on hospital characteristics, such as patient severity mix, bed size, and location; (2) the operational dataset with information about nursing care unit characteristics such as unit type, nurse staffing, and patient turnover; and (3) the clinical dataset of inpatient discharge data, such as age, diagnosis and procedure codes, and complications. Additional hospital characteristics data were extracted from the American Hospital Association (AHA) Annual Survey of Hospitals to calculate a measure of hospital technological complexity.

Study Sample

The UHC is a voluntary organization of about 90% of non-profit teaching hospitals in the U.S. which have reported their hospital administrative data (University HealthSystem Consortium, 2006). Fifty-seven of the 234 UHC affiliated hospitals provided data to the databases uses 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 registered nurse (RN) staffing below the 1st percentile or above the 99th percentile. Moreover, hospital and unit quarters were omitted when they reported zero or missing values for either input (admissions and transfers in) or output (discharges and transfers out) of patient fluctuation volume. Consequently, this study analyzed quarterly data for the year 2005 from 42 teaching hospitals, with a total of 759 nursing care units - 512 adult general units and 247 adult intensive care units (ICUs) - reflecting data for about one million inpatient discharges.

The hospitals in this sample had on average 571 operating beds (SD, 192.26); whereas, in 2006, U.S. hospitals averaged 159 beds (Department of Health and Human Services, 2006). Of the hospitals included in this study, 81% were located in metropolitan areas; 15% and 4% were in suburban and rural areas, respectively. The hospitals were predominantly owned by universities (47%) or local governments (31%); communities and religious sponsors owned the other hospitals (17% and 5%, respectively). The UHC removed all identifiers of hospitals and patients from the data.

Measures

Nurse staffing. All information on nurse staffing was retrieved from the nursing care unit-level dataset. We measured nurse staffing as nursing care hours per patient day (HPPD) for registered nurses (RNs) and non-RN nursing personnel. Hours worked by licensed practical nurses (LPNs) and certified nursing assistants (CNAs) were summed to measure non-RN staffing. To calculate nurse staffing, productive nursing care hours were used while excluding hours paid for sick call or vacation as well as those 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 by the type of unit (adult general units and ICUs) because the outcome variable, FTR, was calculated at the hospital/quarter level.

Patient turnover. There is no standard for how to measure patient turnover in the literature. We modified the Norrish (1999) and Lawrenz (1992) measure, using the number of admissions, discharges, and transfers divided by patient days obtained from the midnight census. We calculated patient turnover as a ratio of the patient fluctuation volume to the midnight census volume. In the calculation of the numerator, we summed the number of admissions, discharges, transfers in, transfers out, and outpatient observation stays. When compared to the Norrish and Lawrenz measure, we counted the volume of transfers in and out separately. Moreover, we considered outpatient observations as a factor affecting nursing workload related to patient fluctuation and therefore included them in the numerator. In the UHC data, the outpatient observations were defined as the number of patients who were admitted to and discharged from the unit for evaluation for admission, who were waiting for a procedure or were recovering from a procedure. For the regression equations, patient turnover levels were calculated at the nursing care unit level and then aggregated at the hospital/quarter level, separating patient turnover on adult general units from that on adult ICUs.

Hospital characteristics. To control for differences in system characteristics and patient severity of illness among hospitals, we selected variables of technology complexity and patient severity of illness based on a review of previous studies (Blegen, Vaughn, & Vojir, 2008; Harless & Mark, 2010; Kovner, Jones, Zhan, Gergen, & Basu, 2002; Mark & Harless, 2010; Mark, Harless, McCue, & Xu, 2004). We used the Saidin Index to measure hospital technological complexity levels. The index uses the weighted number of technologies and services in terms of relatively complicated, rare, new, or expensive technology services (Spetz, 1999). The Medicare Case-Mix Index (CMI) is an index of the average diagnosis-related group (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 CMI was used to control for patient severity of illness at the hospital level.

Patient outcome measures and risk adjustment. We used failure to rescue (FTR) to measure patient outcomes. FTR was defined as mortality preceded by a hospital-acquired complication. The algorithms in the AHRQ PSI software (2007) was used to calculate FTR, defined as death following hospital-acquired pneumonia, deep vein thrombosis or pulmonary embolism, sepsis, acute renal failure, shock or cardiac arrest, and gastrointestinal hemorrhage or acute ulcer.

For the regression analysis, 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, the AHRQ algorithms estimated the likelihood that patients at risk would die after a complication, controlling for differences in patient characteristics, such as the patient's age, gender, and risk based on the All Patient Refined (APR) DRGs. Hospitals with FTR O/E ratios greater than 1.0 were those with more FTR cases than expected; whereas, FTR O/E ratios less than 1.0 indicated hospitals with better patient outcomes and fewer FTR events than expected.

Statistical Analysis

Before conducting multivariate regressions, we examined whether multicollinearity might be a concern among the predictor variables (RN staffing, non-RN staffing, patient turnover, Saidin Index, and CMI) by calculating correlations and the variance inflation factor (VIF). There was no multicollinearity concern; the absolute values of bivariate correlations were less than 0.45, and mean VIF values were 1.25 and 1.11 for adult general units and ICUs respectively (VIF greater than 10 demonstrates a high degree of multicollinearity). Using residual analysis, we checked regression diagnostics, such as normality and homoscedasticity, for the models conducted in this study.

For regression analyses, our unit of analysis was quarters nested within hospitals. The dependent variable was the FTR O/E ratio. The explanatory variables of interest were RN HPPD and patient turnover; we controlled for patient and hospital characteristics, and non-RN staffing. We estimated mixed-effects linear regression equations that included fixed coefficients for predictor variables and random effects for each hospital. The random effects for hospitals correct for correlations among quarters within a hospital (Rabe-Hesketh & Skrondal, 2008).

For this study, we first estimated the main effects of RN staffing on FTR before and after adjustment for non-RN staffing, patient severity of illness, and hospital technological complexity (Models 1 and 2, respectively, in Tables 2 and 3). After that, we added patient turnover to the model to learn whether it is a confounding variable that affects both RN staffing levels and FTR (Model 3). Second, we included an interaction term of patient turnover multiplied by RN staffing to evaluate whether the effect of RN staffing on FTR differed according to patient turnover (Model 4). Third, we estimated the slopes and 95% confidence intervals 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 examine whether the models were significantly different according to the inclusion of additional predictors. In this study, the analytic procedures for the models were performed for each unit type (adult general units and adult ICUs). All data analyses were conducted using Stata Version 11.0.

Results

From 42 hospitals, 159 quarters for adult general units and 158 quarters for adult ICUs were analyzed. Table 1 presents descriptive statistics for nurse staffing, patient turnover rates, hospital characteristics, and FTR. The mean RN hours per patient day were 6.74 (SD, 1.40) on adult general units; adult ICUs had greater RN hours per patient day, averaging 15.52 (SD, 2.03). The patient turnover rates averaged 56.1% (SD, 17.87) on adult general units and 45.4% (SD, 14.09) on adult ICUs, indicating that adult general units had higher and wider-ranging patient turnover rates than adult ICUs.

Tables 2 and 3 display the results of mixed-effects regression models for adult general units and adult ICUs, respectively. In the tables, Models 1 to 3 examined the main effect of RN staffing and the confounding effects of other variables on FTR. The unadjusted model (Model 1) showed that there was no significant association between RN staffing and FTR on adult general units ($p = 0.13$). However, after adjusting for non-RN staffing, patient severity of illness, and hospital technological complexity, higher RN staffing levels on adult general units were significantly associated with lower rates of FTR ($p = 0.03$). There was a change of 43.1% in the coefficients for RN staffing on adult general units before and after the adjustment. A coefficient change over 10% can be considered as substantial (Greenland, 1989; Vittinghoff, Glidden, Shiboski, & McCulloch, 2005). Unlike the results for adult general units, the unadjusted effect of RN staffing on FTR in adult ICUs was statistically significantly ($p = 0.02$). On adult ICUs, the RN staffing effect changed by 13.7% after adjustment for the control variables used in Model 2. The direct effect of patient turnover on FTR was not statistically significant for either adult general units or adult ICUs (Model 3). When comparing before and after the adjustment for patient turnover (Model 2 vs. 3), the changes in the coefficients for RN staffing were less considerable (11.1% for adult general units and 7.5% for adult ICUs). According to the likelihood ratio tests, Model 3 did not provide a better fit compared with Model 2 for adult general units (LR χ^2 (1) = 0.12, $p = 0.728$) or adult ICUs (LR χ^2 (1) = 1.12, $p = 0.291$).

Model 4 examined the interaction between patient turnover and RN staffing. We found a significant association in the interaction of patient turnover and RN staffing with FTR in adult general units ($p < 0.01$). Model 4 presented a significantly better fit when compared with the model without the interaction term (LR χ^2 (2) = 6.37, $p = 0.041$). Using the Stata *lincom* command, we estimated the coefficients of RN staffing and their 95% confidence intervals (CI) at different levels of patient turnover on adult general units (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 magnitudes of the inverse relationships between RN staffing and FTR diminished as patient turnover levels increased. When patient turnover rates increased from 48.6% (25th percentile) to 60.7% (75th), the effect of RN staffing on FTR was reduced by 11.55%. At the median value of patient turnover (53.5%), a one-hour increase in RN staffing per patient day on adult general units was associated with a 0.053 decrease in FTR O/E ratios (95% CI −0.085 to −0.020, $p = 0.001$).

There was no significant interaction between patient turnover and RN staffing on adult ICUs. For adult ICUs, the model without the patient turnover effect, controlling only for non-RN staffing, technological complexity, and patient severity of illness, showed the best fit (Model 2).

Of the control variables, hospital technological complexity measured by the Saidin Index demonstrated significant associations with FTR in adult general units as well as in ICUs, holding other predictors constant (Models 2 to 4). Higher technological complexity levels at hospitals were related to lower rates of FTR ($p < 0.01$).

Discussion

This study examined the relationship of RN staffing with FTR and evaluated the effect of patient turnover on the relationship. In general, we found that a greater number of RN hours per patient day were associated with lower rates of FTR. This finding is consistent with that of previous studies that found an inverse relationship between RN staffing and FTR (Blegen, Goode, Spetz, Vaughn, & Park, 2011; Harless & Mark, 2010; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002; Silber, et al., 2000). We found that higher technological complexity in hospitals was related to lower FTR ratios, whereas previous studies showed mixed evidence regarding the technology effect on patient outcomes (Mark & Harless, 2010; Mark, et al., 2004).

Our results demonstrated no direct effect of patient turnover on reduction in FTR rates. However, we found an interaction between patient turnover and RN staffing on adult general units, indicating that the inverse association between RN staffing and FTR differed significantly depending on the level of patient turnover. To be specific, we found that adult general units with higher patient turnover rates require more RN hours per patient day to decrease FTR rates as compared to lower levels of patient turnover. This might result from increases in nursing workloads that are generated from nursing activities related to admissions, discharges, and transfers of patients. Based on our findings for the interaction effect, we suggest that patient turnover is an important factor affecting nursing workload and thus requires more RNs to yield better patient outcomes, as indicated in previous studies (Jennings, 2008; Unruh & Fottler, 2006). Similarly, Needleman and colleagues (2011) emphasized the importance of adequate RN staffing levels based on their findings that the nursing work environment with the increasing exposure to high patient turnover was more likely to yield increased mortality.

For adult ICUs, a significant interaction between patient turnover and RN staffing was not found in this study. The inconsistent findings might arise from the differences in unit characteristics between the two types of nursing care units. ICUs have higher RN staffing levels, but lower patient turnover rates compared to general units. Nursing workloads in ICUs are targeted to provide more intensive nursing care for much sicker patients in a complicated environment, which may result in patient turnover having less impact on overall workload.

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. However, in general, patient turnover and nurse staffing tend to present more variation at the nursing care unit level as well as by each day (or each shift) rather than at the hospital level. Although we aggregated the two measures to the hospital level by the unit types and therefore attempted to reduce the discrepancy between the unit-level and hospital-level analyses, the aggregation might bias out estimates of the relationships between patient turnover, nurse staffing, and patient outcomes.

Our findings might not be generalizable to all hospitals because our sample included teaching hospitals, most of which were relatively large. Although we used risk-adjustment and control variables for data analysis 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. Although FTR measures have demonstrated strong relationships with nurse staffing, Silber and colleagues (2007) demonstrated less reliability for FTR as defined in the AHRQ PSI software as compared to the FTR algorithm originally developed by the Silber team.

Nurses experience different workloads depending on patient turnover levels at the hospitals. The levels of patient turnover vary daily, seasonally, and by unit type. This study suggests that patient turnover rates should be considered when allocating nursing personnel resources—especially RNs—because patient outcomes differ in relation to nurse staffing as well as to patient turnover levels. This was the first study to examine the relationships among nurse staffing, patient turnover, and FTR using administrative data from multiple hospitals. Further research using other measures of patient outcomes and analyzing data at the nursing care unit level may help to establish a stronger base of evidence on the effect of patient turnover on the relationship between nurse staffing and patient outcomes.

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Table 1

Descriptive Statistics for Measures of Nurse Staffing, Patient Turnover, Hospital Characteristics, and Outcomes (n = 159 Quarters from 42 Hospitals)

Variable of Nurse Staffing and Patient Turnover	*General*	*ICU***
	Mean (SD)	*Mean (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		*Mean (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. RN = registered nurse; ICU = intensive care unit; SD = standard deviation.
* O/E = observed rates/expected rates.
** N = 158.

Table 2

Regression Model Results on Adult General Units (N = 159)

Variable	Failure to Rescue			
	Model 1	Model 2	Model 3	Model 4
	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)
RN hours per patient day	−0.019 (−0.044 to 0.006)	−0.027 ** (−0.052 to −0.002)	−0.030 ** (−0.060 to −0.0001)	−0.081 *** (−0.127 to −0.035)
Non-RN hours per patient day		0.012 (−0.032 to 0.056)	0.011 (−0.033 to 0.056)	0.018 (−0.024 to 0.059)
Saidin		−0.015 *** (−0.024 to −0.005)	−0.015 *** (−0.024 to −0.005)	−0.013 *** (−0.022 to −0.005)
Case mix index		0.059 (−0.172 to 0.290)	0.067 (−0.168 to 0.301)	0.066 (−0.153 to 0.285)
Patient turnover			0.0004 (−0.002 to 0.003)	−0.005 ** (−0.010 to −0.0004)
RN hours per patient day ×Patient turnover				0.001 *** (0.0001 to 0.001)
Wald Chi-squared statistic	2.26	13.55 ***	13.71 **	23.54 ***
Log likelihood	65.65	70.46	70.52	73.65

Note. RN = registered nurse; CI = confidence interval.
* $p < .10$. ** $p < .05$. *** $p < .01$.

Table 3

Regression Model Results on Adult ICUs (N = 158)

Variable	Failure to Rescue			
	Model 1	Model 2	Model 3	Model 4
	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)	Coefficient (95% CI)
RN hours per patient day	−0.021 ** (−0.038 to −0.004)	−0.023 *** (−0.040 to −0.007)	−0.022 ** (−0.039 to −0.005)	−0.016 (−0.083 to 0.051)
Non-RN hours per patient day		0.020 (−0.015 to 0.054)	0.019 (−0.015 to 0.053)	0.019 (−0.014 to 0.053)
Saidin		−0.013 *** (−0.022 to −0.005)	−0.014 *** (−0.023 to −0.005)	−0.014 *** (−0.023 to −0.005)
Case mix index		0.059 (−0.163 to 0.281)	0.042 (−0.179 to 0.263)	0.043 (−0.177 to 0.264)
Patient turnover			−0.002 (−0.004 to 0.001)	0.0004 (−0.020 to 0.020)
RN hours per patient day ×Patient turnover				−0.0001 (−0.001 to 0.001)
Wald Chi-squared statistic	5.59 **	17.69 ***	19.48 ***	19.80 ***
Log likelihood	66.23	70.99	71.55	71.57

Note. ICU = intensive care unit; RN = registered nurse; CI = confidence interval.
* $p < .10$. ** $p < .05$. *** $p < .01$.

Table 4

The Effects of RN Staffing on Failure-to-rescue Ratios By Changes in Patient Turnover Levels on Adult General Units

	Percentile Value for Patient Turnover		
	25th	50th	75th
Outcomes	48.63	53.49	60.69
Failure-to-rescue	−0.055 *** (−0.089 to −0.022)	−0.053 *** (−0.085 to −0.020)	−0.049 *** (−0.080 to −0.018)

Note. RN = registered nurse.
95% Confidence Intervals (in parentheses) beside the coefficients of the nurse staffing effects.
* $p < .10$. ** $p < .05$. *** $p < .01$.

Chapter 5

Summary

The purpose of this dissertation was to refine the evidence of the relationship between nurse staffing and patient outcomes using strategies to reduce measurement errors that result from diverse nurse staffing operational definitions, imprecise nurse staffing allocation methods, and unmeasured factors. Despite the critical roles of nurses, especially registered nurses (RNs), in preventing adverse events, evidence of the effect of nurse staffing on patient outcomes is still weak because previous studies have demonstrated methodological limitations and thus have resulted in inconsistent findings (Blegen, 2006; Kane, Shamliyan, Mueller, Duval, & Wilt, 2007; Mark, 2006).

To establish strong evidence and add to the knowledge base about nurse staffing and patient safety, three studies were conducted with separate aims. The specific aims were: (1) to select the best method of measuring nurse staffing based on the Akaike Information Criterion (AIC) statistic; (2) to use the appropriate nurse staffing allocation method in describing the relationship between nurse staffing and patient outcomes for surgical care; and (3) to examine how the effect of nurse staffing on patient outcomes differed according to patient turnover, which has never been adjusted for in previous studies. The three studies used hospital administrative data collected by the University Health System Consortium (UHC) for the year 2005. About 208 quarters of data from 54 teaching, short-term acute care hospitals, reflecting approximately 970 adult care units and one million inpatient discharges, were analyzed for these studies.

Overall, this dissertation provides a significant addition to the current evidence of the relationship between nurse staffing and adverse patient outcomes. All the studies in this dissertation demonstrated that higher RN staffing levels were associated with lower rates of failure to rescue (FTR), controlling for patient and hospital characteristics. The findings of the dissertation are consistent with those from previous studies (Blegen, Goode, Spetz, Vaughn, & Park, 2011; Harless & Mark, 2010; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002; Silber, et al., 2000). This dissertation measured patient outcomes while using the Agency for Healthcare Research and Quality (AHRQ) Patient Safety Indictors (PSI) software. Of the patient outcomes measures examined in the three studies, FTR showed a more consistent and significant relationship to RN staffing levels when compared to other patient outcome indicators, such as decubitus ulcers, infections, and post-operative outcomes.

Regarding other predictions, the dissertation found that higher technological complexity in hospitals was associated with lower rates of FTR, whereas previous studies showed mixed findings in terms of the technology effect on patient outcomes (Mark & Harless, 2010; Mark, Harless, McCue, & Xu, 2004). Patient severity of illness measured by Medicare Case Mix Index was not significantly related to patient outcomes in the three studies in this dissertation. The three studies showed mixed or non-significant findings with regard to the effect of non-RN staffing (combination of licensed practical nurses and certified nursing assistants) on patient outcomes. The main findings from studies reported in Chapters 2 to 4 are discussed below.

Main Findings of the Dissertation

The study in Chapter 2 compared various sets of operational definitions of nurse staffing. They included two types of staffing measures (RN hours per patient days vs. RN skill mix) and four types of methods of identifying nursing hours (based on the inclusion or exclusion of non-direct patient care-related time). The models having the smallest AIC values were selected as the best methods. The study demonstrated that nurse staffing measures based on productive hours of both direct and indirect providers performed the best overall. Whereas previous studies considered the use of productive hours by direct care providers as the ideal method (Donaldson, et al., 2005; Spetz, Donaldson, Aydin, & Brown, 2008), this study suggests that the contribution of nursing administrative and support staff may be important in describing the effect of nurse staffing on patient outcomes. The comparison between RN skill mix and RN hours per patient day (HPPD) displayed different strengths across patient outcome indicators as well as by nursing care unit types.

Despite the model selection findings of the study presented in Chapter 2, the candidate models tested in this study showed small AIC differences, which were all less than four. These small AIC differences indicated that the inclusion or exclusion of non-direct patient care-related time and the comparison of RN skill mix with RN HPPD did not yield considerable differences. Therefore, based on these findings, the evidence for selecting the best nurse staffing measurements is weak because of the small AIC differences and divergent model selections. Using this AIC method to compare more widely variant measures such as patient to nurse ratio, FTE per patient day may yield much more useful findings.

The AHRQ PSIs included surgical patient outcome indicators. It is meaningful that the study reported in Chapter 3 identified nursing staffing only for surgical care to be matched to surgical patient outcomes. Moreover, nurse staffing predictors of RN HPPDs and non-RN HPPDs for surgical non-ICUs and for surgical ICUs were simultaneously tested in the regression models tested in this study. As a result, this study could examine the effect of individual staffing predictors on patient outcomes, controlling for other staffing levels in hospitals. For these reasons, this study might have yielded fewer nurse staffing allocation errors when compared to previous studies, which included nursing staff on non-surgical as well as surgical units (Cho, Ketefian, Barkauskas, & Smith, 2003; Mark & Harless, 2010; Needleman, et al., 2002). However, the findings were similar to other studies that combined staffing from all units.

In Chapter 3, this study found a significant association of RN staffing with FTR and post-operative sepsis. To be specific, a greater number of RN hours per patient day on surgical non-intensive care units (ICUs) was significantly related to lower rates of FTR and post-operative sepsis. This dissertation found a significant inverse relationship between surgical non-ICU RN staffing and post-operative sepsis, whereas previous studies conducted at the hospital level showed no association between nurse staffing and post-operative sepsis (Cho, et al., 2003; Mark & Harless, 2010; Needleman, et al., 2002).

Unlike the findings for surgical non-ICUs in Chapter 3, there were no significant inverse relationships between RN staffing on surgical ICUs and patient outcomes. The different effects on patient outcomes might result from the fact that the hospitals might already have had high and adequate levels of RN staffing on surgical ICUs when compared to surgical non-ICUs. However, surgical non-ICU RN staffing levels might vary across hospitals and might yield different effects on patient outcomes. Therefore, the findings from this study suggest that hospital administrators should consider increasing RN staffing levels on surgical non-ICUs to reduce adverse surgical patient outcomes.

Previous studies of nurse staffing have estimated patients' needs based on the midnight census and thus have not accounted for nursing activities resulting from patient turnover. Thus, the findings from the study in Chapter 4 contribute to the understanding of how patient turnover levels affect nurse workload and therefore patient outcomes. In this study, patient turnover was not directly related to FTR. However, this study found a significant moderating effect of patient turnover on the relationship between RN staffing on adult general units and FTR. Higher RN staffing levels on adult general units were associated with lower FTR rates; however, the inverse association decreased when patient turnover levels increased. When patient turnover rates increased from 48.6% (25th percentile) to 60.7% (75th percentile), the effects of adult general RN staffing on FTR were reduced by 11%. This study demonstrated that higher patient turnover levels might yield more demand for nursing hours provided by RNs on adult general units in order to reduce FTR rates. The findings were consistent with those of Needleman and colleagues' (2011) recent study that showed the significant effect of nursing work environment having high patient turnover levels on increased mortality.

The study in Chapter 4 did not find either direct or moderating patient turnover effects for adult ICU staffing. These findings might result from nursing unit characteristics in ICUs, having higher RN staffing levels, but lower patient turnover rates. In addition, nursing workloads in ICUs might be affected more by providing more intense nursing care for more severely ill patients in a complicated environment rather than by providing nursing activities related to admissions, discharges, and transfers. Therefore, based on the findings in Chapter 4, this dissertation suggests that hospital administrators should consider the fluctuation in patient volume, which is patient turnover, in determining RN staffing levels on adult general units.

The three studies conducted in this dissertation had several limitations. The samples for the three studies were mostly from large teaching hospitals. The findings from the studies might not be representative of small or non-teaching hospitals. Risk adjustment methods and hospital characteristics variables used in the studies might not be sufficient to control for differences in patient or hospital characteristics. Moreover, there is the possibility that unmeasured factors related to nurse staffing or patient outcomes might yield measurement bias.

Implications for Future Research

This dissertation suggests the need for further research. Although the findings from the study in Chapter 2 showed small AIC differentiations among the candidate sets of nurse staffing measures, AIC was a useful methodological approach to compare non-nested models with different sets of nurse staffing predictors. Moreover, this study was the first study to examine the various measures of nurse staffing based on the AIC statistic Therefore, if it is possible to obtain data including more precise information about nursing hours by the types of nursing personnel as well as at the nursing care unit level, future research using the AIC approach may be able to produce strong evidence supporting specific operational definitions for the best measures of nurse staffing.

The study in Chapter 3 had the strength of improving the match between nurse staffing and patient outcomes for surgical care and, as a result, reducing nurse staffing allocation error. The staffing allocation method used in this study was based on an assumption that all surgical patients would be cared for on surgical units. However, medical or other types of units might have surgical patients and have surgical adverse events. Some surgical patients might be admitted to more than one type of nursing care unit during their hospitalization. For this reason, further research needs to identify information on the nursing care units to which surgical patients were admitted and then measure surgical patient outcomes at the level of the patient or nursing care unit. By doing that, future research would be able to match nurse staffing to patient outcomes more precisely.

For analysis, the study in Chapter 4 distinguished patient turnover levels on adult general units from those in adult ICUs. This distinction made it possible to account for differences in workload related to patient turnover between adult general units and ICUs. However, the levels of patient turnover may differ depending on more specific types of adult general units and ICUs. For example, of adult general units, intermediate units or cardiology units have higher patient turnover levels in comparison to other types of adult general units (Labor Management Institute, 2008). Thus, they may have a different intensity of workload in terms of patient turnover. Moreover, patient turnover levels and workload may differ by shift type as well as by daily or seasonal patterns. Further studies are needed to evaluate patient turnover according to specific types of nursing care units, shifts, as well as day to day, or seasonal patterns.

In conclusion, the findings of this dissertation demonstrate that higher RN staffing contributes to patient safety by decreasing adverse patient outcomes. This dissertation emphasizes that decreasing measurement errors is critical for establishing strong evidence of the effect of nurse staffing on patient outcomes. When describing the relationship between nurse staffing and patient outcomes, this dissertation applied the AIC methodological approach to select the best measures of nurse staffing. The dissertation improved the match between nurse staffing and patient outcomes through reduced allocation error. Moreover, this dissertation examined patient turnover as a factor which has been unmeasured in previous studies and showed that the inclusion of patient turnover could provide a better model fit.

Based on the findings of these three studies, the following research questions for future studies can be suggested while focusing more on patient turnover issues: (1) what kinds of nursing workload nurses experience when their units are exposed to high patient turnover; (2) how can we accurately measure patient turnover or nursing workload caused by fluctuations in patient volume; (3) how differently nursing work environments with high patient turnover rates affect patient outcomes and thus hospital financial outcomes as compared to those with low patient turnover; and (4) how different nursing resource allocation decision-making is needed to improve patient safety and quality of care in nursing care units with high patient turnover. Answers to these questions would contribute to improvement in our understanding of the extent to which high patient turnover increases nursing workload and demand for nursing resources and thus how it affects patient care outcomes and hospital financial performance. Also, they could provide hospital administrators and policy makers with evidence of how the nursing work environment should be designed according to patient turnover levels.

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