2015

The Impact of Nursing Skill Mix on the Outcomes of Hospitalized Adult Surgical Patients

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Abstract

ABSTRACT

THE IMPACT OF NURSING SKILL MIX ON THE OUTCOMES OF HOSPITALIZED ADULT SURGICAL PATIENTS

Danielle Altares Sarik

Ann Kutney-Lee

Rates of harm to surgical patients remain largely unchanged despite decades of initiatives to address safety concerns, while wide variations in mortality and failure to rescue (FTR) persist between hospitals. Despite the critical role that registered nurses (RNs) play in providing care to hospitalized patients, there has been limited exploration of the relationship between nursing skill mix and surgical patient outcomes. The purpose of this study was to examine the association between nursing skill mix and adult surgical patient 30-day mortality and FTR. This retrospective, cross-sectional, secondary data analysis utilized three datasets to study surgical patient outcomes in four states (California, Florida, New Jersey, Pennsylvania): the 2006-2007 Multi-State Nursing Care and Patient Safety Survey, the 2006-2007 American Hospital Association Annual Survey, and hospital discharge abstracts for patients age 18-85 years who underwent general, orthopedic, or vascular surgical procedures in non-federal acute care hospitals in 2006-2007. A total of 1,267, 516 surgical patients, 29,391 nurses, and 665 hospitals comprised the final sample. Logistic regression models were used to assess the association of nursing skill mix, defined as the proportion of RNs to all nursing staff (RNs, licensed practical and vocational nurses (LPN/LVNs), and unlicensed assistive personnel (UAPs)) on 30-day mortality and FTR. After analysis, each 10% increase in RN skill mix was associated with a 7% decrease in the odds of 30-day mortality ($P<0.001$) and FTR ($P<0.01$) in the surgical patient population. Additionally, each 10% increase in the proportion of LPN/LVNs was associated with a 6% increase in the odds of both 30-day mortality ($P<0.05$) and FTR ($P<0.05$), while every 10% increase in UAP proportion was associated with a 6% increase in the odds of 30-day mortality ($P<0.01$) and a 5% increase in the odds of FTR ($P<0.05$). As healthcare reform continues to place pressure on hospital administrators to increase quality and decrease costs, maintaining a nursing skill mix with a high proportion of RNs may be one strategy to improve surgical patient mortality and FTR.

Degree Type

Dissertation

Degree Name

Doctor of Philosophy (PhD)

Graduate Group

Nursing

First Advisor

Ann Kutney-Lee

Keywords

Nurse Staffing, Nursing, Patient Safety, Policy, Skill Mix, Surgery

Subject Categories

Nursing

THE IMPACT OF NURSING SKILL MIX ON THE OUTCOMES OF HOSPITALIZED

ADULT SURGICAL PATIENTS

Danielle Altares Sarik

A DISSERTATION

in

Nursing

Presented to the Faculties of the University of Pennsylvania

in

Partial Fulfillment of the Requirements for the

Degree of Doctor of Philosophy

2015

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DEDICATION

To my parents; whose unwavering support, encouragement, and love have made all my paths possible.

To my husband; who has walked this journey with me, hand in hand.

"The most important practical lesson that can be given to nurses is to teach them what to observe – how to observe – what symptoms indicate improvement – what the reverse – which are of importance – which are of none…"

--Florence Nightingale, Notes on Nursing

ACKNOWLEDGEMENT

I would like to extend my sincerest gratitude to my dissertation chair and faculty advisor, Dr. Ann Kutney-Lee, who has painstakingly guided me through the dissertation process, as well as supported me through my doctoral studies. You have freely given your time, and I am indebted to you. Additionally, I would like to thank my committee members, Dr. Linda Aiken and Dr. Matthew McHugh, for providing me with the tools to move my dissertation from concept to finished product.

Thank you to the CHOPR faculty for being a constant during my time at Penn. Your vision, enthusiasm, and willingness to include me in your important work has been invaluable to my development as a scholar. To my CHOPR pre- and postdoctoral fellows, both past and present – thank you for being exemplars of scholarship, supporting me through the hard days, and celebrating with me on the good. Jesse Chittams – you've spent the last year teaching me, encouraging me, and telling me when it was time to walk away from STATA. Thank you for helping me to achieve this goal.

Mom and Dad – you were my first and continue to be my most important teachers. Thank you for the sacrifices that you have made so that I could pursue my dreams. Timothy, Erin & Colleen – my life would be incomplete without you. Thank you for tolerating and loving me through this process. Finally, words cannot express my gratitude to my wonderful husband and personal surgical expert. Jonathan – thank you for walking this doctoral journey with me, and for being there to pick me up when I fell.

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Rates of harm to surgical patients remain largely unchanged despite decades of initiatives to address safety concerns, while wide variations in mortality and failure to rescue (FTR) persist between hospitals. Despite the critical role that registered nurses (RNs) play in providing care to hospitalized patients, there has been limited exploration of the relationship between nursing skill mix and surgical patient outcomes. The purpose of this study was to examine the association between nursing skill mix and adult surgical patient 30-day mortality and FTR. This retrospective, cross-sectional, secondary data analysis utilized three datasets to study surgical patient outcomes in four states (California, Florida, New Jersey, Pennsylvania): the 2006-2007 Multi-State Nursing Care and Patient Safety Survey, the 2006-2007 American Hospital Association Annual Survey, and hospital discharge abstracts for patients age 18-85 years who underwent general, orthopedic, or vascular surgical procedures in non-federal acute care hospitals in 2006-2007. A total of 1,267, 516 surgical patients, 29,391 nurses, and 665 hospitals comprised the final sample. Logistic regression models were used to assess the association of nursing skill mix, defined as the proportion of RNs to all nursing staff (RNs, licensed practical and vocational nurses (LPN/LVNs), and unlicensed assistive

personnel (UAPs)) on 30-day mortality and FTR. After analysis, each 10% increase in RN skill mix was associated with a 7% decrease in the odds of 30-day mortality (*P*<0.001) and FTR (*P*<0.01) in the surgical patient population. Additionally, each 10% increase in the proportion of LPN/LVNs was associated with a 6% increase in the odds of both 30-day mortality (*P*<0.05) and FTR (*P*<0.05), while every 10% increase in UAP proportion was associated with a 6% increase in the odds of 30-day mortality (*P*<0.01) and a 5% increase in the odds of FTR (*P*<0.05). As healthcare reform continues to place pressure on hospital administrators to increase quality and decrease costs, maintaining a nursing skill mix with a high proportion of RNs may be one strategy to improve surgical patient mortality and FTR.

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Chapter 1: INTRODUCTION

The Problem

Each year over 50 million surgical procedures are performed in United States (US) hospitals (Centers for Disease Control and Prevention, 2010). These procedures are not without risk; approximately one in every four general or vascular surgical patients experience a complication (Ghaferi, Birkmeyer, & Dimick, 2009b), with up to 400,000 estimated deaths due to preventable medical errors annually (James, 2013). Additionally, unexplained variations in surgical patient outcomes, such as mortality and failure to rescue (FTR), or death following a complication, have been well documented across hospitals (Ghaferi, Birkmeyer, & Dimick, 2009a; Ghaferi et al., 2009b; Sheetz et al., 2013). In response, widespread initiatives to improve patient safety and decrease the burden of morbidity and mortality have been the focus of many institutional, organizational, and national programs over the last two decades (American College of Surgeons, 2014; Institute of Medicine, 1999; The Joint Commission, 2014; World Health Organization, 2009). However, the majority of initiatives to address surgical patient outcomes have focused on hospital and physician factors, yet fail to account for the important contribution of nursing care in achieving quality outcomes.

The limited inclusion of nursing care and exploration of the role of nursing in surgical patient outcomes is surprising. Over 60% of the three million registered nurses (RNs) in the US are employed in hospitals, representing the largest segment of the healthcare workforce (American Nurses Association, 2011; US Department of Health and Human Services, 2010). The care provided by RNs is especially critical during a surgical admission, as patients are at increased risk of negative outcomes due to common sequelae of surgery (Bernard, Davenport, Chang, Vaughan, & Zwischenberger, 2009; Billeter, Hohmann, Druen, Cannon, & Polk, 2014; Guarino, 2014; Wakeam, Hyder, Jiang, Lipsitz, & Finlayson, 2015). During the postoperative period RNs provide intensive monitoring and assessment, with an average of over 60 interactions with patients during the first 24 hours after surgery (Zeitz, 2005).

The care of surgical patients often involves a team approach where RNs, licensed practical or vocational nurses (LPN/LVNs), and unlicensed assistive personnel (UAP) work together to care for patients. Educational preparation, training, and clinical responsibility vary greatly between RNs, LPN/LVNs, and UAPs (American Association of Critical Care Nurses, 2004), and therefore the care that they provide to patients is qualitatively different. While RNs provide technically skilled care, patient assessment, and medication calculation and administration (American Nurses Association, 2014), LPN/LVNs may be limited in their ability to provide this care to patients (American Association of Critical Care Nurses, 2004; Bureau of Labor Statistics, 2014c). Additionally, the role of the UAPs is limited to patient support and comfort activities (Bureau of Labor Statistics, 2014b, 2014d). The combination of nursing personnel providing patient care can be referred to as nursing skill mix, and for the purposes of this study was defined as the proportion of RNs to all nursing staff (RN + LPN/LVN + UAP). When used, other variations of the skill mix measure (LPN/LVN or UAP proportion) were specifically noted.

While limited, studies have shown that increased proportions of RNs in the skill mix are associated with lower mortality and FTR in both the medical and surgical patient population (Blegen, Goode, Spetz, Vaughn, & Park, 2011; He, Almenoff, Keighley, & Li, 2013; Twigg, Duffield, Bremner, Rapley, & Finn, 2012). Additionally, a growing number of studies have demonstrated a positive impact of a higher proportion of RNs on a range of adverse outcomes including rates of hospital-acquired pneumonia, wound infections, medication errors, and blood stream infections (Blegen et al., 2011; Cho, Ketefian, Barkauskas, & Smith, 2003; McGillis Hall, Doran, & Pink, 2004; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). However, there is a lack of consensus in the literature concerning the relationship between an increased proportion of RNs and improvements in patient outcomes (Hickey, Gauvreau, Connor, Sporing, & Jenkins, 2010; Needleman et al., 2002; Ridley, 2008; Sasichay-Akkadechanunt, Scalzi, & Jawad, 2003; Yang, Hung, Chen, Hu, & Shieh, 2012), leading to equivocal conclusions about the impact of nursing skill mix on surgical patient mortality and FTR.

As healthcare reform unfolds in the US, changes to nurse staffing may be seen as a strategy for hospital administrators and policy-makers to address cost and quality pressures. Nursing labor costs account for almost a third of hospital budgets (Welton, 2011), and as such the nursing workforce may be particularly vulnerable to efforts to decrease hospital operating expenses (Aiken et al., 2014; Buchan, 2000; Kurtzman et al., 2011; Waters, 2006). The substitution of less skilled nursing providers (LPN/LVNs and UAPs) for RNs, has been explored as one strategy to control expenditures and manage staffing challenges (Crossan & Ferguson, 2005; Dubois & Singh, 2009; McGillis Hall, 2009; McKinsey & Company, 2015). Such reductions may have significant negative repercussions for the delivery of care to surgical patients.

It is hypothesized that surveillance is one of the principal mechanisms through which nursing skill mix exerts an influence on surgical patient outcomes. The concept of surveillance is defined as the process through which nurses monitor, observe, analyze and respond to patient clinical status (Kelly & Vincent, 2011; Kutney-Lee, Lake, & Aiken, 2009). In the clinical setting, RNs are charged with quickly recognizing and responding to clinical deterioration, and often initiate the institutional response to life-threatening patient conditions (Minick & Harvey, 2003). Therefore, adequate surveillance is key to the timely detection and appropriate treatment of life-threating complications that could ultimately lead to mortality or FTR for surgical patients. Alterations in the composition of the nursing skill mix may have significant repercussions for surveillance, and consequently, surgical patient outcomes.

The purpose of this study was to expand the existing body of research describing the relationship between nurse staffing and surgical patient outcomes, and to specifically examine the association between nursing skill mix and adult surgical patient 30-day mortality and FTR. While nurse staffing (Kane, Shamliyan, Mueller, Duval, & Wilt, 2007; Lankshear, Sheldon, & Maynard, 2005; Shekelle, 2013), nurse education (Aiken et al., 2011; Kutney-Lee, Sloane, & Aiken, 2013), and the nurse practice environment (Friese, Lake, Aiken, Silber, & Sochalski, 2008; Lake, 2007) have been well documented to impact patient outcomes, there is a lack of research examining the association of nursing skill mix with surgical patient outcomes. It is theorized that changes to nursing skill mix may impact the ability of healthcare systems to react quickly and effectively when faced with a critical patient condition, which in turn may have deleterious effects on surgical patient outcomes.

Study Overview, Specific Aim, and Hypothesis

This study was a retrospective, cross-sectional, secondary data analysis of patient outcomes using nurse, patient and hospital data. Three datasets were merged to study nursing skill mix and surgical patient outcomes: the 2006-2007 Multi-State Nursing Care and Patient Safety Survey from four states (California, Florida, New Jersey, Pennsylvania), the 2006-2007 American Hospital Association Annual Survey, and hospital discharge abstracts for patients age 18-85 years who underwent general, orthopedic, or vascular surgical procedures in non-federal acute care hospitals in 2006-2007 in the same four states. These datasets were linked, and analytical models were specified to adjust for hospital characteristics, patient characteristics, and organizational nursing characteristics. Nursing skill mix represented the main independent variable, and 30-day mortality and FTR served as dependent variables. One main aim was addressed:

Specific Aim: *To examine the association between hospital nursing skill mix and adult surgical patient outcomes (30-day mortality and FTR).*

Hypothesis: *A nursing skill mix with a higher proportion of RNs among all nursing personnel will be associated with decreased odds of 30-day mortality and FTR among adult surgical patients.*

Significance and Innovation

Despite widespread efforts to improve patient safety as outlined in the seminal Institute of Medicine report *To Err is Human (Institute of Medicine, 1999)*, research continues to describe unknown, inconsistent, or inconsequential improvements to patient outcomes (Consumer Union, 2009; Landrigan et al., 2010; Stelfox, Palmisani, Scurlock, Orav, & Bates, 2006; Wang et al., 2014). A recent study examining adverse event rates among Medicare patients hospitalized for four common conditions found no improvement for surgical patients, although some improvement was noted in other patient populations (Wang et al., 2014). Additionally, rates of surgical patient mortality and FTR continue to show great variation across institutions, with a study examining patients undergoing pancreatectomy estimating risk-adjusted FTR rates ranging from 6-40% across sample hospitals (Ghaferi, Osborne, Birkmeyer, & Dimick, 2010).

Few studies (Blegen et al., 2011; Cho et al., 2003; He et al., 2013; Needleman et al., 2002) address the relationship between nursing skill mix and adult surgical patient 30-day mortality and FTR in the US. As pressure mounts to control costs and increase quality in the hospital setting, administrators may consider changes to the nursing skill mix, including substitution of less educated nursing personnel for RNs. Inadequate research exists to separate the unique contributions of nursing skill mix versus absolute nurse staffing (Manojlovich & Talsma, 2007) and to quantify the way in which changes to nursing skill mix may influence surgical patient risk. This study provides evidence to guide administrators in their decision to recruit, hire, and retain the mixture of nursing personnel that optimizes surgical patient outcomes.

Existing studies on the impact of nursing skill mix on surgical patient outcomes are often small, geographically or population limited, and encompass only single units, institutions, or hospital systems (Hickey et al., 2010; Sasichay-Akkadechanunt et al., 2003; Yang et al., 2012). This study addressed these limitations and examined a large, geographically diverse patient population. To the author's knowledge this is the first large-scale, US study to examine the association between nursing skill mix and 30-day mortality and FTR in the adult general, orthopedic, and vascular surgery patient population while controlling for hospital characteristics, patient characteristics, and organizational nursing characteristics (staffing, education, and practice environment). By examining a large patient population and thoroughly controlling for patient characteristics and aspects of the practice environment that could confound the impact of nursing skill mix, the results of this study are more widely generalizable.

Additionally, there is a great deal of variability and inconsistency in the measurement and construction of the skill mix variable in published literature. The nursing skill mix measure utilized in this study was derived from nurse-reports of the type and number of nursing staff providing care on their unit. This method of data collection helps to eliminate inclusion of nursing staff engaged solely in administrative duties, avoids inclusion of nurses in ambulatory as opposed to hospital practice, and decreases overestimation of staffing due to reliance on large administrative datasets. An additional strength of this approach is the uniform manner in which staffing data is collected across surveyed hospitals. Therefore, comparison between hospitals does not rely on data standardization between systems that collect staffing data using diverse measures, which has been a limitation of past research (Needleman et al., 2002). Due to the unique survey data utilized for this study, information on the full complement of nursing staff (RN, LPN/LVNs, UAPs) was available, the lack of which has been a limitation of past skill mix measures.

An additional strength and innovation of this study was the ability to account for hospital and nursing characteristics previously not included in explorations of skill mix. Previous studies have not controlled for the relationship of key organizational features on outcomes in their analysis, such as nurse practice environment, which is noted to be an important contextual issue to address in the study of skill mix (McGillis Hall, 2009). In this analysis, practice environment at the hospital level was controlled for using the Practice Environment Scale of the Nursing Work Index, a National Quality Forum endorsed measure used to measure modifiable features of the hospital environment (Lake, 2002; National Quality Forum, 2004). This represents a significant improvement in methodology as a growing body of literature suggests that the practice environment influences surgical patient outcomes (Aiken et al., 2011; Aiken, Clarke, Sloane, Lake, & Cheney, 2008; Friese et al., 2008). Additionally, the proportion of RNs educated at the

BSN level or above was included in analysis, which has not been adjusted for in previous skill mix literature.

Finally, previous studies have not specifically tested for possible interactions between levels of staffing and nursing skill mix within the hospital setting. Theoretically, the association of nursing skill mix with surgical patient outcomes may change depending on overall levels of staffing. This study tested for such an interaction directly, and included a measure of nurse staffing as a variable in analysis.

Summary

Rates of harm to surgical patients remain largely unchanged despite decades of initiatives to address safety concerns (Wang et al., 2014), while wide variations in mortality and FTR persist between hospitals (Ghaferi et al., 2009b; Sheetz et al., 2013). In the midst of efforts to improve care quality and address patient safety concerns, hospital administrators and policy-makers continue to experience pressure to control growing healthcare costs. Due to the large fraction of hospital expenditures that stem from nursing labor (Welton, 2011), changes to nursing skill mix may be targeted as one strategy to decrease operating expenses. The concept of nursing skill mix remains largely unexplored, with existing studies leading to equivocal conclusions about the relationship between nursing skill mix and surgical patient 30-day mortality and FTR (He et al., 2013; Hickey et al., 2010; Needleman et al., 2002; Ridley, 2008). Without clear evidence to guide staffing decisions, surgical patients may be at an increased risk of mortality and FTR secondary to nursing skill mix changes, as less educated nursing personnel are substituted for RNs. This study addresses these gaps by examining the relationship between nursing skill mix and 30-day mortality and FTR in the US adult surgical patient population.

Chapter 2: BACKGROUND AND SIGNIFICANCE

Chapter Two begins with an introduction to and historical overview of the concept of nursing skill mix. The conceptual framework used to guide the study, the Quality Health Outcomes Model (QHOM) is then discussed in detail. The following sections provide a review of the relevant literature, examine the variables of interest associated with each component of the QHOM, and provide context for the study. The chapter concludes with a summary of gaps in the existing literature base.

Concept Introduction

Nursing Skill Mix

Care is provided in the hospital setting by a variety of nursing personnel whom each play a role in patient care. Nursing skill mix, a term that describes the mixture of nursing providers in a hospital setting, is a measure that can be used to define staffing configurations and was the primary variable of interest in this study. The concept of nursing skill mix has been described in the literature by a variety of names including personnel mix, staffing level, staffing mix, and grade mix (Buchan & Dal Poz, 2002), and is often discussed in the context of what roles or tasks can be safely shifted to less educated nursing personnel (McGillis Hall, 2009). While skill can refer to multiple individual characteristics (length of time in practice, education, licensure), licensure was used to define skill mix in this study.

Although the term nurse is often used colloquially to refer to individuals providing some form of patient care, there is marked diversity in the education and preparation of different designations of nursing staff. The US has two categories of licensed nurses: registered nurses (RNs) and licensed practical or vocational nurses (LPN/LVNs). RNs and LPN/LVNs differ in regards to education, training, and scope of practice (American Association of Critical Care Nurses, 2004; Bureau of Labor Statistics, 2012, 2014c). In addition to RNs and LPN/LVNs, unlicensed assistive personnel (UAPs) often provide supportive care to patients during a hospital stay (Bureau of Labor Statistics, 2014d). Together, these individuals provide the majority of direct care to surgical patients during the perioperative period.

In order to be licensed as a RN in the US, an individual must attend and graduate from an accredited or approved nursing program after 12 years of general education or the equivalent, and subsequently sit for and pass the National Council Licensure Examination-RN (American Nurses Association, 2013). RNs receive focused post-secondary education in patient care, assessment, and medication calculation and administration. Additionally, RNs may delegate tasks to their LPN/LVN and UAP colleagues, within their respective scope of practice (American Association of Critical Care Nurses, 2004).

In comparison to the educational preparation of RNs, LPN/LVN education generally consists of a one year long, post-secondary training program after completing a high school education (Bureau of Labor Statistics, 2014a; Licensed Practical Nurse, 2014; Pennsylvania Department of Health Bureau of Health Planning, 2013). These programs may not prepare graduates for the same clinical competencies as RNs, as

LPN/LVNs have a more limited legal scope of practice than RNs which varies by state. Depending on the state and institution in which they are employed, LPN/LVNs may be prohibited from medication administration, intravenous fluid initiation, or blood product administration (Bureau of Labor Statistics, 2014c).

The third category of nursing care providers in the hospital settings are UAPs. UAPs do not receive a national license and are instead trained in education programs that vary by state (Bureau of Labor Statistics, 2014b). Therefore, wide variations in their training and qualifications exist. Generally, UAPs receive training in supportive patient care activities such as bathing, feeding, and repositioning, however, they are unable to perform the core responsibilities of a RN (American Association of Critical Care Nurses, 2004; Bureau of Labor Statistics, 2014d). Unlike RNs, UAPs are not trained in advanced clinical assessment or core nursing skills. Certain nursing tasks, including initial patient assessment, updating plans of care, communicating with physicians, and medication administration, may never be delegated to UAPs (American Association of Critical Care Nurses, 2004).

Differences between categories of nursing personnel are key considerations when discussing the care provided by nursing staff in the hospital setting. As nursing providers, RN education prepares these professionals to synthesize clinical observations into a comprehensive understanding of patient status and plan care appropriately. Additionally, researchers have hypothesized that the ongoing surveillance role that RNs play is critical to the early detection and treatment of life-threating complications that could ultimately lead to mortality and FTR for hospitalized patients (Henneman, Gawlinski, & Giuliano, 2012; Kutney-Lee, Lake, et al., 2009).

Historical Context of Nursing Skill Mix

Nursing is indisputably a crucial feature of hospital care. However, despite the clinical importance of nursing care, changes to nurse staffing and the hospital operating environment have been widespread over the last three decades (Aiken, Sochalski, & Anderson, 1996; Mark, Harless, & McCue, 2005; Norrish & Rundall, 2001; Pope & Menke, 1990). One such example of a change that subsequently influenced hospital operating environment and the nursing workforce is the 1983 implementation of the Medicare Prospective Payment System (PPS), in which Medicare altered reimbursement for hospital care from payment based on length of stay, to a fixed payment based instead on diagnosis (Altman, 2012). Following implementation of the PPS, there was a 17% reduction of in-patient days from 1980-1988, an increase in RN skill mix (56% to 65%) from 1980-1987, and a concomitant increase in patient acuity (Pope & Menke, 1990). Concurrently, the use of LPN/LVNs in the hospital setting also fell, with a 22% decrease noted in a seven year period, which was attributed to the need to care for a more medically complex patient population (Pope & Menke, 1990). In a ten year span from the mid-1980s to the mid-1990s, a significant increase of approximately 30% was noted in the RN to patient ratio in community hospitals, although researchers reported that after adjustment for patient acuity the increase disappeared (Aiken et al., 1996). While RN employment in hospital settings has remained relatively constant since 2000, the proportion of LPN/LVNs working in these settings has fallen over 5% between 2000 and 2010, with less than one third of the total LPN/LVN workforce employed in hospitals (US Department of Health and Human Services, 2013). This decrease in the utilization of LPN/LVNs in hospital care represents a great change in staffing patterns.

Due to the high cost of nursing care, hospital administrators and policy-makers have often utilized strategies that modify nurse staffing in an effort to decrease expenses (Crossan & Ferguson, 2005; Dubois & Singh, 2009). Ongoing attempts to control hospital costs through staffing changes and reorganization efforts is partially a consequence of the significant price tag associated with hospital care, with nursing labor costs estimated at over $200 billion annually (Welton, 2011). Historically, one method explored by hospital administrators to manage staffing challenges was the use of non-clinical staff, such as UAPs, in order to shift tasks deemed wasteful of RN time to other providers (Norrish & Rundall, 2001). With the rise of managed care in the 1990s, hospital restructuring efforts began substituting less educated providers such as UAPs and LPN/LVNs for RN labor in an attempt to lower overall costs (Norrish & Rundall, 2001). From an administrative perspective, the substitution of less-educated staff is one mechanism to decrease hospitals expenditures (Buerhaus, 1994), but the effects of such staffing shifts on clinical outcomes are poorly understood.

As healthcare reform continues in the US, the debate over ways to decrease costs while providing high-quality care continues. Due to provisions within the Affordable Care Act, hospitals are increasingly held accountable for patient care outcomes, and stand to lose reimbursement if quality goals are not met (Kurtzman et al., 2011). Similar to attempts in the 1980s and 1990s, substitution of less skilled nursing staff such as LPN/LVNs and UAPs for RNs may be a tactic used to decrease the administrative cost of nursing care while still keeping the absolute number of nursing staff consistent (Blegen, Goode, & Reed, 1998; Jacob, McKenna, & D'Amore, 2013). However, strategies that attempt to control costs through nursing substitution may be shortsighted.

As research on the impact of nursing skill mix on surgical patient outcomes is limited, attempts to reduce hospital costs through nursing substitution may be offset by increased adverse events or decreased quality of care. A handful of existing studies examining the financial consequences of changes to the RN skill mix support either a net reduction in hospital costs when total nursing hours are kept stable and proportion of RN hours is increased (Needleman, Buerhaus, Stewart, Zelevinsky, & Mattke, 2006), or a decrease in patient care costs associated with increases in RN skill mix (Martsolf et al., 2014).

Conceptual Framework

The QHOM was used as the theoretical basis to examine the role of nursing skill mix on surgical patient outcomes in this study (**Figure 1**) (Mitchell, Ferketich, & Jennings, 1998). The QHOM builds upon and extends the Structure – Process – Outcomes framework originally proposed by Avedis Donabedian (Donabedian, 1966). Donabedian's model was proposed as a way to examine the role that various factors play in reaching quality outcomes (Donabedian, 1988; Mitchell et al., 1998), and has served as the basis for decades of health outcomes studies.

Despite the strength of Donabedian's framework in conceptualizing the role of components of care on outcomes, researchers have criticized the model for being overly linear in nature (Mitchell et al., 1998). In order to address these concerns the QHOM was created by Mitchell and colleagues. Building on the basic components of Donabedian's framework, the QHOM has been used to help explicate the dynamic roles that systems, clients, and interventions hold in relation to outcomes (Mitchell et al., 1998). In this way, the QHOM encompasses the multiple and changing relationships that occur during the complex process of care, and is hypothesized to more completely capture the role of nursing.

The QHOM is comprised of four major components: **system**, **client**, **intervention**, and **outcome**. Bidirectional relationships, depicted by arrows, exist between the main concepts in the model. According to Mitchell and colleagues, the bidirectional nature of these relationships exemplifies the reciprocal nature of the components of the model (1998), which is a deviation from the linear flow of Donabedian's framework. Additionally, the QHOM postulates that the effect of any variable represented by the intervention component of the model must be mediated through either the system or client, and therefore cannot directly influence outcomes (Mitchell et al., 1998).

In this study the **system** component of the model was conceptualized to include both the organization of nursing as well as hospital characteristics. Organization of nursing includes the variable of nursing skill mix, which was the main concept under investigation. However, nurse staffing and nurse education, specifically the proportion of the workforce educated at the BSN level, also represent system components that have a demonstrated association with surgical patient outcomes (Aiken, Clarke, Cheung, Sloane, & Silber, 2003; Aiken et al., 2014; Kutney-Lee et al., 2013). Additionally, the nurse practice environment, as measured by the Practice Environment Scale of the Nursing Work Index (PES-NWI), has been demonstrated to play an important role in patient outcomes and was therefore also included as a key component of the organization of nursing (Aiken et al., 2011; Aiken, Clarke, Sloane, Lake, & Cheney, 2009; Friese et al., 2008).

Hospital characteristics are also represented under the system component of the QHOM. These characteristics include hospital teaching status, technology status, bed size, geographic location, ownership, and state; all of which are theoretically associated with care delivery in the hospital setting. These system factors were controlled for in the analysis.

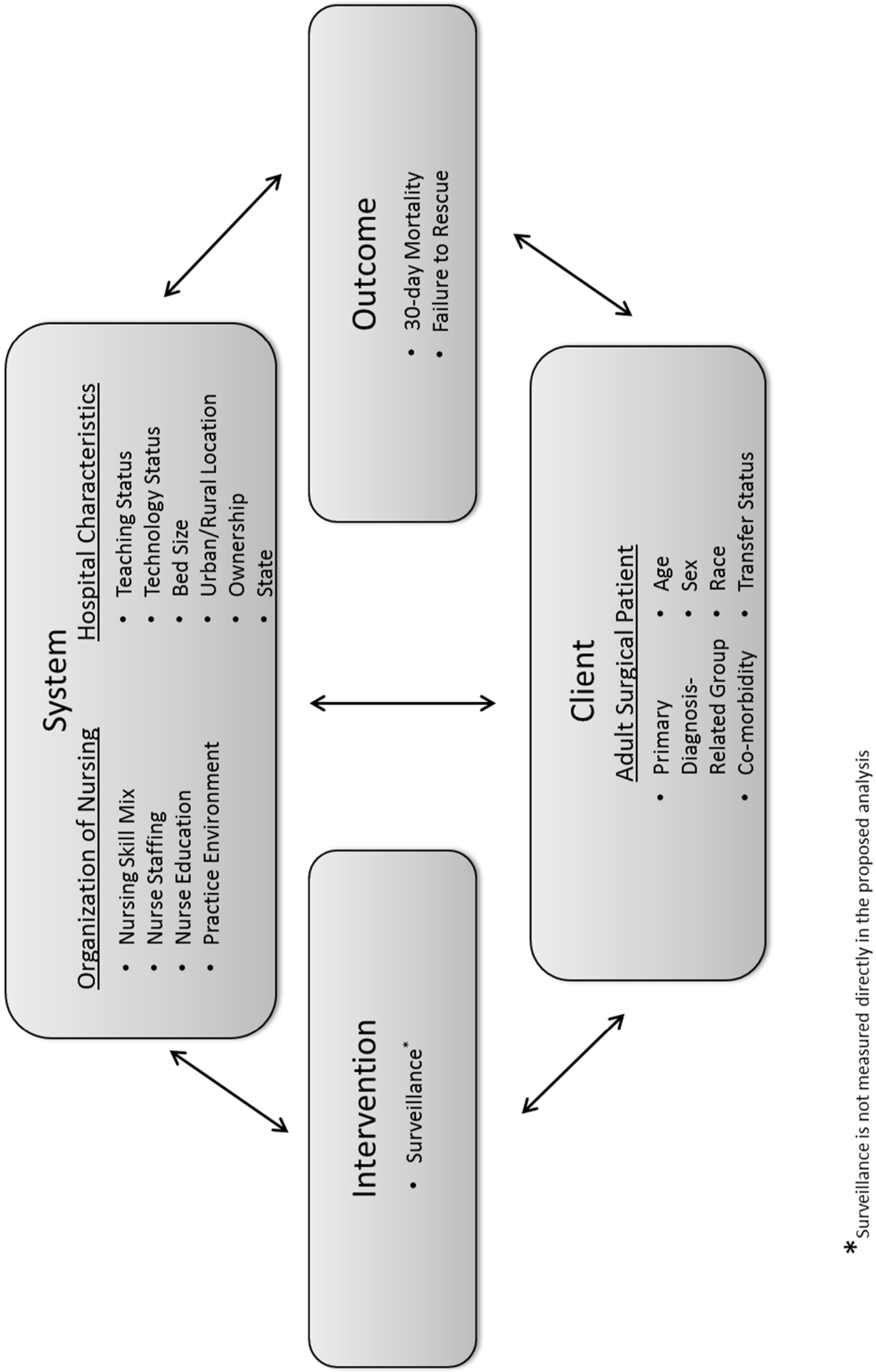
Characteristics of adult surgical patients represent the **client** component of the QHOM. Demographic variables (age, sex, race), surgical diagnostic category and procedure, medical comorbidities, and transfer status may all play a role in determining the clinical outcome of an individual undergoing surgery. In addition to demographic characteristics which are either known or postulated to influence surgical patient outcomes, it is hypothesized that patients are also influenced by the system in which they receive care as well as by specific care interventions. For example, in this study the client may be impacted by both the teaching status of the hospital in which they receive care (system), as well as how comprehensively they are assessed and how thoroughly surveillance is completed by nursing staff (intervention). In this way, both individual-level characteristics as well as system characteristics influence patient clinical outcomes.

In this study the QHOM component of **intervention** was represented by the concept of surveillance provided to surgical patients. As staffing changes occur at the hospital level, specifically pertaining to nursing skill mix, it is hypothesized that there is a subsequent impact on the ability of the nursing staff to provide necessary care and appropriate monitoring to the surgical patient population. In the event of an acute change in patient status, outcomes depend on timely identification of the complication, appropriate response, and the adequacy of hospital systems to provide needed care (Kelly & Vincent, 2011; Kutney-Lee, Lake, et al., 2009). This monitoring, assessment, and response is encompassed in the concept of surveillance. Surveillance is hypothesized to represent the clinical intervention provided to surgical patients. Surveillance will not be measured directly in this study.

Finally, the **outcome** component of the QHOM model includes the study outcomes of interest, 30-day mortality and FTR. In addition to the more commonly studied 30-day mortality, FTR was chosen as a conceptually appropriate outcome for study due to the theorized relationship between complication development, recognition, and appropriate management (Silber, Williams, Krakauer, & Schwartz, 1992). Both outcomes are conceptualized to be influenced by system variables (nursing organization and hospital characteristics) as well as the client characteristics previously discussed. Furthermore, while interventions such as surveillance may impact 30-day mortality and FTR, these interventions are moderated through the client or system components of the model, and are not conceptualized to have an independent effect on outcomes.

The QHOM has strength in the dynamic relationships it depicts between interventions, clients, and systems, addressing a major criticism of Donabedian's original model. Additionally, the model has been used as the conceptual basis for a large body of outcomes research examining the role of nursing care on patient outcomes (Aiken et al., 2003; Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Kelly, Kutney-Lee, McHugh, Sloane, & Aiken, 2014; Mark & Harless, 2010; Mitchell & Lang, 2004; Tubbs-Cooley, Cimiotti, Silber, Sloane, & Aiken, 2013; Wilson, Effken, & Butler, 2010). The QHOM modified for nursing skill mix is graphically represented in **Figure 1**, with the elements of the study outlined below each component.

Figure 1. Quality Health Outcomes Model, Modified for Nursing Skill Mix



Background

Outcomes

This study examined two main outcomes measures, 30-day mortality and FTR. The following section will outline the construction of these measures, as well as the literature exploring the role of skill mix on both outcomes. Additionally, literature on the association of skill mix and adverse events will be reviewed.

Nursing Skill Mix, Mortality, and Failure to Rescue

Mortality is a widely studied outcome measure and may be argued to be the gold standard of care quality. When confounding factors such as patient and system characteristics are adequately adjusted for, any remaining differences in mortality across settings of care can be argued to reflect the quality of care itself (Silber et al., 1992). As many factors including transfer rates (Vasilevskis et al., 2009), length of stay (Drye et al., 2012), and care received after discharge (Medicare.gov, 2015) may bias mortality rates, use of a standardized measure is important for comparison across hospitals. In a study examining the incidence of death in patients undergoing surgical procedures with significant mortality, almost a quarter of total patient mortality occurred post-discharge, with 95% of mortality occurring within 21 days of discharge (Yu, Chang, Osen, & Talamini, 2011). In light of these studies, the 30-day mortality measure was chosen as the main outcome of interest in order to address concerns about variations in care style across institutions.

The second outcome measure studied, FTR, is defined as death after a patient develops a complication secondary to receiving medical care (Silber et al., 2007). Studies indicate that complications experienced during hospitalization may be more related to patient characteristics than hospital characteristics, and suggest that FTR may therefore be more directly tied to the ability of hospital systems to respond appropriately if such complications occur (Ghaferi et al., 2009b; Silber, Rosenbaum, Schwartz, Ross, & Williams, 1995; Silber et al., 1992). Delayed recognition or inadequate treatment of complications due to deficient nursing care may be associated with increased mortality in the surgical patient population, as recent research has reported index complications greatly increase the risk of secondary complications and mortality in surgical patients (Wakeam et al., 2015).

Using established methodology, the FTR rate is calculated by taking the number of individuals that died after developing a specified complication (Appendix B) and dividing by the total number of individuals who develop a complication, therefore calculating the probability that a patient experiencing a complication ultimately dies (Silber et al., 1992). Theoretically, mortality can therefore be tied to an inciting event which could have been identified and addressed by adequate surveillance and appropriate action. As such, FTR represents a conceptually appropriate outcome to study in relation to skill mix due to the theorized role that nurses play in recognizing complications and acting in a timely manner to address changes in patient status (Kutney-Lee, Lake, et al., 2009).

Literature exploring the relationship between skill mix and surgical patient 30-day mortality and FTR remains scarce. Therefore, studies that include both surgical and medical patients, as well as literature examining the relationship between skill mix and adverse events, are included in this review in order to fully explore the literature base.

Mortality

Among some of the earliest research to elucidate the relationship between nursing skill mix and patient mortality is a 1989 study examining Medicare patients in over 3,000 hospitals in which increased RN proportion was found to be associated with a statistically significant decrease in the mean mortality rate (Hartz et al., 1989). Since this early study a growing body of literature supports the association between high proportions of RNs in the skill mix, and decreased mortality (Estabrooks, Midodzi, Cummings, Ricker, & Giovannetti, 2011; Krakauer et al., 1992; Tourangeau et al., 2007; Twigg et al., 2012). To further elucidate the relationship between nursing skill mix and surgical mortality, Cho and colleagues examined over 120,000 surgical patients from 20 surgical primary diagnosis–related groups (DRGs) (2003). The authors found that after analysis, each 10% increase in the proportion of RNs in the skill mix was significantly associated with a 9.5% decrease in the odds of postoperative pneumonia, which was subsequently associated with over three times the odds of death in the surgical patients studied (Cho et al., 2003). In a study on medical patients, Estabrooks and colleagues found that a nursing skill mix with a higher proportion of RNs was associated with a 17% decrease in odds of 30-day mortality (2011). Additionally, a study examining the relationship between nursing skill mix and 30-day mortality in hospitalized medical and surgical patients within the Veterans Affairs system found that for each 10% increase in nursing skill mix, odds of mortality were decreased between 4-7% for non-intensive care unit (ICU) patients, dependent on risk adjustment model ($P<0.05$) (He et al., 2013).

Studies examining rates of mortality associated with increases in LPN/LVN staffing help to provide additional information on the relationship between skill mix and outcomes. A recent study examining the trauma patient population, which is largely surgical in nature, reported that for every 1% increase in the ratio of LPN/LVN to total nursing hours, a subsequent 4% increase in the odds of mortality was noted (Glance et al., 2012). The authors interpreted these results as reflective of substitution of LPN/LVNs for RNs. Additionally, increases in the absolute number of LPN/LVNs at the hospital level, as measured by the number of LPN/LVNs to total hospital beds, has been associated with an increased risk of mortality for Medicare patients (Bond, Raehl, Pitterle, & Franke, 1999).

Failure to Rescue

Additionally, there is a growing body of literature on FTR and association with nursing skill mix. In a study examining nurse staffing in general units and ICUs in safety-net and non-safety net hospitals, 1.1 million medical and surgical patient discharges were reviewed (Blegen et al., 2011). Researchers found that FTR rates were significantly lower in hospitals with higher RN skill mix on general units, in both safety-net and non-safety-net hospitals. In safety-net hospitals, RN skill mix was also associated with decreased FTR in ICU settings (Blegen et al., 2011). A similar association between nursing skill mix and FTR has been found in a large-scale study which examined the effect of changes in skill mix at the hospital level (Twigg et al., 2012). In this study authors examined over 100,000 combined medical and surgical adult patient records, and found that a 1% increase in in the proportion of RN hours was associated with a statistically significant decrease in FTR in the combined medical and surgical patient population in one of the three hospitals studied, and a statistically significant decrease in medical patient mortality in one of the three hospitals studied. However, the relationship between skill mix and outcomes was not consistent across patient populations or hospitals, which authors speculated may have been due to the different levels of skill mix present at each hospital at the beginning of data collection (Twigg et al., 2012).

Despite research that has demonstrated an association between nursing skill mix and mortality and FTR, conflicting studies have failed to find a relationship (Hickey et al., 2010; Needleman et al., 2002; Sales et al., 2008; Sasichay-Akkadechanunt et al., 2003; Yang et al., 2012). In a 2002 study examining over one million surgical patient discharges, a higher proportion of care provided by RNs was not associated with a decrease in surgical patient mortality or FTR, although increases in skill mix did lead to reduced medical patient FTR (Needleman et al., 2002). These contradictory finding may be due in part to the method used to calculate skill mix in this study, which did not include UAPs, or the modified FTR measure used that was restricted to a subset of the original FTR complications. A separate study which examined the association between nursing skill mix and pediatric congenital heart surgery patient outcomes also failed to find a significant relationship (Hickey et al., 2010). However, skill mix did not vary significantly in the sample hospitals (median skill mix of 98% RNs) and the patient population was narrowly defined (pediatric congenital heart surgery), which may have contributed to the null findings.

Methodological weaknesses in the existing studies may help to explain null findings. For example, in a study examining medical or surgical patients discharged from a single institution in Thailand with four common diagnoses, skill mix was not found to be a statistically significant predictor of outcomes (Sasichay-Akkadechanunt et al., 2003). However, while authors adjusted for severity of patient illness, the patient population studied was heterogeneous in nature and the study was conducted in a single institution (Sasichay-Akkadechanunt et al., 2003). Similarly, in a study by Sales and colleagues examining the association between nursing skill mix and in-patient mortality in over 100 Veterans Affairs hospitals, no significant relationship was identified at the hospital level (2008). However, authors reported that an increased proportion of RNs in skill mix was associated with a 2% increase in the odds of mortality for ICU patients, which is contradictory to the expected relationship (Sales et al., 2008). This discrepancy may be due to the use of an in-patient mortality measure as opposed to a 30-day mortality measure, as well as potentially inadequate risk adjustment for patient and hospital characteristics.

Nursing Skill Mix and Adverse Events

Defined as an unintentional harm to a patient related to an aspect of medical care, adverse events are widespread and account for an estimated cost of up to $29 billion annually in the US (Institute of Medicine, 1999). While estimates of the prevalence of adverse events among surgical patients vary, studies report that up to 68% of patients undergoing major elective general surgery may experience some form of adverse event (Symons, Almoudaris, Nagpal, Vincent, & Moorthy, 2013). Echoing the ubiquitous nature of adverse events, a 2013 systematic review found that on average over 14% of surgical patients were reported as suffering from a serious adverse outcome, with over a third being categorized as preventable (Anderson, Davis, Hanna, & Vincent, 2013).

In addition to studies examining mortality and FTR, a growing number of studies have demonstrated a positive impact of a higher proportion of RNs in the skill mix on a range of adverse events including rates of hospital-acquired pneumonia (Cho et al., 2003), wound infection (McGillis Hall et al., 2004), medication error (Frith, Anderson, Tseng, & Fong, 2012; Patrician et al., 2011), sepsis (Blegen et al., 2011), pressure ulcers (Hart & Davis, 2011), and urinary tract infections (Needleman et al., 2002; Yang et al., 2012). In a study examining over 100,000 patient records, increases in nursing skill mix were associated with decreases in the rates of eight nursing-sensitive indicators, including deep vein thrombosis, shock and gastritis (Twigg et al., 2012). A recent study which looked at staffing changes at the shift-level reported that each 10% decrease in

RN skill mix was associated with a 36% increase in the odds of fall with injury on critical care units (Patrician et al., 2011). These outcomes represent fairly common complications that can occur during hospitalization, and support the theoretical relationship between nursing skill mix and quality of patient care. Additionally, positive impacts of nursing skill mix including increased ratings of self-care ability and decreased patient-reported perception of pain have been associated with a high proportion of RNs (Potter, Barr, McSweeney, & Sledge, 2003).

Despite encouraging findings of the impact of skill mix, a recent study examining longitudinal effects of skill mix changes on the medical/surgical patient population over three years failed to find any association between an increase in RN skill mix and eight nursing sensitive quality indicators (Martsolf et al., 2014). However, the two constructions of skill mix used in this study (RN/ (RN + LPN/LVN)) and ((RN + LPN/LVN)/ ((RN + LPN/LVN + UAP))) are a departure from the more commonly used measure of RN to all nursing staff, which may account for the null findings. Additionally, the construction of these measures may be problematic as the first excludes an entire category of nursing staff (UAPs) and the second equates the roles of RNs and LPN/LVNs.

Research also points to an increase in adverse events and poor patient outcomes as proportions of LPN/LVNs and UAPs in the skill mix increases. In a recent study examining medication errors, each one hour increase above the mean LPN/LVN hours per patient day for medical/surgical patients was associated with a 3% increase in the probability of a medication error (Frith et al., 2012). In the acute myocardial infarction population, patients treated in hospitals that fell within the highest quartile of LPN/LVN staffing had a 7% increase in odds of in-hospital mortality as compared to their peers treated in hospitals with the lowest quartile of LPN/LVN staffing (Person et al., 2004). An association between skill mix and patient falls has also been found, with an approximately 3% increase in fall risk for each additional hour of daily care provided by LPN/LVNs and a 1.5% increase for every additional hour of care provided by UAPs (Lake, Shang, Klaus, & Dunton, 2010). Additionally, a 2004 study reported that as the proportion of professional nurses (similar to RNs and LPN/LVNs in the US) in the skill mix dropped, indicating a higher use of unlicensed personnel, medical/surgical patients in teaching hospitals experienced higher rates of medication errors and wound infections (McGillis Hall et al., 2004). Taken together these findings provide evidence that while an increase in RN staffing is beneficial, a converse increase in LPN/LVN or UAP staffing is associated with negative patient outcomes.

Summary on Mortality, Failure to Rescue, and Adverse Events

Published literature on the relationship between nursing skill mix and patient outcomes is inconclusive in part due to the limitations of the studies themselves. Specifically, the studies reviewed are limited by their size, geographic distribution, population of interest, measurement of skill mix, and methods of model adjustment. For example, in the 2002 Needleman et al. study, the definition of FTR used in the study has been modified to restrict the number of complications that have historically been used to construct the measure, and the measure of nursing skill mix excludes UAPs. These changes alone could account for the null findings reported. Furthermore, staffing estimates used in skill mix studies are often drawn from large administrative databases and extrapolated across hospitals. Inadequate control of confounding factors and inadequate risk adjustment, additional methodological weaknesses, have the ability to either obscure or inflate the relationship between nursing skill mix and mortality/FTR. However, despite the limitation of the studies reviewed, there is evidence to support a trend toward an increase in the proportion of care provided by RNs and decreased negative patient outcomes.

System

Nursing Organization and Outcomes

In addition to the main variable of interest, nursing skill mix, additional characteristics of nursing organization were also included in the analysis to better examine the association of skill mix and adult surgical outcomes. Adequate adjustment for these variables is critical, as a robust body of literature has explored the role of organization of nursing care on patient outcomes and supports an association between increased nurse staffing (Aiken et al., 2002; Kane et al., 2007; Lankshear et al., 2005; Shekelle, 2013), higher nurse education (Aiken et al., 2003; Aiken et al., 2014), and positive nurse practice environments (Aiken et al., 2011; Aiken et al., 2008; Friese et al., 2008) and decreased odds of mortality and FTR. These factors comprise part of the system component of the QHOM and are hypothesized to mediate the impact of clinical interventions on patient outcomes.

It was a central goal of this study to disentangle the relationship between nurse staffing and nursing skill mix, and to examine how these two features of nursing organization influence patient outcomes. While several studies have examined nursing skill mix and nurse staffing concurrently, no studies examining interaction effects between skill mix and staffing levels have been identified. Studies that include both skill mix and a nurse staffing measure simultaneously in analytical models have not supported a uniform relationship. Some studies have found that when both staffing measures are included in the analytical model they are both predictive of decreased mortality or failure to rescue (Tourangeau et al., 2007), while others have found a mixed relationship with only one of the two measures showing significant associations with mortality or FTR (Needleman et al., 2002; Tourangeau, Giovannetti, Tu, & Wood, 2002). More research is needed to elucidate the relationship and possible interaction between nursing skill mix and staffing on surgical patient outcomes.

In addition to nurse staffing, nurse education has been demonstrated to impact patient outcomes. Research supports a relationship between a high proportion of nurses educated at the BSN level in a hospital setting and decreased odds of mortality (Aiken et al., 2003; Estabrooks et al., 2011; Kelly et al., 2014; Kutney-Lee et al., 2013). A possible mechanism of action for the role of this variable is the ability of nurses with higher levels of education to provide more comprehensive and critical surveillance (Kutney-Lee, Lake, et al., 2009). Therefore, nursing education is hypothesized to represent an important determinant of surgical patient outcomes.

In addition to nursing workforce characteristics, the practice environment within a hospital setting has been demonstrated to influence patient outcomes. The concept of practice environment refers to the aspects of an organization that contribute to productivity, job satisfaction, and allow for quality nursing; these qualities can be measured using the Nursing Work Index (NWI) (Kramer & Hafner, 1989). The NWI serves as the basis of the PES-NWI (Lake, 2002). The PES-NWI represents an organizational measure of the hospital practice environment, and encompasses information on modifiable characteristics such as nurse participation in hospital affairs, nursing foundations for quality of care, nurse manager abilities, staffing and resource adequacy, and nurse-physician relationships (Aiken et al., 2012; Lake, 2002). Decreased mortality and FTR among surgical patients has been demonstrated with improvements in the quality of the nurse practice environment (Aiken et al., 2011; Aiken et al., 2008; Friese et al., 2008).

Hospital Structures and Outcomes

Hospital characteristics and structures, which are represented under the system component of the QHOM, are also hypothesized to play an important role in patient outcomes. A critical review of the literature identified several significant characteristics that were often controlled for when studying hospital mortality rates, including hospital teaching status, technology status, hospital size, urban/rural location, and hospital profit status (Ghaferi et al., 2010; Rosenthal, Harper, Quinn, & Cooper, 1997; Schultz & Servellen, 2000; Silber et al., 2009). While this list does not necessarily provide a comprehensive description of all aspects of the hospital system, it does provide a baseline of characteristics that are theoretically important to control for in analyses of outcomes clustered within hospitals. These main characteristics are included in the conceptual framework used to study the relationship between skill mix and surgical patient mortality.

High technology status, as represented by the ability of a hospital to perform open heart surgery, organ transplant, or have a burn unit, has consistently been found to be associated with lower mortality and FTR (Ghaferi et al., 2010; Hartz et al., 1989; Silber et al., 1992). The relationship between technology and patient outcomes may be due to the ability of such hospitals to respond quickly and appropriately once a complication is identified. In addition to hospital technology status, research suggests that hospital teaching status is also associated with patient outcomes, with involvement in teaching often being associated with decreased mortality and FTR (Bond et al., 1999; Ghaferi et al., 2010; Hartz et al., 1989; Kuhn, Hartz, Krakauer, Bailey, & Rimm, 1994; Rosenthal et al., 1997; Silber et al., 2009). Furthermore, hospital size or bed size has also been associated with mortality (Hartz et al., 1989), with bed size greater than 200 associated with significantly reduced FTR (Ghaferi et al., 2010) .

Additional hospital characteristics may also play a role in patient outcomes, or in patterns of care or staffing. Hospital characteristics such as hospital location and ownership (Bond et al., 1999; Hartz et al., 1989) have been postulated to impact the delivery of care and patient outcomes. Factors such as geographic location may also be associated with the available supply of nurses, and research has suggested that some of the variation in nursing skill mix can be explained by the size of a metropolitan area (Mark, Salyer, & Wan, 2000).

Client

Characteristics of Surgical Patients

The average American is predicted to undergo approximately three in-patient and nine total surgeries in an 85 year lifespan (Lee & Gawande, 2008), representing a significant financial, physiological, and psychological burden. Surgical patients may be at particular risk of mortality during hospitalization due to the sequelae of common intraoperative and postoperative events such as hyperglycemia, anemia from blood loss, and hypovolemia from fluid shifts and insensible losses that are associated with profound negative outcomes (Bernard et al., 2009; Billeter et al., 2014; Guarino, 2014; Kwon et al., 2013; Wakeam et al., 2015). A 2014 observational study reported that the most commonly reported adverse event prompting recognition of a complication in surgical patients was respiratory derangement (Helling, Martin, Martin, & Mitchell, 2014), which may be of particular concern to patients returning to spontaneous respiration postoperatively. Additionally, nurses are tasked with monitoring respiratory status postoperatively and responding to derangements appropriately.

Research suggests that patient characteristics are significantly associated with the risk of experiencing a complication, adverse event, or mortality while hospitalized. These variables are captured under the client component of the QHOM, and may represent determinants of mortality or FTR in the surgical patient population. One major characteristic which may be directly related to surgical patient outcomes includes the DRG. The DRG classifies similar procedures and diagnoses into discrete groups depending on their level of complexity (Centers for Medicare and Medicaid Services, 2013). Some diagnoses may inherently represent more risk or may encompass more life-threatening conditions, making this patient attribute an important factor when considering patient outcomes and risk adjustment. Additionally, admission source can often serve as a proxy for patient clinical severity. Patients transferred from an outside hospital for treatment are often high acuity, and have a higher likelihood of mortality (Rosenberg, Hofer, Strachan, Watts, & Hayward, 2003). Therefore, admission from an outside hospital was accounted for in this analysis.

Patient demographic characteristics are also important to control for when examining surgical patient outcomes (Iezzoni, 2003), and often include age, sex and race. Differences in mortality rates of black surgical patients have been demonstrated across multiple surgical and medical patient populations (Carthon, Kutney-Lee, Jarrin, Sloane, & Aiken, 2012; Lucas, Stukel, Morris, Siewers, & Birkmeyer, 2006; Silber et al., 2009), and as such warrant controlling for race. In a recent study examining outcomes for elderly patients undergoing general, orthopedic, or vascular surgery, researchers found that after adjusting for age and sex, black race was associated with a 42% increase in the odds of 30-day mortality (Carthon et al., 2012). In addition to race, age has also been demonstrated to be significantly associated with surgical patient morbidity and mortality across a range of procedures (Duron et al., 2011; Lidsky, Thacker, Lagoo-Deenadayalan, & Scarborough, 2012; Polanczyk et al., 2001). In a 2011 study of older patients undergoing major digestive surgery, being 65 years of age or older was found to be an independent risk factor for mortality (Duron et al., 2011), while a separate study examining patient outcomes in nonemergent noncardiac procedures found that the odds of mortality were more than twice as high for patients age 80 and above (Polanczyk et al., 2001). Patient gender has also been associated with differences in surgical patient morbidity and mortality, although gender is not consistently associated with rates of harms across conditions (Alam et al., 2013; Badheka et al., 2014; Schoenfeld, Reamer, Wynkoop, Choi, & Bono, 2014; Singh, Kwoh, Richardson, Chen, & Ibrahim, 2013).

Additionally, patient comorbidities, as defined as clinical conditions that are unrelated to the principal admitting diagnoses (Iezzoni, 2003), place patients at increased risk of morbidity and mortality. Comorbidities encompass a number of chronic conditions, including diabetes and hypertension, and are important to control for when studying variation in patient outcomes (Elixhauser, Steiner, Harris, & Coffey, 1998). Multiple studies have demonstrated an association between an increased number of comorbidities and increased surgical patient mortality (Badheka et al., 2014; Ferrier, Spuesens, Le Cessie, & Baatenburg de Jong, 2005; Kaplan et al., 2011). Research supports the use of the Elixhauser comorbidity index as an optimal risk adjustment strategy for use with large administrative datasets (Sharabiani, Aylin, & Bottle, 2012).

Interventions

Surveillance

Within this study, surveillance represents the theorized clinical intervention provided to surgical patients as a result of an increase in proportion of RNs. As previously discussed, surveillance encompasses the process through which nurses actively monitor patients, observe clinical status and vital signs, analyze trends or changes in those observations, and subsequently take action to avert negative outcomes through early recognition of clinical deterioration and appropriate intervention (Henneman et al., 2012; Kelly & Vincent, 2011; Kutney-Lee, Lake, et al., 2009). Surveillance is conceptualized as a cumulative intervention (Kutney-Lee, Lake, et al., 2009) and represents both a cognitive as well as a behavioral process (Kelly & Vincent, 2011). As a patient safety strategy, surveillance is one mechanism to both prevent and quickly address adverse events in the hospital setting (Henneman et al., 2012). In a study that examined the direct impact of nursing surveillance, as measured by an electronic medical record, authors reported that patient receiving twelve or more instances of surveillance daily experienced a significantly decreased rate of FTR (Shever, 2011). A nursing skill mix with a low proportion of RNs, indicating possible substitution of less educated staff (LPN/LVNs, UAPs) for more educated RNs, may not be able to conduct effective surveillance.

Additionally, while surveillance is likely important for all patient populations, it may be especially critical for surgical patients during the postoperative period. While the immediate transition out of surgery often occurs in specialized settings such as post-anesthesia care units (PACUs), the transition from PACU and ICU settings to medical/surgical nursing units represents a time of increased risk for patients (Helling et al., 2014), and may result in adverse events and mortality if nurse staffing and surveillance is inadequate (Chaboyer, James, & Kendall, 2005). Underscoring this risk, a study by Helling and colleagues found that over 90% of surgical patients experiencing a failure event had recently been transferred from PACU and ICUs settings to general medical/surgical floors (2014). Additionally, an observational study of the first 24 hours of postoperative care on general surgical wards reported that patients received an average of 2.8 interactions with nurses hourly for the first 24 hours, with over 40% of the interactions occurring in the first four hours subsequent to a return to the ward (Zeitz, 2005). Therefore, the outcomes of surgical patients during the postoperative time period may be tied to intensive nursing services, and any decrease in the nursing skill mix may be particularly detrimental to surveillance efforts.

Summary and Gaps in the Literature

While a large and growing body of literature addressing aspects of nurse staffing exists, there is a lack of large-scale studies that explore the impact of nursing skill mix on surgical patient mortality in the US. The existing studies examining nursing skill are either limited by geography (Estabrooks et al., 2011; Tourangeau et al., 2007), population of interest (Hickey et al., 2010; Sasichay-Akkadechanunt et al., 2003), unit of analysis (Sasichay-Akkadechanunt et al., 2003; Yang et al., 2012), inconsistency in measurement or definition of skill mix (Martsolf et al., 2014; Needleman et al., 2002), or method of risk adjustment (Sales et al., 2008). Additionally, the use of a variety of methods to measure and describe nursing skill mix is evident in the literature, leading to inconsistencies in analysis and difficulty in comparison between studies.

Chapter 3: METHODS AND DESIGN

This section introduces the study methods. The research design, data sources, sample, and study variables and instruments are discussed. A detailed overview of the data analysis plan is presented, and human subject protection considerations are also outlined.

Research Design

This study was a retrospective, cross-sectional, secondary data analysis of nurse survey data and adult general, vascular and orthopedic surgical patient outcomes in four states (California, Florida, New Jersey, and Pennsylvania). Three datasets were utilized for analysis: 1) nurse survey data from 2006-2007 Multi-State Nursing Care and Patient Safety Survey (California, Florida, New Jersey, and Pennsylvania) 2) the 2006-2007 American Hospital Association (AHA) Annual Survey, and 3) state discharge abstracts for patients age 18-85 years who underwent general, orthopedic, or vascular surgical procedures in non-federal acute care hospitals in 2006-2007. These data sources were linked to form the analytical dataset. The nurse survey data utilized for this study originated from work conducted by researchers at the University of Pennsylvania School of Nursing Center for Health Outcomes and Policy Research (RO1NR04513; PI: Aiken).

Sample

Hospitals

All hospitals included in this analysis were non-federal acute care facilities in California, Florida, New Jersey, and Pennsylvania, excluding specialty and psychiatric hospitals. Consistent with previous studies, to qualify for inclusion in the sample each hospital had a minimum of 10 nurse respondents to the Multi-State Nursing Care and Patient Safety Survey to ensure reliable estimates of organizational features, including skill mix (Aiken et al., 2011; Aiken et al., 2002). Each hospital identified for inclusion was also represented in the 2006-2007 AHA Survey. A total of 665 hospitals comprised the final sample.

Nurses

The nurse sample used in this study was drawn from the Multi-State Nursing Care and Patient Safety Survey. The sampling frame for this survey was created from state nurse licensure lists in the states of study and consisted of a random sample of between 25% and 50% of RNs with an active license in California (40 %), Florida (25%), New Jersey (50%), and Pennsylvania (40%). RNs selected for study inclusion were mailed a paper copy of the Multi-State Nursing Care and Patient Safety Survey, which included questions concerning practice environment, workload, and quality issues relating to their employing institution. Collection of survey data in California, New Jersey, and Pennsylvania occurred between September 2005 and August 2006, while survey data collection in Florida occurred between November 2007 and April 2008 (Aiken et al., 2011). Using a modified Dillman approach, a total of two survey mailings and a postcard follow up was sent to each identified individual (Aiken et al., 2010). In total, 272,783 surveys were mailed and over 100,000 surveys were returned, including 39,038 survey responses from staff nurses working in the hospitals of interest (Aiken et al., 2011). The final response rate for the survey ranged from 30-50%, with an overall response of 39% (Aiken et al., 2011).

A two-stage sampling design was employed to determine whether bias existed between respondents and nonrespondents to the initial survey. In total, 1,300 nonrespondents were targeted with repeat survey methods (shortened survey, telephone reminders, and monetary incentive), with a 91% response rate (Aiken et al., 2011; Aiken et al., 2010; Smith, 2009). While demographic differences between the respondent and nonrespondents groups did exist, no significant differences were identified on variables of interest (Aiken et al., 2010; Aiken et al., 2011).

The geographic and demographic differences between the surveyed states allowed for collection of information on a diverse sample of hospitals, nurses, and patients (Aiken et al., 2010). All nurses included in this study identified their primary place of work as an adult, non-federal, acute care hospital, and were involved in direct patient care. A total of 29,391 nurses comprised the final sample.

Patients

Discharge data from patients age 18-85 years who underwent a general, orthopedic, or vascular surgical procedure in 2006 and 2007 at hospitals which met inclusion criteria were included in the study. To qualify for study inclusion, the discharge abstract identified a diagnosis-related group (DRG) classification of general, orthopedic, or vascular surgery as specified by Silber et al. and used in previous research (Appendix A) (Silber et al., 2007). This patient population was chosen in order to explore the surgical outcomes of a wide-range of adult patients undergoing common surgical procedures, as well as to include only non-emergent surgical procedures where patients could reasonably be expected to survive postoperatively. A total of 1,267,516 patients comprised the final sample.

Variables and Instruments

Hospital Variables

Hospital characteristics were extracted from the 2006-2007 AHA Annual Survey and were used to control for factors that are known or theorized to impact patient outcomes, consistent with previous published work using this dataset (Aiken et al., 2011; Aiken et al., 2010). Models were specified to adjust for teaching status, technology status, bed size, geographic location, ownership, and state.

Teaching status

Teaching status was derived from the reported resident and fellow to bed ratio, and was reported as major (resident to bed ratio of greater than 1:4), minor (resident to bed ratio less than or equal to 1:4), or nonteaching (no postgraduate trainees). Teaching status was included in analysis as a categorical variable.

Technology status

Technology status, indicated in the AHA Annual Survey, is reported as high (hospitals that perform open heart surgery and/or organ transplants) or low (no open heart surgery and/or organ transplants). Technology status was included in the analysis as a dichotomous variable.

Bed Size

Hospitals were categorized based on bed size. Hospitals were categorized as small (less than 100 beds), medium (101-250 beds), or large (greater than 251 beds). Bed size was included in analysis as a categorical variable.

Geographic Location

A variable representing geographic location of the study hospitals was derived using the Core-Based Statistical Area (CBSA) designations found in the AHA Annual Survey: Division (>2.5 million), Metropolitan (50,000-2.5 million), Micropolitan (10,000-50,000), and Rural (<10,000). CBSA designation was included in the analysis as a categorical variable.

Ownership

Hospitals were categorized as either *non-profit, profit,* or *government-owned.* Ownership was included in the analysis as a categorical variable.

State

This variable identifies the state in which a hospital is located (California, Florida, New Jersey, and Pennsylvania) and was included in analysis as a categorical variable.

Nurse Variables

All nurse variables were derived from responses to the Multi-State Nursing Care and Patient Safety Survey. Nurse responses were aggregated to the hospital level for analysis.

Nursing Skill Mix

Nursing skill mix was calculated and explored in relation to surgical patient outcomes. The skill mix variables were derived from the response to the following survey question: "Counting yourself, how many of each of the following provided direct patient care on your unit the most recent shift/day you worked?". Response was requested on the number of RNs, LPN/LVNs, and UAPs that the respondent worked with on the most recent shift. These responses were then aggregated to the hospital level to provide an institutional measure of nursing skill mix. The nursing skill mix variable, unless otherwise noted, represents the mean proportion of RNs as part of the total nursing staff, and was continuous in nature. The measure of RN skill mix was calculated using the following equation:

$$\text{RN Skill Mix} = \text{RN}/\ (\text{RN} + \text{LPN/LVN} + \text{UAP})$$

For the purposes of this study, the skill mix measure was calculated as a proportion using the counts of RNs, LPN/LVNs, and UAPs. For example, if an RN reported working with five RNs, two LPN/LVNs, and three UAPs on their last shift, skill mix would be calculated as:

$$6/\ (6+2+3) = 6/11 = .55$$

Therefore, 55% of the nursing care team is comprised of RNs in the above example. Individual nurse reports of skill mix were aggregated to the hospital-level.

In order to examine the unique contributions of various categories of nursing providers, both the LPN/LVN and UAP skill mix were also calculated and used in analyses. These proportions were calculated in the same manner as the RN skill mix, with the exception that the numerator was changed to represent the nursing provider of interest. For example, LPN/LVN skill mix was calculated by finding the proportion of LPN/LVNs to all nursing staff (RN + LPN/LVN + UAP), while the UAP skill mix was calculated as the proportion of UAPs to all nursing staff.

Nurse Staffing

For this study, patient to all staff (RN + LPN/LVN + UAP) ratio served as a measurement for nursing workload. The patient to all staff ratio was calculated using nurses' response to two survey questions: "On the most recent shift/day you worked, how many patients were on your unit?" and "On the most recent shift/day you worked, counting yourself, how many RNs, LPN/LVNs, and UAPs provided direct patient care?". Analysis was restricted to nurses who reported involvement in direct patient care, to avoid inclusion of those RNs functioning in an administrative role. The patient to all staff ratio was calculated for each nurse respondent, and then subsequently aggregated to the hospital level. This variable was included in analysis independent of the skill mix variable. The patient to all staff variable is continuous in nature.

Nurse Education

As a growing body of research has demonstrated the relationship between nurse education and patient outcomes (Aiken et al., 2011; Aiken et al., 2014; Kutney-Lee et al., 2013), a nurse education variable was calculated and included in analysis. This variable was derived from the following question: "What are the highest degrees you hold in nursing?", where the respondent may choose diploma, associate degree, baccalaureate degree, master's degree, or doctoral degree. Nurse responses were categorized as those that had received a baccalaureate degree or higher (yes/no), which was then aggregated to the hospital-level to provide the proportion of nurses educated at the baccalaureate level or above. This variable represents the hospital mean proportion of RNs educated at the baccalaureate level or above, and is continuous.

Nurse Practice Environment

The quality of the nurse practice environment of a hospital has been linked to patient outcomes (Aiken et al., 2011; Aiken et al., 2009; Friese et al., 2008), and was hypothesized to be conceptually important to surgical patient outcomes in this study. Therefore a variable to represent practice environment was included in the analysis. Measurement of the practice environment was captured through use of the Practice Environment Scale of the Nursing Work Index (PES-NWI), a National Quality Forum-endorsed measure which has been validated through use in previous outcomes work (Aiken et al., 2011; Aiken et al., 2009; Friese et al., 2008). The PES is derived from the NWI, a survey-based measure of 65 questions originally developed to study hospitals that were successful at attracting and retaining nurses during periods of nursing shortage during the 1980s (Lake, 2002). Lake (2002) identified five subscales that have been extracted from the original NWI survey instrument to create the PES, which include 1) Nurse Participation in Hospital Affairs (9 items), 2) Nursing Foundations for Quality of Care (10 items), 3) Nurse Manager Ability, Leadership, and Support of Nurses

(5 items), 4) Staffing and Resource Adequacy (4 items), and 5) Collegial Nurse-Physician Relations (3 items). As part of the 2006-2007 Multi-State Nursing Care and Patient Safety Survey nurse survey respondents were asked to answer each question of a modified PES through use of a 4-point Likert scale, where 1 indicated that the respondent would “strongly disagree” and 4 indicated “strongly agree.”

Nurse-level means for each subscale were calculated, aggregated to the hospital-level, and subsequently collapsed to create an aggregate hospital-level mean PES-NWI score. This composite score was then used to identify the overall hospital nurse work environment, with high scores indicating better work environments. Due to a significant correlation between the Staffing and Resource Adequacy subscale and the patient to all staff measure used in the analysis (-0.43), this subscale was excluded from creation of the composite PES-NWI score. The PES-NWI score utilized for analysis was continuous.

Percent of Nurse Respondents in Medical/Surgical and Intensive Care Unit (ICU) Settings

To help account for hospitals with different mixtures of patient care units, and therefore potential differences in staffing, the percent of nurses from each hospital who reported working in a medical/surgical unit or an ICU during their last shift was included in the final regression as a continuous variable.

Patient Variables

Information on patient demographics, including clinical information and risk adjustment variables, were collected through state discharge abstracts. The abstracts were obtained from several sources including the 1) Pennsylvania Health Care Cost

Containment Council, 2) California Office of Statewide Health Planning and Development Inpatient Discharge Dataset, 3) Florida Agency for Health Care Administration Hospital Inpatient Discharge Data, and the 4) New Jersey State Department of Public Health.

Demographics

Several demographics including age, sex, and race were controlled for in this analysis. The age variable indicates a patient's age upon admission to the hospital and was continuous in nature. The sex variable indicated whether a patient was identified as male or female, and was dichotomous in nature. Race was identified using the categories of white, black, or other. The race variable used in analysis was categorical in nature.

Primary Diagnosis

The primary diagnosis or procedure was extracted using the DRG classification listed on individual discharge abstracts. To qualify for study inclusion, these primary diagnoses fell within the specified list of general, vascular, or orthopedic surgical procedures previously published (Silber et al., 1992; Silber et al., 2007) and listed in Appendix A. These specified DRGs have been validated in past work (Aiken et al., 2002).

Comorbid Conditions

Patient comorbidities are conceptually important to control for in analysis, as they may alter the client response to any care provided during the course of a hospitalization. Comorbidities were identified by examining the secondary diagnosis fields in the state discharge abstracts. The risk adjustment method used to account for the association of comorbidities with patient outcomes was based on the Elixhauser comorbidity risk adjustment approach (Elixhauser et al., 1998), which has previously been used with surgical patients (Volpp et al., 2007). While the Elixhauser method encompasses 29 comorbidities, the modified approach used in this analysis excluded fluid and electrolyte disorders and coagulopathy, consistent with previous studies (Volpp et al., 2007), as they have been postulated to be reflective of complications and not comorbidities (Glance, Dick, Osler, & Mukamel, 2006; Silber et al., 2007). The Elixhauser method was chosen due to the superiority demonstrated in mortality risk models examining populations of individuals admitted for common diagnoses, as opposed to the Deyo et al. adaptation of Charlson (Stukenborg, Wagner, & Connors, 2001). Systematic reviews have demonstrated the advantage of the Elixhauser risk adjustment measure when working with administrative datasets, such as discharge abstracts (Sharabiani et al., 2012). Additionally, it has been validated for use with ICD-9 coding (Li, Evans, Faris, Dean, & Quan, 2008; Quan et al., 2005). Consistent with previous work using this methodology, a 180 day look-back period to previous hospitalizations was used to help to identify missing comorbidities from the primary admission, and was used to distinguish between comorbidities and complications (Aiken et al., 2002).

Transfer Status

The mode of hospital admission is included on patient discharge abstracts, and was accounted for in analysis. A dichotomous variable, indicating whether a patient was transferred from an outside hospital, was included in the final regression.

Outcomes

30-day mortality

Mortality within 30 days of admission was used as one of two primary outcomes of interest, and was determined through review of state discharge abstracts. The 30-day mortality was calculated by subtracting the date of admission from the date of death for each discharge abstract. The 30-day mortality variable is dichotomous in nature.

Failure to Rescue (FTR)

FTR, or death following development of a complication, represents the second outcome measure studied. While related to 30-day mortality, the FTR measure has been demonstrated to provide different yet complimentary information on hospital care quality, and to be more closely associated with hospital characteristics than patient characteristics (Silber et al., 2007). In order to calculate the FTR rate, the number of individuals that died after developing a specified complication (Appendix B) is divided by the total number of individuals who developed a complication, therefore identifying the probability that a patient experiencing a complication died (Silber et al., 2007). Exclusion criteria for complications are outlined in Appendix B and C. The procedure governing which complications to include in the FTR measure, as well as how to distinguish between complications and comorbidities, has been supported by expert consensus and is consistent with previous studies used as a template to guide this analysis (Aiken et al., 2011; Aiken et al., 2002; Friese et al., 2008; Silber et al., 2007).

Data Analysis

Data Linkage

The three main sources of data, the 2006-2007 Multi-State Nursing Care and Patient Safety Survey, the 2006-2007 AHA Annual Survey, and state discharge abstracts for general, orthopedic, and vascular surgical patients were linked using a unique hospital identifier. Nurse survey data was aggregated to the hospital-level and then merged with hospital characteristics extracted from the AHA annual survey using unique hospital ID. This combined hospital-level dataset was then merged with a patient-level outcomes dataset by unique hospital ID. The final merge of these three datasets produced the analytic dataset, comprising patient-level outcomes and both patient- and hospital-level predictors.

Analysis Plan

Specific Aim: *To examine the association between hospital nursing skill mix and adult surgical patient outcomes (30-day mortality and FTR).*

> ***Hypothesis:*** *A nursing skill mix with a higher proportion of RNs among all nursing personnel will be associated with decreased odds of 30-day mortality and FTR among adult surgical patients.*

Descriptive analyses were used to identify the distribution of demographics of interest in the linked dataset. Chi-square tests were used to determine significance of categorical variables and ANOVA tests were used for continuous variables. Pearson correlations were used to assess correlations between study variables.

These initial analyses were followed by a series of nested, multivariable logistic regression models to assess the association of nurse, patient, and hospital characteristics with 30-day mortality and FTR. Models were adjusted for potential nurse, patient, and hospital confounders previously described. RN skill mix represented the primary independent variable in the main analysis, with 30-day mortality and FTR representing the main outcomes of interest. In order to robustly account for clustering of patients and nurses at the hospital level, Huber-White procedures or sandwich estimators were used (Huber, 1967; White, 1980). Model discrimination was assessed using receiver operating characteristics curves. All analyses were completed using Stata IC 13.1, with statistical significance set at $P<0.05$.

In addition to the main independent variable, RN skill mix, additional logistic regression models assessing the association of LPN/LVN and UAP skill mix with 30-day mortality and FTR were also constructed. All nurse, patient, and hospital characteristics previously discussed were included in the analysis, with the models remaining constant.

Exploratory Analyses

Two exploratory analyses were performed in an attempt to gain a better understanding of the relationship between nursing skill mix and patient outcomes. First, analysis was conducted to test for a potential moderator effect of nurse staffing on the relationship between nursing skill mix and 30-day mortality and FTR. A model with both continuous main predictors (patient to all staff ratio, RN skill mix) and an interaction term (patient to all staff ratio*RN skill mix) was generated to test for a significant interaction between staffing and skill mix. A fully adjusted logistic regression model stratified by hospital staffing levels (low, medium, high) was created to explore the relationship between RN skill mix and surgical patient outcomes at different levels of staffing. The staffing levels were derived based on tertiles of the patient to all staff (RN+ LPN/LVN + UAP) ratio. Both 30-day mortality and FTR were explored in this stratified analysis.

A second exploratory analysis of the association between discrete stratified levels of nurse staffing (RN, LPN/LVN, and UAP) and the outcomes of 30-day mortality was also generated. Hospitals were categorized as those with staffing levels either above or below the median value for patient to RN ratio, patient to LPN/LVN ratio, and patient to UAP ratio. Two separate patient-level mortality measures were then created, the crude (unadjusted) 30-day mortality rate and the residual 30-day mortality rate (adjusted for all patient characteristics discussed in Patient Variable section). The crude and residual 30-day mortality rates were then calculated as a function of discrete staffing levels of the three categories of providers. A separate analysis for each combination of staffing (eight total combinations) was generated, and the associated crude and residual 30-day mortality rates were derived.

Human Subjects

This study was a secondary analysis of preexisting data. The survey data from nurse respondents, as well as the patient discharge abstracts used in this study, were previously de-identified. Additionally, the AHA data used for risk adjustment in this study was de-identified, such that no hospitals are identifiable in the final analysis. All study results are presented in aggregate and as a function of characteristics of hospitals as opposed to outcomes of individual hospitals. All study data is stored on a University of Pennsylvania protected server, and will be monitored and protected as outlined in data use agreements. Institutional Review Board approval was obtained prior to study commencement (IRB protocol #820056, Appendix D).

Chapter 4: RESULTS

The purpose of this study was to explore the association between nursing skill mix and the outcomes of hospitalized adult surgical patients, including 30-day mortality and failure to rescue (FTR). It was hypothesized that a nursing skill mix with a higher proportion of RNs to total nursing personnel would be associated with decreased odds of 30-day mortality and FTR. To explore this aim and test the stated hypothesis, logistic regression models were used to assess the relationship between variation in nursing skill mix on adult surgical patients controlling for patient, nurse and hospital characteristics known, or theorized, to be associated with surgical patient outcomes. Although RN skill mix was the primary independent variable of interest, other measures of skill mix (proportion of LPN/LVN and UAP) were also explored. Additionally, the possibility of a moderating effect of staffing on the relationship between nursing skill mix and adult surgical outcomes was examined through stratified logistic regression analyses. A preliminary predictive analysis to examine how 30-day mortality (crude and residual mortality rate) might differ as a function of variation in the staffing level of the three categories of nursing personnel (RN, LPN/LVN, UAP) was also conducted.

This chapter provides the results of these analyses. The final analytic sample included 1,267,516 adult surgical patients and 29,391 nurses from 665 hospitals. Descriptive characteristics of the patient and nurse sample are first presented and discussed. Hospital characteristics for the 665 study hospitals are then presented in aggregate, as well as stratified by tertile of RN skill mix. Hospital-level nursing characteristics are then presented, both in aggregate and stratified by tertile of RN skill mix. Patient outcomes of interest (30-day mortality and FTR) are then summarized. Logistic regression models corresponding to the main aim are presented and discussed. An exploratory stratified staffing analysis is presented. Finally, the results of an exploratory predictive model examining the association of discrete staffing levels (RN, LPN/LVN, UAP) with crude and residual 30-day mortality is summarized.

Characteristics of the Study Population: Patients, Nurses, and Hospitals

A summary of patient demographics can be found in **Table 1**. A total of 1,267,516 adult surgical patients comprised the study sample. On average, the sample patient population had a mean age of 59.1 years (SD: 17) and ranged from 18-85 years of age. Approximately 44% of patients were male. The sample was predominantly white (73.34%), with 8.3% of patients identified as black. A small percentage of patients (1.2%) were admitted from an outside hospital. Patients were identified as belonging to one of three major surgical categories, as defined by their primary diagnosis-related group (DRG). The majority of patients in the sample underwent an orthopedic procedure (51.7%), followed by a general surgical procedure (42.9%), with vascular procedures representing the least commonly occurring procedures (5.5%). Within the three major surgical categories, patients are further differentiated into six major diagnostic categories (Circulatory System, Digestive System, Hepatobiliary System & Pancreas, Musculoskeletal System & Connective Tissue, Skin, Subcutaneous Tissue & Breast, Endocrine, Nutritional, Metabolic Diseases & Disorders). The most common surgical diagnostic category was Musculoskeletal System and Connective Tissue procedures (51.8%), with Skin, Subcutaneous Tissue & Breast representing the least common surgical diagnostic category (3.6%).

Table 1. Surgical Patient Characteristics (N= 1,267,516)	
	n (%)
Age (years), mean (SD)	59.1 (17.0)
Sex (male)	553,762 (43.7)
Race	
White	929,572 (73.3)
Black	105,513 (8.3)
Other	232,431 (18.3)
Transferred from Outside Hospital	15,103 (1.2)
Major Surgical Category	
General Surgery (MDC 6,7,9,10)	543,184 (42.9)
Orthopedic Surgery (MDC 8)	655,294 (51.7)
Vascular Surgery (MDC 5)	69,038 (5.5)
Major Diagnostic Category (MDC)	
Circulatory System (5)	66,753 (5.5)
Digestive System (6)	270,180 (22.0)
Hepatobiliary System & Pancreas (7)	139,799 (11.4)
Musculoskeletal System & Connective Tissue (8)	634,574 (51.8)
Skin, Subcutaneous Tissue & Breast (9)	43,949 (3.6)
Endocrine, Nutritional, Metabolic Diseases & Disorders (10)	70,488 (5.8)

Note: Percentages may not add to 100% due to rounding.

SD: standard deviation

A summary of patient comorbidities can be found in **Table 2**. The sample patient population had an average of 1.6 of the 27 Elixhauser comorbidities identified for inclusion in this study, with a standard deviation of 1.5 comorbidities. The number of reported comorbidities ranged from 0-12. Of the total sample patient population, 73.8% had a minimum of one comorbidity reported. Among patients with a minimum of one reported comorbidity, the average number of comorbidities was 2.2 (SD: 1.3). The most prevalent reported comorbidities in the sample include complicated and uncomplicated hypertension (47.6%), uncomplicated diabetes (15.1%), and chronic pulmonary disease (14.5%).

Table 2. Distribution of Surgical Patient Comorbidities (N= 1,267,516)	
Elixhauser Comorbidity Diagnosis	n (%)
Hypertension (complicated + uncomplicated)	603,150 (47.6)
Diabetes (uncomplicated)	191,072 (15.1)
Chronic Pulmonary Disease	183,612 (14.5)
Deficiency Anemias	169,370 (13.4)
Hypothyroidism	115,751 (9.1)
Obesity	113,287 (8.9)
Depression	92,238 (7.3)
Congestive Heart Failure	59,878 (4.7)
Renal Failure	59,519 (4.7)
Peripheral Vascular Disease	54,986 (4.3)
Valvular Disease	54,677 (4.3)
Neurological Disorders	49,277 (3.9)
Diabetes (complicated)	43,299 (3.4)
Metastatic Cancer	40,408 (3.2)
Alcohol Abuse	31,190 (2.5)
Liver Disease/Dysfunction	30,113 (2.4)
Rheumatoid Arthritis/Collagen Vascular Diseases	29,955 (2.4)
Psychoses	24,591 (1.9)
Weight Loss	21,402 (1.7)
Blood Loss Anemia	20,091 (1.6)
Drug Abuse	18,683 (1.5)
Paralysis	17,764 (1.4)
Solid Tumor without Metastasis	14,308 (1.1)
Pulmonary Circulation Disorders	12,591 (1.0)
Lymphoma	5,589 (0.4)
AIDS	2,172 (0.2)
Peptic Ulcer Disease (excluding bleeding)	834 (0.1)
Comorbidities Per Patient, mean (SD)	2.20 (1.3)

Note: Comorbidities per patient represents the average number of comorbidities present in those patients with a minimum of one reported comorbidity.

SD: standard deviation

A summary of nurse characteristics can be found in **Table 3**. The final sample included 29,391 nurses working in direct patient care positions in 665 hospitals across four states (California, Florida, New Jersey, Pennsylvania). The mean reported age of nurse respondents was 44.9 years, with a standard deviation of 10.7 years. The majority of nurses were female (93.2%) and over half were educated at either the diploma or associates degree level (18.8% and 38.5% respectively). Approximately 40% of respondents reported having a baccalaureate degree in nursing. Across the sample, 17.5% of nurses reported working in medical/surgical units on their last shift, while 23.6% worked in intensive care units (ICUs). On average, respondents reported 16.7 years of experience working as an RN, with a standard deviation of 11 years.

Table 3. Nurse Characteristics (N= 29,391)	
Age (years), mean (SD)	44.9 (10.7)
Female, n (%)	27,267 (93.2)
Nurse Education, n (%)	
Diploma	5,261 (18.8)
Associates	10,744 (38.5)
Bachelors	11,070 (39.7)
Masters	830 (3.0)
Doctorate	8 (0.03)
Unit Type, n (%)	
Medical/Surgical Unit	4,167 (17.5)
Intensive Care Unit	5,634 (23.6)
Year of RN Experience, mean (SD)	16.7 (11.0)

Note: Percentages may not add to 100% due to rounding. Totals may not equal sample size of 29,391 due to missing values. Nurse sample represents RNs reporting a role as a staff nurse in the 665 study hospitals. Nurse Education denotes the highest degree achieved in nursing.

SD: standard deviation

A summary of sample hospital characteristics are shown in **Table 4**. This table describes the structural characteristics of the 665 study hospitals in aggregate, as well as divided into three tertiles of RN skill mix (low, medium and high). The majority of study hospitals were located in California (40.8%), followed by Florida (25.3%), Pennsylvania (23.0%), and New Jersey (11.0%). There were 226 hospitals in the low skill mix category, 221 in the medium skill mix category, and 218 in the high skill mix category. The average RN skill mix across all hospitals was 0.75, with a standard deviation of 0.07. The mean RN skill mix (and standard deviation) across groups from low to high was 0.68 (0.05), 0.76 (0.02), and 0.83 (.04), respectively (P<0.001).

The majority of hospitals had greater than 100 beds, with only 15.1% of total hospitals reporting 100 beds or less. Bed size varied significantly across tertile of RN skill mix (P=0.023). The majority of hospitals were nonteaching (53.0%), and did not have the capability to perform open heart surgery and/or organ transplant (60.7%). Teaching status was not significantly associated with RN skill mix tertile after Chi-square testing. However, technology status did vary significantly by RN skill mix tertile (P =0.033).

Core-Based Statistical Area (CBSA) identifies study hospitals as being located in four categories based on the population of the geographic area: Division (>2.5 million), Metropolitan (50,000-2.5 million), Micropolitan (10,000-50,000), and Rural (<10,000). The majority of study hospitals were located in either Division (41.0%) or Metropolitan (48.1%) locations. Chi-square testing demonstrated that CBSA category was significantly associated with tertile of RN skill mix (*P*<0.001). Of note, 60% of hospitals in Micropolitan areas and 50% of hospitals in Rural areas were identified as being low RN skill mix institutions. The majority of sample hospitals (69.4%) were reported as non-profit institutions. For-profit hospitals represented 20.8% and government owned hospitals represented 9.8% of the 665 total hospitals. Additionally, skill mix varied significantly across the four states studied (P<0.001).

Table 4. Study Hospital Characteristics by Tertile of RN Skill Mix and Total (N=665)					
	All	**Low (n=226)**	**Medium (n=221)**	**High (n=218)**	***P* - value**
Hospital Characteristic					
RN Skill Mix, mean (SD)	0.75 (.07)	0.68 (0.05)	0.76 (0.02)	0.83 (0.04)	<0.001
Bed Size, n (%)					0.023
≤100	100 (15.1)	44 (44.0)	24 (24.0)	32 (32.0)	
101-250	300 (45.2)	108 (36.0)	94 (31.3)	98 (32.7)	
>250	264 (39.8)	74 (28.0)	102 (38.6)	88 (33.3)	
Teaching Status, n (%)					0.598
Nonteaching (No postgraduate trainees)	352 (53.0)	123 (34.9)	114 (32.4)	115 (32.7)	
Minor (Resident to bed ratio ≤ 1:4)	266 (40.1)	92 (34.6)	90 (33.8)	84 (31.6)	
Major (Resident to bed ratio > 1:4)	46 (6.9)	11 (23.9)	16 (34.8)	19 (41.3)	
Technology Status, n (%)					0.033
High (Open heart and/or organ transplant)	261 (39.3)	74 (28.4)	98 (37.6)	89 (34.1)	
Low (No open heart and/or organ transplant)	403 (60.7)	152 (37.7)	122 (30.3)	129 (32.0)	
Core-Based Statistical Area, n (%)					<0.001
Division (>2.5 million)	258 (41.0)	51 (19.8)	113 (43.8)	94 (36.4)	
Metropolitan (50,000-2.5 million)	303 (48.1)	120 (39.6)	84 (27.7)	99 (32.7)	
Micro (10,000-50,000)	55 (8.7)	33 (60.0)	10 (18.2)	12 (21.8)	
Rural (<10,000)	14 (2.2)	7 (50.0)	3 (21.4)	4 (28.6)	
Ownership, n (%)					0.897
Government	62 (9.8)	22 (35.5)	19 (30.7)	21 (33.9)	
Non-profit	437 (69.4)	142 (32.5)	151 (34.6)	144 (33.0)	
Profit	131 (20.8)	47 (35.9)	40 (30.5)	44 (33.6)	
State, n (%)					<0.001
California	271 (40.8)	64 (23.6)	87 (32.1)	120 (44.3)	
Florida	168 (25.3)	67 (39.9)	51 (30.4)	50 (29.8)	
New Jersey	73 (11.0)	18 (24.7)	39 (53.4)	16 (21.9)	
Pennsylvania	153 (23.0)	77 (50.3)	44 (28.8)	32 (20.9)	

Note: Percentages may not add to 100% due to rounding. Values may not equal sample size of 665 due to missing values in American Hospital Association data. *P*-values calculated using ANOVA tests for continuous variables and Chi-square tests for categorical variables. RN Skill Mix is calculated using the equation (RN/ (RN + LPN/LVN + UAP)). SD: standard deviation.

Table 5 describes the nursing characteristics of the 665 study hospitals in aggregate, as well as divided into three tertiles of RN skill mix (low, medium, and high). Nurse responses on nursing characteristics of interest (nursing skill mix, staffing, education, and practice environment) were aggregated to the hospital level, creating hospital-level measures for use in the analysis. The average patient to RN ratio (patient/RN) was 5.48 (SD: 1.63) for all hospitals and the difference across RN skill mix tertiles was statistically significant ($P<0.001$). The average number of patients cared for by each RN was almost two patients higher in hospitals with low RN skill mix (6.47) versus hospitals with high RN skill mix (4.72). This trend was not present in the patient to all staff ratio (patient/ (RN + LPN/LVN + UAP)). On average, study hospitals reported 3.66 (SD: 0.87) patients per nursing staff. There was no significant difference in the patient to all staff ratio across tertile of RN skill mix ($P=0.47$).

The average percentage of RNs educated at the baccalaureate level or higher across all study hospitals was 37% (SD: 14%). The proportion of nurses educated at the baccalaureate level or above varied significantly ($P<0.001$) by RN skill mix tertile, with an almost 10 percentage point difference between hospitals in the lowest tertile of RN skill mix (32%) and those in the highest tertile of RN skill mix (41%). Hospitals were categorized into three groups (poor, mixed, better) based on their overall score on the PES-NWI measure, and the distribution of hospitals within each category is presented below. Across all hospitals, 26% were identified as having better practice environments, 48% were identified as having mixed practice environments, and 26% were identified as falling into the poor category of practice environment. This was found to vary significantly across RN skill mix tertiles (*P*=0.004). Among hospitals categorized as poor practice environments, 43.9% also had low RN skill mix, while 28.9% had high RN skill mix. This trend was reversed in hospitals with better practice environments, with 24.3% of hospitals with better practice environments being categorized as low RN skill mix and 38.7% categorized as high RN skill mix hospitals.

Table 5. Hospital-Level Organization of Nursing Characteristics by Tertile of RN Skill Mix and Total (N=665)					
	All	**Low (n=226)**	**Medium (n=221)**	**High (n=218)**	***P* - value**
Nursing Characteristic					
RN Skill Mix, mean (SD)	0.75 (0.07)	0.68 (0.05)	0.76 (0.02)	0.83 (0.04)	<0.001
Patient to RN Ratio, mean (SD)	5.48 (1.63)	6.47 (1.93)	5.21 (1.04)	4.72 (1.24)	<0.001
Patient to All Staff (RN + LPN/LVN + UAP) Ratio, mean (SD)	3.66 (0.87)	3.72 (0.91)	3.62 (0.74)	3.64 (0.94)	0.4691
BSN education, mean (SD)	0.37 (0.14)	0.32 (0.14)	0.39 (0.13)	0.41 (0.15)	<0.001
PES-NWI, n (%)					0.004
Poor	173 (26.0)	76 (43.9)	47 (27.2)	50 (28.9)	
Mixed	319 (48.0)	108 (33.9)	110 (34.5)	101 (31.7)	
Better	173 (26.0)	42 (24.3)	64 (37.0)	67 (38.7)	

Note: Percentages may not add to 100% due to rounding. Values may not equal sample size of 665 due to missing values. *P*-values calculated using ANOVA tests for continuous variables and Chi-square tests for categorical variables. RN skill mix is calculated using the equation (RN/ (RN + LPN/LVN + UAP)). BSN education is the proportion of nurses at the hospital-level who have earned a minimum of a bachelor degree in nursing. PES-NWI: Practice Environment Scale of the Nursing Work Index, broken into tertiles (poor, mixed and better), excluding Staffing and Resource Adequacy subscale.

SD: standard deviation

Figure 2 depicts the distribution of RN skill mix across the 665 sample hospitals. RN skill mix is calculated using the equation: (RN/ (RN + LPN/LVN + UAP)). RN skill mix ranged from 0.34 to 1.0 across study hospitals, with a mean of 0.75 (SD: 0.07). The RN skill mix variable approximates a normal distribution.

Figure 2. Distribution of RN Skill Mix (RN/ (RN + LPN/LVN + UAP) Across Sample Hospitals

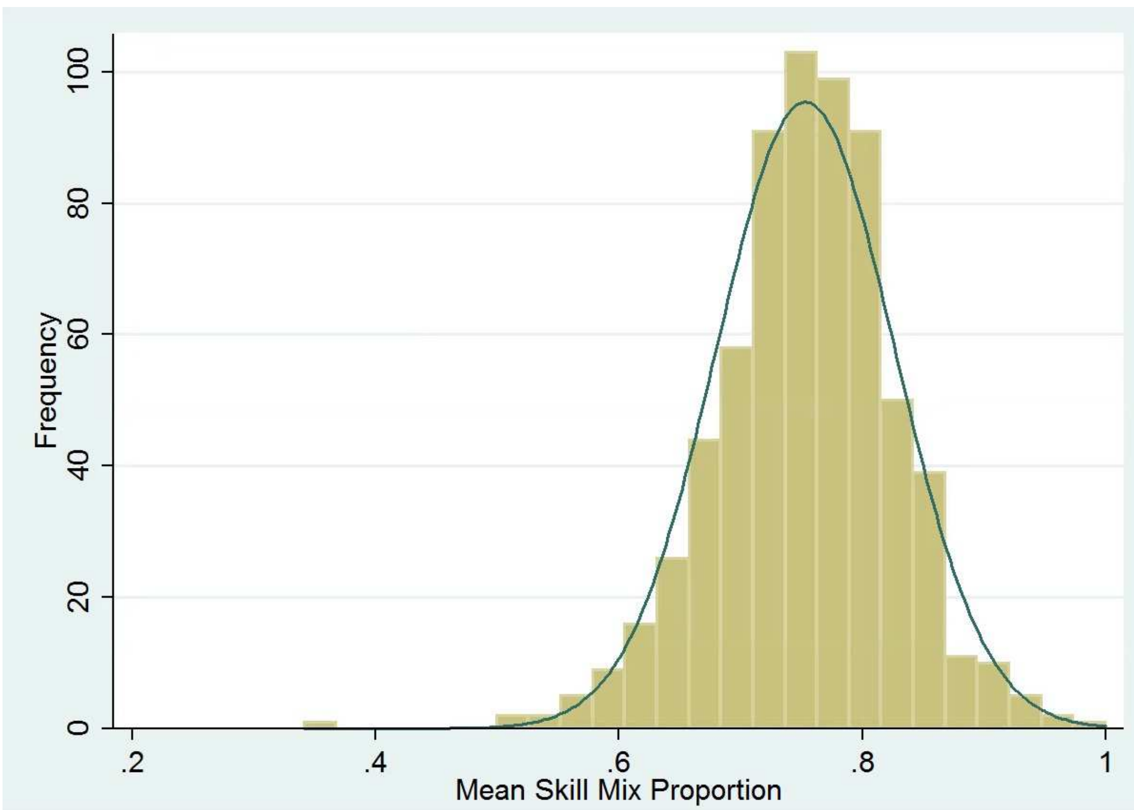
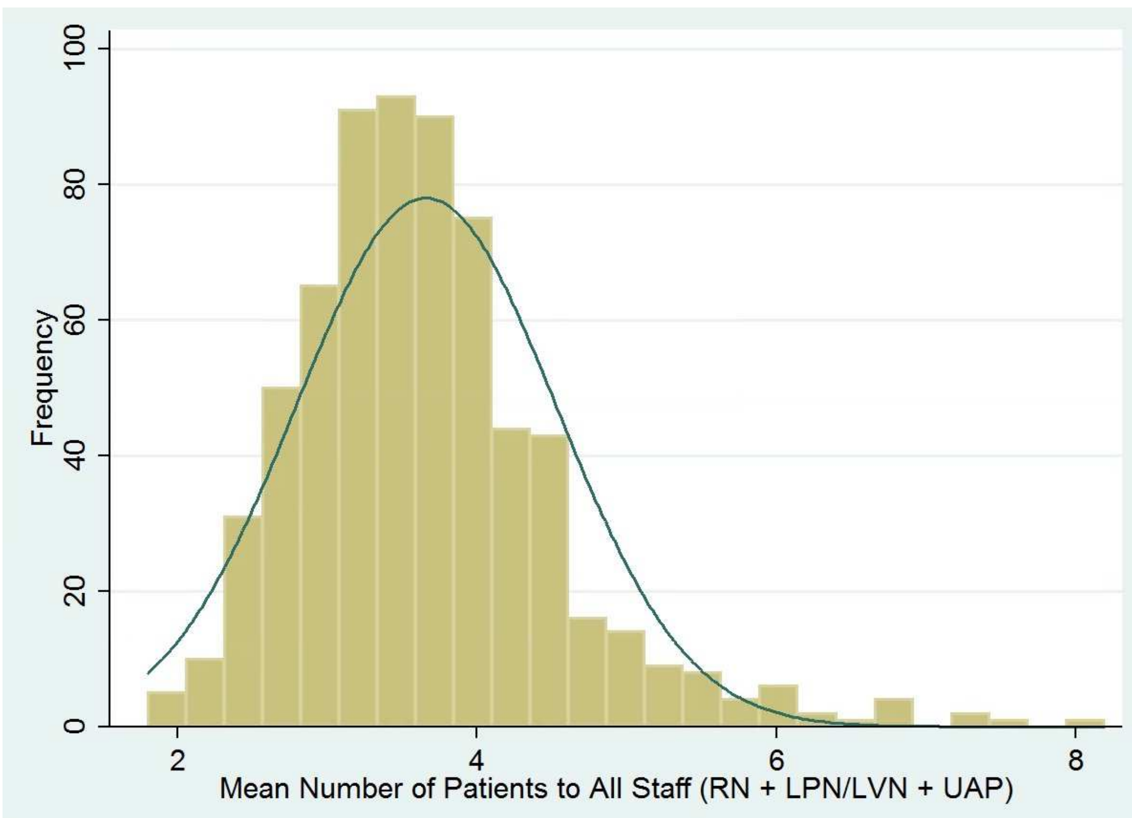


Figure 3 depicts the distribution of the patient to all staff ratio across the 665 sample hospitals. The patient to all staff ratio is calculated using the equation: (Patient/ (RN + LPN/LVN + UAP)). The average number of patients to all staff ranged from 1.8 to 8.2 across study hospitals, with a mean of 3.66 patients per staff (SD: 0.87). The distribution of the patient to all staff ratio variable demonstrates a positive, or right, skew.

Figure 3. Distribution of Patients to All Staff (RN+ LPN/LVN +UAP) Across Sample Hospitals



In addition to the RN population of interest, nursing skill mix also depends on the number of LPN/LVNs and UAPs present within the hospital. The distribution of these nursing staff at the hospital level is presented in **Table 6**. The mean proportion of LPN/LVNs to total nursing staff (RN + LPN/LVN + UAP) in the 665 sample hospitals was 0.07 (SD: 0.06), which ranged from 0.00-0.44. This proportion varied significantly across tertiles of RN skill mix, ranging from 0.11 at hospitals in the lowest tertile of RN skill mix to 0.04 in hospitals in the highest tertile of RN skill mix (P<0.001). A similar trend was observed with UAPs. The mean proportion of UAPs to total nursing staff (RN + LPN/LVN + UAP) was 0.18 (SD: 0.06), which ranged from 0.00-0.44. Therefore, on average, UAPs comprised almost one fifth of total nursing staff in the study hospitals. Similarly to the LPN/LVN variable, significant variation in proportion of UAPs was seen across hospitals with different tertiles of RN skill mix, ranging from 0.22 in hospitals in the lowest tertile of RN skill mix to 0.13 in hospitals in the highest tertile of RN skill mix (P<0.001).

Table 6. Proportion of LPN/LVNs and UAPs to Total Staff by Tertile of RN Skill Mix (N=665)					
	All	**Low (n=226)**	**Medium (n=221)**	**High (n=218)**	***P* - value**
Provider					
RN, mean (SD)	0.75 (0.07)	0.68 (0.05)	0.76 (0.02)	0.83 (0.04)	<0.001
LPN/LVN, mean (SD)	0.07 (0.06)	0.11 (0.07)	0.05 (0.04)	0.04 (0.03)	<0.001
UAP, mean (SD)	0.18 (0.06)	0.22 (0.07)	0.19 (0.04)	0.13 (0.04)	<0.001

Note: Percentages may not add to 100% due to rounding. P-values calculated using ANOVA tests for continuous variables.

SD: standard deviation

A summary of patient outcomes (30-day mortality and FTR) in aggregate and divided into tertile of RN skill mix (low, medium, and high) can be found in **Table 7**. Thirty-day mortality rates for general, orthopedic and vascular surgery ranged from 0.9%-7.5%, with a mean 30-day mortality rate of 1.7% among the 1,267,516 adult surgical patients included in the study. The crude 30-day mortality rate differed significantly across tertile of RN skill mix (*P*=0.014). The crude mortality rate among general surgery patients also differed significantly (*P*<0.001) across tertile of RN skill mix.

Rates of complications are described as well, as the number of individuals experiencing a complication is used to create the failure to rescue (FTR) measure. The overall complication rate among the study population was 33.6%, which ranged from 28.5%-66.8% across surgical categories, with over two thirds (66.8%) of vascular surgery patients experiencing a complication. The total complication rate for all surgeries in aggregate did not differ significantly across tertile of RN skill mix (*P*=0.814). However, complication rate did differ significantly when patient outcomes were stratified by category of surgery, with those undergoing general and orthopedic surgery (*P*<0.001) and vascular surgery (*P*=0.013) with significantly different complication rates across tertile of RN skill mix.

The overall FTR rate is calculated by dividing the total number of 30-day deaths in the sample by those patients who experienced a complication (n=425,680) as specified in Appendix B. This measure theoretically represents patients in which a complication was not addressed adequately (untimely response or inadequate treatment), leading to mortality. Across the three categories of surgery (general, orthopedic, and vascular), the FTR rate ranged from 3.1%-11.2%, with a mean FTR rate of 5.0%. The total FTR rate for all surgeries in aggregate was found to differ significantly across tertile of RN skill mix (P=0.011). When stratified by category of surgery, FTR in patients undergoing general surgery also varied significantly across tertile of RN skill mix (P<0.001), while the FTR rate among orthopedic and vascular patients was not significantly different.

Table 7. General, Orthopedic, and Vascular Surgical Patient Outcome Distribution by Tertile of RN Skill Mix (N=1,267,516)					
	All	**Low (n=226)**	**Medium (n=221)**	**High (n=218)**	***P* - value**
Outcome					
30-day Mortality, n (%)					
All Surgery^	21,615 (1.7)	6,522 (1.7)	8,029 (1.7)	7,064 (1.7)	0.014
General	10,690 (2.0)	3,327 (2.1)	4,022 (2.0)	3,341 (1.8)	<0.001
Orthopedic	5,747 (0.9)	1,835 (0.9)	2,018 (0.9)	1,894 (0.9)	0.155
Vascular	5,178 (7.5)	1,360 (7.3)	1,989 (7.5)	1,829 (7.6)	0.485
Complication, n (%)					
All Surgery^	425,680 (33.6)	126,970 (33.5)	155,603 (33.6)	143,107 (33.6)	0.814
General	192,894 (35.5)	57,029 (36.0)	72,271 (35.6)	63,594 (35.0)	<0.001
Orthopedic	186,653 (28.5)	57,451 (28.5)	65,509 (28.1)	63,693 (28.9)	<0.001
Vascular	46,133 (66.8)	12,490 (67.4)	17,823 (67.1)	15,820 (66.1)	0.013
Failure to Rescue, n (%)					
All Surgery^	21,615 (5.0)	6,522 (5.1)	8,029 (5.1)	7,064 (4.9)	0.011
General	10,690 (5.5)	3,327 (5.8)	4,022 (5.5)	3,341 (5.2)	<0.001
Orthopedic	5,747 (3.1)	1,835 (3.2)	2,018 (3.1)	1,894 (3.0)	0.092
Vascular	5,178 (11.2)	1,360 (10.8)	1,989 (11.1)	1,829 (11.5)	0.185

Note: ^: The 'All Surgery' category encompasses General, Orthopedic & Vascular Surgeries as outlined in Appendix A. Complication refers to the number of patients who experienced one of the 39 complications listed in Appendix B after undergoing a surgical procedure as specified in Appendix A. The FTR measure is constructed by calculating the proportion of patients who died after experiencing a complication.

The results of Pearson correlation analysis to identify significant associations between hospital characteristics and hospital-level measures of nursing skill mix, nurse staffing, nurse education, and the PES-NWI can be found in **Table 8**. Due to sample size, all correlations appeared significant at $P < 0.001$, with the exception of division/staffing ($P = 0.6$), rural/skill mix ($P = 0.18$), and nonprofit/staffing ($P = 0.32$). RN skill mix and education were found to have a weak positive relationship (r=0.29), and all other nursing and hospital characteristics were found to have a negligible relationship with RN skill mix, the main variable of interest. All study variables were found to be at most moderately correlated, with the exception of Ownership/profit and Ownership/nonprofit, which were strongly correlated (-0.65). Pearson and Spearman correlation analysis produced consistent correlation estimates, therefore only Pearson correlations are reported here.

Table 8. Pearson Correlation Between the Organization of Nursing and Hospital Characteristics (N=665)

Variables	1	2	3	4	5	6	7	8a	8b	8c	8d	9a	9b	9c
1. RN Skill Mix	---													
2. Nurse Staffing	-0.04	---												
3. Education	0.29	-0.23	---											
4. PES-NWI	0.13	-0.30	0.25	---										
5. Teaching Status	0.08	-0.10	0.24	0.01	---									
6. Technology Status	0.04	-0.11	0.17	0.13	0.22	---								
7. Bed Size	0.02	-0.06	0.30	0.10	0.37	0.44	---							
8. CBSA														
a. Division	0.18	-0.001	0.32	0.06	0.12	0.03	0.03	---						
b. Metro	-0.10	0.1	-0.24	-0.01	-0.04	0.10	0.07	-0.85	---					
c. Micro	-0.16	0.003	-0.18	-0.11	-0.08	-0.16	-0.16	-0.17	-0.20	---				
d. Rural	0.001	0.03	-0.05	0.02	-0.06	-0.06	-0.07	-0.05	-0.06	-0.01	---			
9. Ownership														
a. Government	-0.01	-0.12	-0.03	0.01	0.09	0.05	0.10	0.02	0.01	-0.01	-0.02	---		
b. Nonprofit	-0.02	0.001	0.13	0.22	0.03	0.05	0.13	0.04	0.05	0.04	0.04	-0.53	---	
c. Profit	0.04	0.13	-0.14	-0.28	-0.07	-0.02	-0.20	0.01	0.03	-0.02	-0.03	-0.14	-0.65	---

Note: All correlations significant at $P<0.001$ with the exception of Division/Staffing ($P= 0.6$), Rural/Skill mix ($P = 0.18$), and Nonprofit/Staffing ($P = 0.32$).

RN skill mix is calculated using the equation (RN/ (RN + LPN/LVN + UAP)). Nurse staffing refers to the Patient to All Staff (RN + LPN/LVN + UAP) ratio. Education is measured by percent of nurses who hold a BSN degree at the hospital level. PES-NWI: Practice Environment Scale of the Nursing Work Index, excluding Staffing and Resource Adequacy subscale. CBSA: Core-Based Statistical Area is broken into four categories (Division: Areas representing >2.5 million, Metropolitan: Areas representing 50,000-2.5 million, Micro: Areas representing 10,000-50,000, Rural: Areas representing <10,000).

Pearson correlation analyses to identify significant correlations between RN skill mix, nurse staffing and the PES-NWI (aggregate measure and subscales) are reported in **Table 9**. The PES-NWI aggregate measure and its subscales were, at most, weakly correlated with the RN skill mix measure, ranging from 0.08 for the Nurse Participation in Hospital Affairs subscale to 0.19 for the Staffing and Resource Adequacy subscale. However, when exploring correlation between the subscales of the PES-NWI and the nurse staffing measure (patient to all staff ratio, (RN + LPN/LVN + UAP)), the Staffing and Resource Adequacy subscale was found to be moderately and negatively associated with the patient to all staff ratio (-0.43). Therefore, this subscale was omitted when creating the PES-NWI measure for use in the final logistic regression analysis. As expected, the composite PES-NWI measure and the subscale measures were all highly correlated. All correlations were significant at $P<0.001$. Pearson and Spearman correlation analysis produced consistent correlation estimates, therefore only Pearson correlation is reported here.

Table 9. Pearson Correlation Between RN Skill Mix, Staffing, and Subscales of the PES-NWI								
Variables	**1**	**2**	**3**	**3a**	**3b**	**3c**	**3d**	**3e**
1. RN Skill Mix	---							
2. Nurse Staffing	-0.04	---						
3. Practice Environment	0.13	-0.30	---					
a. Staffing and Resource Adequacy	0.19	-0.43	0.80	---				
b. Nurse-Physician Relationships	0.15	-0.29	0.77	0.62	---			
c. Nurse Manager Ability, Leadership, and Support	0.11	-0.24	0.89	0.75	0.57	---		
d. Foundations for Quality of Care	0.12	-0.27	0.94	0.76	0.64	0.80	---	
e. Nurse Participation in Hospital Affairs	0.08	-0.26	0.93	0.71	0.60	0.77	0.89	---

Note: All correlations significant at *P* <0.001. RN Skill Mix is calculated by (RN/ (RN + LPN/LVN + UAP)). Nurse staffing refers to the patient to all staff (RN + LPN/LVN + UAP) ratio. PES-NWI: Practice Environment Scale of the Nursing Work Index, composite measure excluding Staffing and Resource Adequacy subscale. Subscales, including staffing and resource adequacy, are listed separately.

Pearson correlation analyses to identify significant correlations between RN skill mix, LPN/LVN skill mix, and UAP skill mix are reported in **Table 10**. LPN/LVN skill mix was found to be moderately and negatively correlated with RN skill mix (-0.57), indicating that as RN proportion increased, LPN/LVN proportion decreased. A moderate to strong, negative correlation was observed between UAP skill mix and RN skill mix (-0.71). All correlations were significant at $P<0.001$.

Table 10. Pearson Correlation Between RN Skill Mix, LPN/LVN Skill Mix, and UAP Skill Mix			
Variables	**1**	**2**	**3**
1. RN Skill Mix	---		
2. LPN/LVN Skill Mix	-0.57	---	
3. UAP Skill Mix	-0.71	-0.17	---

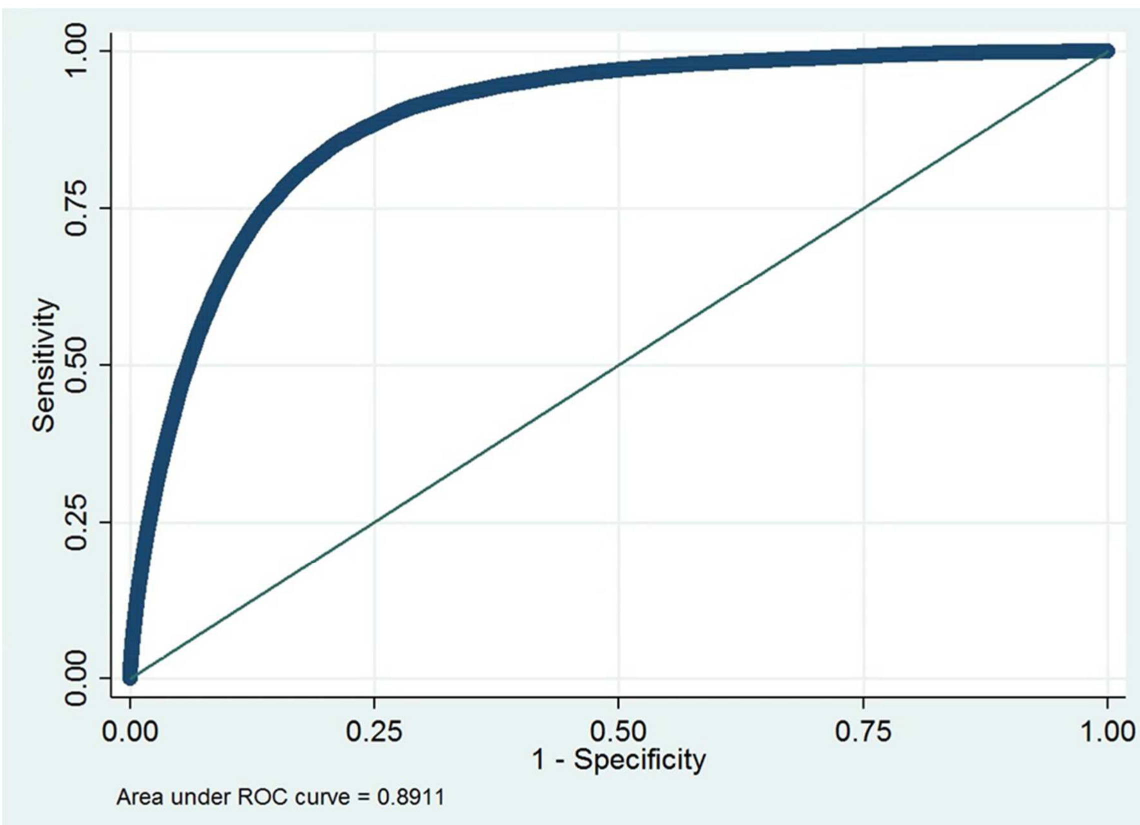
Note: All correlations significant at *P* <0.001. RN skill mix is calculated by (RN/ (RN + LPN/LVN + UAP)), LPN/LVN skill mix is calculated by ((LPN/LVN)/ (RN + LPN/LVN + UAP)), and UAP skill mix is calculated by (UAP/ (RN + LPN/LVN + UAP)).

Risk Adjustment Models

Risk adjustment models for adult general, orthopedic, and vascular surgical patients were estimated for the outcomes of 30-day mortality and FTR. As both 30-day mortality and FTR are dichotomous outcomes, logistic regression models were used. A series of nested multivariable logistic regression models were created to control for patient, nurse, and hospital characteristics that were either known or theorized to be related to surgical patient outcomes. The patient characteristics that were controlled for included primary DRG, modified Elixhauser comorbidity measure (27 conditions), age, sex, race, and transfer status. Hospital characteristics controlled for include teaching status, technology status, bed size, CBSA location, ownership, and state. Nursing characteristics controlled for in the analysis include patient to all staff (RN + LPN/LVN + UAP) ratio, nurse education (% BSN), PES-NWI, and percent of nurses at the hospital-level working in ICU or Medical/Surgical settings on their last shift. Model fit, as indicated by C-statistics, revealed good discrimination.

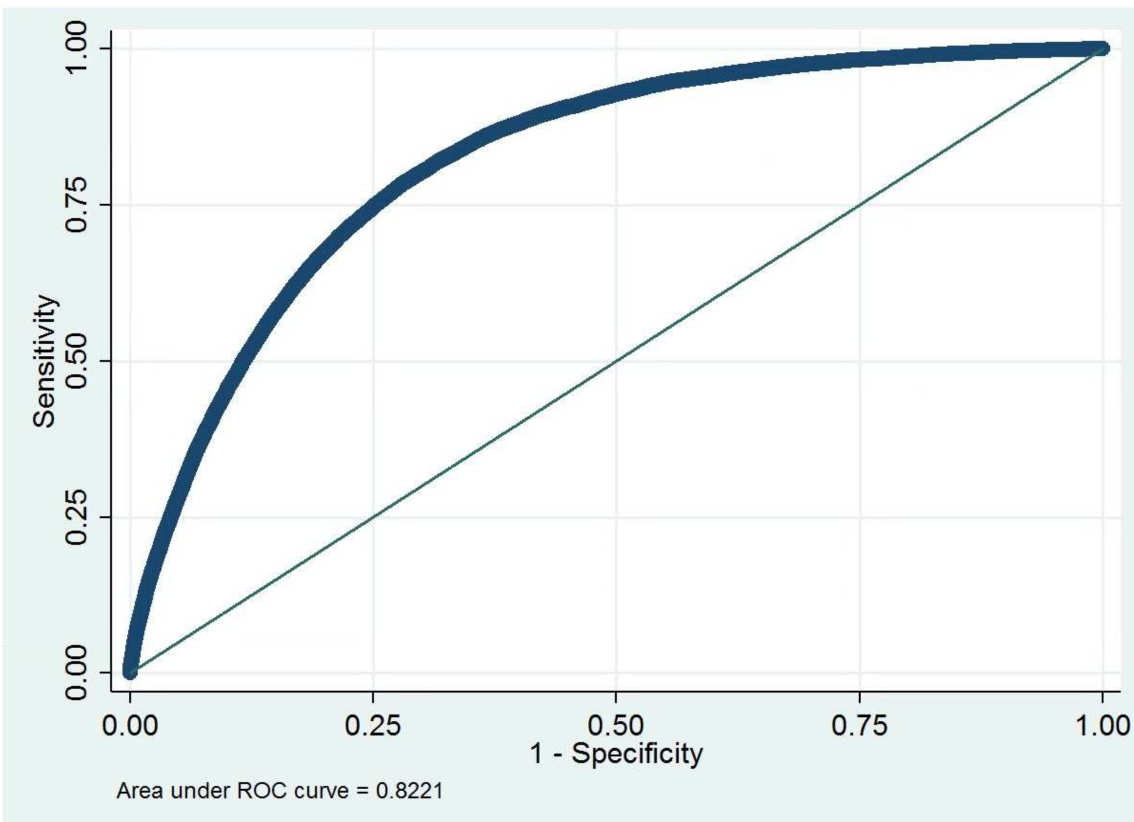
Figure 4 provides a graphical representation of the receiver operating characteristic (ROC) curve for the full, jointly adjusted 30-day mortality logistic regression. The ROC curve and associated C-statistic demonstrated good model discrimination (C=0.8911), indicating that the model adequately reflected the contributions of characteristics of patients, nurses, and hospitals to prediction of the outcome of 30-day mortality.

Figure 4. Receiver Operating Characteristic Curve, Full Model, 30-day Mortality



Similarly, **Figure 5** provides a graphical representation of the ROC curve for the full, jointly adjusted FTR logistic regression. The ROC curve and associated C-statistic demonstrated good model discrimination (C=0.8221), indicating that the model adequately reflected the contributions of characteristics of patients, nurses, and hospitals to prediction of the outcome of FTR.

Figure 5. Receiver Operating Curve, Full Model, Failure to Rescue



Specific Aim Analysis

Specific Aim: *To examine the association between hospital nursing skill mix and adult surgical patient outcomes (30-day mortality and FTR).*

> **Hypothesis:** *A nursing skill mix with a higher proportion of RNs among all nursing personnel will be associated with decreased odds of 30-day mortality and FTR among adult surgical patients.*

The following section presents the results of analyses to address the Specific Aim. Analyses were completed using hierarchical, nested, logistic regression models that accounted for clustering at the hospital level. Nurse and hospital characteristics were aggregated to the hospital-level and used to fully adjust models that provided information on the patient-level outcomes of 30-day mortality and FTR.

Table 11 describes the results of the logistic regression that examined the association of RN skill mix and other organizational nursing characteristics of interest with the odds of 30-day mortality in adult surgical patients. The unadjusted bivariate relationship between each nursing characteristic and the outcome of 30-day mortality is reported in the first column. The unadjusted relationship between RN skill mix and 30-day mortality was not found to be significant. The unadjusted bivariate relationships between 30-day mortality and patient to all staff (RN + LPN/LVN + UAP) ratio, education (%BSN), and PES-NWI were significant.

The second column reports results from the partially adjusted logistic regression, which controlled for both patient (primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status) and hospital characteristics (teaching status, technology status, bed size, CBSA designation, ownership, state) in the model. A significant association was noted between nursing skill mix, education (%BSN), and PES-NWI and decreases in the odds of 30-day mortality in the partially adjusted model. No significant association was noted between the patient to all staff ratio and 30-day mortality.

The third column reports the results of the fully adjusted logistic regression models that jointly assess the associations of the nursing variables of interest with 30-day mortality. This full model allows for examination of the relationship between nursing skill mix and 30-day mortality while accounting for all other nursing, hospital, and patient characteristics. In addition to the previously mentioned patient and hospital characteristics, this model also includes nursing characteristics (skill mix, patient to all staff ratio, nurse education, the PES-NWI continuous measure, and proportion of nurses at each hospital who work in medical/surgical or ICU settings) aggregated to the hospital level.

In the full model, jointly adjusted, each 10% increase in the proportion of RNs was associated with a 7% decrease in the odds of 30-day mortality for adult surgical patients ($P \leq 0.001$). Additionally, each 10% increase in the percentage of nurses in a hospital holding a baccalaureate degree or higher was associated with a 3% decrease in the odds of 30-day mortality for adult surgical patients ($P<0.01$), and each point increase in the PES-NWI was associated with a 7% decrease in the odds of 30-day mortality ($P \leq 0.001$).

Table 11. Odds Ratios Estimating the Effect of Organizational Nursing Features on 30-day Mortality In Adult Surgical Patients			
	Unadjusted (Bivariate)	**Partially Adjusted (Patient and Hospital Characteristics)**	**Full Model (Patient, Hospital, Nursing Characteristics Jointly Adjusted)**
Nursing Characteristic of Interest, OR (95% CI)			
RN Skill Mix	0.97 (0.92-1.03)	0.94 (0.90-0.98) **	0.93 (0.89-0.97)***
Patient to All Staff (RN + LPN/LVN + UAP) Ratio	1.07 (1.02- 1.11)**	1.04 (1.0-1.08)	1.03 (0.99- 1.08)
Nursing Education (% BSN)	0.95 (0.92-0.97)***	0.96 (0.94-0.98)***	0.97 (0.95-0.99)**
PES-NWI	0.90 (0.87-0.94)***	0.91 (0.88-0.95)***	0.93 (0.90-0.96)***

***: $P \leq 0.001$

**: $P<0.01$

*: $P<0.05$

Note: RN Skill Mix is calculated by (RN/ (RN + LPN/LVN + UAP)) and represents the change in odds of mortality associated with a 10% increase in the proportion of RNs to all staff. Nursing education (% BSN) represents the change in the odds of mortality associated with a 10% increase in the percentage of nurses in a hospital holding a baccalaureate degree or higher. PES-NWI: Practice Environment Scale of the Nursing Work Index, excluding Staffing and Resource Adequacy subscale. Patient characteristics include: Primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status. Hospital characteristics include: teaching status, technology status, bed size, CBSA status, ownership, state. Nursing characteristics include: ratio of patients to all staff, nursing education (% BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings.

OR: odds ratio, CI: confidence interval

Table 12 summarizes the logistic regression results that examined the association between RN skill mix and other organizational nursing characteristics and the odds of FTR in adult surgical patients. The unadjusted or bivariate relationship between these variables and FTR is reported in the first column. The unadjusted relationship between RN skill mix and FTR was not found to be significant. The unadjusted bivariate relationships between patient to all staff ratio, education (BSN %), and the PES-NWI were found to be statistically significant. The second column reports results from the partially adjusted analysis, with both patient (primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status) and hospital characteristics (teaching status, technology status, bed size, CBSA status, ownership, state) included in the model. Significant associations were noted between RN skill mix, patient to all staff ratio, education (%BSN), and PES-NWI and decreases in FTR in the partially adjusted model.

The third column reports the associations between RN skill mix and the other nursing variables of interest and FTR in the full, jointly adjusted logistic regression model. The full model allows for examination of the relationship between RN skill mix and FTR while accounting for all other nursing, hospital, and patient characteristics. In addition to the previously mentioned patient and hospital characteristics, this model also includes nursing characteristics (RN skill mix, patient to all staff ratio, nurse education, the PES-NWI continuous measure, and proportion of nurses at each hospital who work in medical/surgical or ICU settings) aggregated to the hospital level.

In the full model, jointly adjusted, each 10% increase in the proportion of RNs was associated with a 7% decrease in the odds of FTR for adult surgical patients ($P<0.01$). Additionally, each 10% increase in the percentage of nurses in a hospital holding a baccalaureate degree or higher was associated with a 4% decrease in the odds of FTR for adult surgical patients ($P<0.01$) and each point increase in the PES-NWI was associated with a 7% decrease in the odds of FTR ($P \leq 0.001$).

Table 12. Odds Ratios Estimating the Effect of Organizational Nursing Features on Failure to Rescue in Adult Surgical Patients

	Unadjusted (Bivariate)	**Partially Adjusted (Patient and Hospital Characteristics)**	**Full Model (Patient, Hospital, Nursing Characteristics)**
Nursing Characteristic of Interest, OR (95% CI)			
RN Skill Mix	0.98 (0.93-1.05)	0.94 (0.90-0.99)*	0.93 (0.89-0.98)**
Patient to All Staff (RN + LPN/LVN + UAP) Ratio	1.07 (1.02-1.12)**	1.05 (1.00-1.09)*	1.04 (1.00-1.09)
Nursing Education (%BSN)	0.94 (0.92-0.97)***	0.95 (0.93-0.98)***	0.96 (0.94-0.99)**
PES-NWI	0.90 (0.86-0.94)***	0.91 (0.87-0.94)***	0.93 (0.89-0.96)***

***: $P \leq 0.001$
**: $P<0.01$
*: $P<0.05$

Note: RN Skill Mix is calculated by (RN/ (RN + LPN/LVN + UAP)) and represents the change in odds of FTR associated with a 10% increase in the proportion of RNs to all staff. Nursing education (% BSN) represents the change in the odds of FTR associated with a 10% increase in the percentage of nurses in a hospital holding a baccalaureate degree or higher. PES-NWI: Practice Environment Scale of the Nursing Work Index, excluding staffing and resource adequacy subscale. Patient characteristics include: Primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status. Hospital characteristics include: teaching status, technology status, bed size, CBSA status, ownership, state. Nursing characteristics include: ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings.

OR: odds ratio, CI: confidence interval

Table 13 provides the results of a logistic regression analysis to examine the association between the main study variable of interest, RN skill mix, and the outcome of 30-day mortality. The first column presents the unadjusted or bivariate relationship between nursing skill mix and 30-day mortality in the adult surgical patient population, which was not significant. The second column presents the logistic regression model partially adjusted for patient characteristics (primary DRG, Elixhauser comorbidity measure, age, sex, race, and transfer status). For every 10% increase in the proportion of RNs in the nursing skill mix, an associated 6% decrease in the odds of 30-day mortality was noted ($P<0.05$). The third column presents the logistic regression model partially adjusted for hospital characteristics (teaching status, technology status, bed size, CBSA status, ownership, and state), in which the association between RN skill mix and 30-day mortality was not significant. The fourth column presents the logistic regression model partially adjusted for nursing characteristics (ratio of patients to all staff, nursing education (% BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or ICU settings), in which the association between RN skill mix and 30-day mortality was not significant. The fifth column represents the full model with all previously described variables (patient, hospital, and nursing characteristics) jointly adjusted. In the full, jointly adjusted model, each 10% increase in the proportion of RNs was associated with a 7% decrease in the odds of 30-day mortality for adult surgical patients ($P < 0.001$).

Table 13. Odds Ratios Estimating the Effect of RN Skill Mix on 30-day Mortality in Adult Surgical Patients					
	Unadjusted (Bivariate)	**Adjusted for Patient Characteristics**	**Adjusted for Hospital Characteristics**	**Adjusted for Nursing Characteristics**	**Fully Adjusted (Patient, Hospital, and Nursing Characteristics)**
RN Skill Mix, OR (95% CI)	0.97 (0.92-1.03)	0.94 (0.90-0.99)*	0.99 (0.94-1.04)	0.97 (0.92-1.03)	0.93 (0.89-0.97)***

***: $P < 0.001$
**: $P < 0.01$
*: $P < 0.05$

Note: RN Skill Mix is calculated by (RN/ (RN + LPN/LVN + UAP)) and represents the change in odds of mortality associated with a 10% increase in the proportion of RNs to all staff. Nursing education (% BSN) represents the change in the odds of mortality associated with a 10% increase in the percentage of nurses in a hospital holding a baccalaureate degree or higher. PES-NWI: Practice Environment Scale of the Nurse Work Index, excluding staffing and resource adequacy subscale. Patient characteristics include: Primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status. Hospital characteristics include: teaching status, technology status, bed size, CBSA status, ownership, state. Nursing characteristics include: ratio of patients to all staff, nursing education (% BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings.

OR: odds ratio, CI: confidence interval

Table 14 provides the results of a logistic regression analysis for the main study variable of interest, RN skill mix, and the outcome of FTR. The first column presents the unadjusted or bivariate relationship between nursing skill mix and FTR in the adult surgical patient population, which was not statistically significant. The second column presents the logistic regression model partially adjusted for patient characteristics (primary DRG, Elixhauser comorbidity measure, age, sex, race, and transfer status). For each 10% increase in the proportion of RNs, there was an associated 5% decrease in the odds of FTR (P<0.05). The third column presents the logistic regression model partially adjusted for hospital characteristics (teaching status, technology status, bed size, CBSA status, ownership, and state), in which the association between RN skill mix and FTR was not significant. The fourth column presents the logistic regression model partially adjusted for nursing characteristics (ratio of patients to all staff, nursing education (% BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or ICU settings), in which the association between RN skill mix and FTR was not significant. The fifth column represents the full model with all previously described variables (patient, hospital, and nursing characteristics) jointly adjusted. In the full, jointly adjusted model, each 10% increase in the proportion of RNs was associated with a 7% decrease in the odds of FTR for adult surgical patients (P<0.01).

Table 14. Odds Ratio Estimating the Effects of RN Skill Mix on Failure to Rescue in Adult Surgical Patients

	Unadjusted (Bivariate)	Adjusted for Patient Characteristics	Adjusted for Hospital Characteristics	Adjusted for Nursing Characteristics	Fully Adjusted (Patient, Hospital, and Nursing Characteristics)
RN Skill Mix, OR (95% CI)	0.98 (0.93-1.05)	0.95 (0.90-1.00)*	0.98 (0.93-1.04)	1.0 (0.94-1.05)	0.93 (0.89-0.98)**

***: $P < 0.001$

**: $P < 0.01$

*: $P < 0.05$

Note: RN Skill Mix is calculated by (RN/ (RN + LPN/LVN + UAP)) and represents the change in odds of FTR associated with a 10% increase in the proportion of RNs to all staff. Nursing education (% BSN) represents the change in the odds of FTR associated with a 10% increase in the percentage of nurses in a hospital holding a baccalaureate degree or higher. PES-NWI: Practice Environment Scale of the Nurse Work Index, excluding Staffing and Resource Adequacy Subscale. Patient characteristics include: Primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status. Hospital characteristics include: teaching status, technology status, bed size, CBSA status, ownership, state. Nursing characteristics include: ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings.
OR: odds ratio, CI: confidence interval

Tables 15 and 16 provide the results of logistic regression analyses that examined the association between the proportion of LPN/LVNs (**Table 15**) and UAPs (**Table 16**) in the nursing skill mix, and the outcome of 30-day mortality. These measures were created utilizing the same method as RN skill mix, but isolated the discrete proportions of these two categories of nursing providers. The first column of these tables presents the unadjusted or bivariate relationship between either LPN/LVN or UAP skill mix and 30-day mortality in the adult surgical patient population. Each 10% increase in the proportion of LPN/LVNs in the skill mix was found to be significantly associated with an 8% increase in 30-day mortality ($P<0.05$), while no significant bivariate relationship was found for a 10% increase in UAPs and 30-day mortality. The second column presents the results of a logistic regression model partially adjusted for patient characteristics (primary DRG, Elixhauser comorbidity measure, age, sex, race, and transfer status). For every 10% increase in the proportion of LPN/LVNs in the nursing skill mix, an associated 12% increase in the odds of 30-day mortality was noted ($P<0.01$). No significant association was noted for UAPs in this model. The third column presents the results of a logistic regression model partially adjusted for hospital characteristics (teaching status, technology status, bed size, CBSA status, ownership, and state), in which a 10% increase in LPN/LVN proportion was found to be associated with a 9% increase in 30-day mortality ($P<0.05$). No significant association was found for a 10% increase in UAP proportion in this model that only adjusted for hospital characteristics. The fourth column presents the logistic regression model partially adjusted for nursing characteristics (ratio of patients to all staff, nursing education (% BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or ICU settings), which was not significant for either the LPN/LVN or UAP proportion variable. The fifth column represents the full model with all previously described variables (patient, hospital, and nursing characteristics) jointly adjusted. In the full, jointly adjusted model, each 10% increase in the proportion of LPN/LVNs or UAPs was associated with a 6% increase in the odds of 30-day mortality for adult surgical patients ($P<0.05$ and $P<0.01$, respectively).

Table 15. Odds Ratios Estimating the Effect of a 10% Increase in the Proportion of LPN/LVNs in Skill Mix on 30-day Mortality in Adult Surgical Patients					
	Unadjusted (Bivariate)	**Adjusted for Patient Characteristics**	**Adjusted for Hospital Characteristics**	**Adjusted for Nursing Characteristics**	**Fully Adjusted (Patient, Hospital, and Nursing Characteristics)**
LPN Proportion, OR (95% CI)	1.08 (1.01-1.16)*	1.12 (1.05-1.19)**	1.09 (1.01-1.17)*	1.03 (0.96-1.10)	1.06 (1.01-1.12)*

***: *P* <0.001

**: *P*<0.01

*: *P*<0.05

Note: LPN proportion is calculated by the equation (LPN/ (RN + LPN/LVN + UAP)). LPN proportion represents the change in odds of 30-day mortality associated with a 10% increase in the proportion of LPNs to all staff. Patient characteristics adjusted for include: Primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status. Hospital characteristics adjusted for include: teaching status, technology status, bed size, CBSA status, ownership, state. Nursing characteristics adjusted for include: ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit setting.

OR: odds ratio, CI: confidence interval

Table 16. Odds Ratios Estimating the Effect of a 10% Increase in the Proportion of UAPs in Skill Mix on 30-day Mortality in Adult Surgical Patients					
	Unadjusted (Bivariate)	**Adjusted for Patient Characteristics**	**Adjusted for Hospital Characteristics**	**Adjusted for Nursing Characteristics**	**Fully Adjusted (Patient, Hospital, and Nursing Characteristics)**
UAP Proportion, OR (95% CI)	0.98 (0.93-1.04)	1.00 (0.96-1.05)	0.96 (0.91-1.01)	1.01 (0.96-1.07)	1.06 (1.02-1.11)**

***: *P* <0.001

**: *P*<0.01

*: *P*<0.05

Note: UAP proportion is calculated by the equation (UAP/ (RN + LPN/LVN + UAP)) and represents the change in odds of 30-day mortality associated with a 10% increase in the proportion of UAPs to all staff. Patient characteristics adjusted for include: Primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status. Hospital characteristics adjusted for include: teaching status, technology status, bed size, CBSA status, ownership, state. Nursing characteristics adjusted for include: ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings.

OR: odds ratio, CI: confidence interval

Tables 17 and 18 provide the results of logistic regression analyses that examined the association between the proportion of LPN/LVNs (**Table 17**) and UAPs (**Table 18**) in the nursing skill mix, and the outcome of FTR. These measures were created utilizing the same method as RN skill mix, but isolated the discrete proportions of these two categories of nursing providers. The first column of these tables presents the unadjusted or bivariate relationship between a 10% increase in the proportion of either LPN/LVN or UAP in the skill mix and FTR in the adult surgical patient population, which was not found to be significant. The second column presents the results of a logistic regression model partially adjusted for patient characteristics (primary DRG, Elixhauser comorbidity measure, age, sex, race, and transfer status). For every 10% increase in the proportion of LPN/LVNs in the nursing skill mix, an associated 13% increase in the odds of FTR was noted (P<0.001). No significant association was noted for UAPs in this model. The third column presents the results of a logistic regression model partially adjusted for hospital characteristics (teaching status, technology status, bed size, CBSA status, ownership, and state), in which neither a 10% increase in LPN/LVN or UAP proportion was found to be significantly associated with FTR. The fourth column presents the logistic regression model partially adjusted for nursing characteristics (ratio of patients to all staff, nursing education (% BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or ICU settings), which was not significant for either the LPN/LVN or UAP proportion variable. The fifth column represents the full model with all previously described variables (patient, hospital, and nursing characteristics) jointly adjusted. In the full, jointly adjusted model, each 10% increase in the proportion of LPN/LVNs was associated with a 6% increase in the odds of FTR, and each 10% increase in the proportion of UAPs was associated with a 5% increase in the odds of FTR for adult surgical patients ($P<0.05$).

Table 17. Odds Ratios Estimating the Effect of a 10% Increase in the Proportion of LPN/LVNs in Skill Mix on Failure to Rescue in Adult Surgical Patients					
	Unadjusted (Bivariate)	**Adjusted for Patient Characteristics**	**Adjusted for Hospital Characteristics**	**Adjusted for Nursing Characteristics**	**Fully Adjusted (Patient, Hospital, and Nursing Characteristics)**
LPN/LVN Proportion, OR (95% CI)	1.07 (1.00-1.16)	1.13 (1.06-1.21)***	1.07 (1.00-1.16)	1.02 (0.95-1.09)	1.06 (1.01-1.12)*

***: *P* <0.001

**: *P*<0.01

*: *P*<0.05

Note: LPN/LVN proportion is calculated using the equation (LPN/ (RN + LPN/LVN + UAP)) and represents the change in odds of FTR associated with a 10% increase in the proportion of LPN/LVNs to all staff. Patient characteristics adjusted for include: Primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status. Hospital characteristics adjusted for include: teaching status, technology status, bed size, CBSA status, ownership, state. Nursing characteristics adjusted for include: ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings.

OR: odds ratio, CI: confidence interval

Table 18. Odds Ratios Estimating the Effect of a 10% Increase in the Proportion of UAPs in Skill Mix on Failure to Rescue in Adult Surgical Patients					
	Unadjusted (Bivariate)	**Adjusted for Patient Characteristics**	**Adjusted for Hospital Characteristics**	**Adjusted for Nursing Characteristics**	**Fully Adjusted (Patient, Hospital, and Nursing Characteristics)**
UAP Proportion, OR (95% CI)	0.97 (0.91-1.04)	0.99 (0.94-1.04)	0.98 (0.92-1.04)	1.0 (0.94-1.05)	1.05 (1.00-1.11)*

***: *P* <0.001
**: *P*<0.01
*: *P*<0.05

Note: UAP proportion is calculated by (UAP/ (RN + LPN/LVN + UAP)) and represents the change in odds of FTR associated with a 10% increase in the proportion of UAPs to all staff. Patient characteristics adjusted for include: Primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status. Hospital characteristics adjusted for include: teaching status, technology status, bed size, CBSA status, ownership, state. Nursing characteristics adjusted for include: ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings.

OR: odds ratio, CI: confidence interval

Exploratory Analysis: Relationship between RN Skill Mix and Staffing

This exploratory analysis aimed to answer the question of whether RN skill mix would remain associated with 30-day mortality and FTR outcomes in a consistent manner regardless of staffing level. The relationship between RN skill mix and 30-day mortality and FTR is postulated to be influenced by overall levels of nurse staffing, such that in hospitals with poor overall staffing the association between RN skill mix and outcomes may be obscured due to staffing deficiencies. After exploring the data and completing the analyses to answer the main aim, this additional analysis was pursued to further clarify this potential relationship.

A preliminary test of the significance of an interaction term between staffing (as measured by patient to all staff ratio) and RN skill mix was first explored in the full, jointly adjusted logistic regression model, and was not found to be significant for either 30-day mortality or FTR (**Table 19**). However, suspecting that the relationship between staffing and skill mix may be non-linear in nature, further analyses were completed. First, hospitals were divided into tertiles based on their patient to all staff ratios: high, medium and low. Hospitals with high patient to staff ratios had on average 4.59 patients/staff (range: 3.87-8.19), medium had on average 3.56 patients/staff (range: 3.24-3.87) and those with low patient to staff ratios has an average of 2.83 patients/staff (range: 1.80-3.24). Second, fully adjusted logistic regression models were used to analyze a restricted sample of hospitals corresponding to each tertile of patient to all staff ratio. By restricting analysis to each tertile of staffing, the author hoped to further evaluate whether the relationship between RN skill mix and 30-day mortality and FTR was influenced by patient to all staff ratios. The results are presented in **Table 20** (30-day mortality) and **Table 21** (FTR).

Table 19. Odds Ratios Estimating the Effect of the Continuous Interaction Term Between Staffing and RN Skill Mix on Mortality and Failure to Rescue in the Adult Surgical Patient Population		
	30-day Mortality, Full Model, Jointly Adjusted (95% CI)	**FTR, Full Model, Jointly Adjusted (95% CI)**
Staffing*Skill Mix	1.03 (0.98-1.08)	1.04 (0.99-1.08)
Staffing	0.82 (0.56-1.22)	0.80 (0.55-1.17)
Skill Mix	0.83 (0.68-1.01)	0.87 (0.79-0.97)*

***: *P* <0.001
**: *P*<0.01
*: *P*<0.05

Note: Staffing*Skill Mix represents the interaction term between the continuous patient to all staff variable and the continuous RN skill mix variable. This term, along with the independent variables, was placed in the full, jointly adjusted logistic model for both 30-day mortality and FTR. Models included adjustment for patient characteristics (primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status), hospital characteristics (teaching status, technology status, bed size, CBSA status, ownership, state), and nursing characteristics (ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings).

CI: confidence interval

Table 20 reports the association of RN skill mix with 30-day mortality in adult surgical patients, stratified by tertile of staffing. In the fully adjusted regression (controlling for patient, nurse and hospital characteristics), limited to hospitals with a high patient to all staff ratio, a nonsignificant association between nursing skill mix and 30-day mortality was identified. However, in fully adjusted regression models restricted to hospitals with medium or low patient to all staff ratios, each 10% increase in the proportion of RNs in the skill mix was associated with an 8% decrease in the odds of 30-day mortality among adult surgical patients ($P<0.05$).

Table 20. Odds Ratio Estimating the Effects of RN Skill Mix on 30-day Mortality in Adult Surgical Patients, Stratified by Tertile of Staffing, Fully Adjusted Model				
	Tertile of Patient to All Staff Ratio (Mean, SD)			
	All (3.66, SD: 0.87)	**High** (4.59, SD: 0.76)	**Medium** (3.56, SD: 0.18)	**Low** (2.83, SD: 0.32)
RN Skill Mix, OR (95% CI)	0.93 (0.89-0.97)**	0.94 (0.87-1.01)	0.92 (0.86-0.99)*	0.92 (0.86-0.99)*

***: *P* <0.001
**: *P*<0.01
*: *P*<0.05

Note: RN Skill Mix is calculated by (RN/ (RN + LPN/LVN + UAP)) and represents the change in odds of 30-day mortality associated with a 10% increase in the proportion of RNs to all staff. Staffing refers to the patient to all staff ratio (patient/ (RN+ LPN/LVN + UAP)). Model includes adjustment for patient characteristics (primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status), hospital characteristics (teaching status, technology status, bed size, CBSA status, ownership, state), and nursing characteristics (ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings).

OR: odds ratio, CI: confidence interval, SD: standard deviation

Table 21 reports the association of RN skill mix with FTR in adult surgical patients, stratified by tertile of staffing (patient to all staff ratio). Three separate, fully adjusted logistic models were constructed to examine the effect of nursing skill mix on surgical patient FTR at tertiles of staffing (high, medium, low). Regressions restricted to hospitals with low and medium staffing demonstrated a nonsignificant association between nursing skill mix and surgical patient FTR. However, in hospitals with the lowest patient to all staff ratios, a 7% decrease in the odds of FTR was associated with every 10% increase in the proportion of RNs in skill mix ($P<0.05$).

Table 21. Odds Ratio Estimating the Effects of RN Skill Mix on Failure to Rescue in Adult Surgical Patients, Stratified by Tertile of Staffing, Fully Adjusted Model				
	Tertile of Patient to All Staff Ratio (Mean, SD)			
	All (3.66, SD: 0.87)	**High** (4.59, SD: 0.76)	**Medium** (3.56, SD: 0.18)	**Low** (2.83, SD: 0.32)
RN Skill Mix, OR (95% CI)	0.93 (0.89-0.98)**	0.95 (0.88-1.02)	0.95 (0.88-1.01)	0.93 (0.86-1.0)*

***: *P* <0.001

**: *P*<0.01

*: *P*<0.05

Note: RN Skill Mix is calculated by (RN/ (RN + LPN/LVN + UAP)) and represents the change in odds of FTR associated with a 10% increase in the proportion of RNs to all staff. Staffing refers to the patient to all staff ratio (patient/ (RN +LPN/LVN + UAP)). Model includes adjustment for patient characteristics (primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status), hospital characteristics (teaching status, technology status, bed size, CBSA status, ownership, state), and nursing characteristics (ratio of patients to all staff, nursing education (%BSN), PES-NWI, and proportion of nurses at each hospital who work in medical/surgical or intensive care unit settings).

OR: odds ratio, CI: confidence interval

Exploratory Analysis: Predictive Modeling of 30-day Mortality by Nurse Provider Staffing Levels

This exploratory analysis aimed to answer the question of how 30-day mortality (crude and residual mortality rate) might vary as a function of the staffing level of the three categories of nursing providers (RN, LPN/LVN, UAP). **Table 22** summarizes the results of these analyses. A trend in 30-day mortality can be seen with both crude and residual mortality rates, with the lowest 30-day mortality in hospitals with high RN staffing (ie RN staffing above the median). The highest rates of both crude and residual mortality are found in hospitals with RN staffing that falls below the median (i.e. low RN staffing). The impact of staffing combinations for other groups (LPN/LVN, UAP) did not demonstrate a consistent pattern in terms of association with crude or residual mortality rates.

Table 22. 30-day Crude and Residual Mortality Rate, Stratified by Level of RN, LPN/LVN, and UAP Staffing				
RN Staffing	**LPN/LVN Staffing**	**UAP Staffing**	**Crude Mortality**	**Residual Mortality^**
High	High	High	1.65	-0.027
High	Low	High	1.60	-0.108
High	High	Low	1.61	-0.103
High	Low	Low	1.59	-0.114
Low	High	High	1.88	0.148
Low	Low	High	1.80	0.010
Low	High	Low	1.73	0.061
Low	Low	Low	1.86	0.128

Note: Staffing variable is patient to provider (RN, LPN/LVN, UAP) ratio. Low denotes staffing at a level below the median value of the sample hospitals (poor staffing), high denotes staffing above the median (good staffing). Eight total staffing combinations are presented.

^ Residual mortality rate was multiplied by 100 for ease of interpretation. A number above zero represents an observed mortality greater than expected; a number below zero represents an observed mortality less than expected. Residual mortality was calculated by predicting 30-day mortality based on patient characteristics (primary DRG, Elixhauser comorbidity measure, age, sex, race, transfer status), and subtracting the expected rates of 30-day mortality from the observed rates.

Chapter 5: DISCUSSION AND CONCLUSION

The purpose of this study was to examine the relationship between nursing skill mix and adult surgical patient outcomes. It was hypothesized that a nursing skill mix with a high proportion of RNs would be associated with decreased odds of 30-day mortality and FTR based on an expected increase in patient surveillance when RNs comprised a larger proportion of the total nursing staff. Jointly adjusted logistic regression models were used to explore the relationship between nursing skill mix and 30-day mortality and FTR. Additionally, exploratory analyses were conducted to investigate whether the relationship between RN skill mix and surgical patient outcomes was different in hospitals with varying levels of overall staffing, and whether any relationship could be discerned by examining the 30-day mortality rates (crude and residual) of hospitals with different staffing levels of RN, LPN/LVN, and UAP providers.

This chapter begins with a discussion of the principal findings concerning nursing skill mix and the major outcomes of interest, 30-day mortality and FTR. A discussion of the exploratory analyses utilized to examine potential interactions between staffing and skill mix, and mortality rates in hospitals with different staffing patterns of nursing skill mix follows. Policy implications, limitations of the study, as well as strengths unique to this analysis, are reviewed. Finally, the chapter closes with future research directions.

Discussion of Principal Findings

This study found that every 10% increase in the proportion of RNs in the nursing skill mix was associated with a 7% decrease in the odds of 30-day mortality (P<0.001) and FTR (*P*<0.01) in the adult surgical patient population. These results are consistent with a study examining RN skill mix in the Veterans Affairs medical/surgical patient population which found a 4-7% decrease in mortality associated with each 10% increase in RN skill mix (He et al., 2013). However, these results contradict previous studies that failed to find a relationship between skill mix and surgical patient mortality (Hickey et al., 2010; Needleman et al., 2002), which may be due to the methodological weaknesses noted in these studies.

Additionally, the association between increasing proportions of LPN/LVNs and UAPs in the nursing skill mix and surgical patient outcomes was also examined, further clarifying the relationship of potential substitution at the expense of RN staffing. Every 10% increase in the proportion of LPN/LVNs in the nursing skill mix was associated with a 6% increase in the odds of 30-day mortality (*P*<0.05) and a 6% increase in the odds of FTR (*P*<0.05). A similar association was found with each 10% increase in the proportion of UAPs, with an associated 6% increase in the odds of mortality (*P*<0.01) and a 5% increase in the odds of FTR (*P*<0.05). These results echo those of previous studies that reported increased fall rates (Lake et al., 2010), medication errors (Frith et al., 2012), and mortality (Glance et al., 2012; Person et al., 2004) as LPN/LVN staffing increased. The results of this study suggest that substitution of less educated nursing staff leads to both increased mortality and FTR in the adult surgical population, and that an increased proportion of care provided by RNs improves surgical patient outcomes.

Surgical patient 30-day mortality, FTR, and complication rates were calculated for the total sample, as well as for the individual sub-categories of surgical procedures (general, orthopedic, vascular), helping to provide a descriptive overview of surgical patient outcomes. A 1.7% overall mortality rate was reported among all patients in the study. In a recent study by Ghaferi and colleagues studying general and vascular surgical patients, a mortality rate of 3-9% across hospitals was noted (2009), which is consistent with the range between the unadjusted general (1.7%) and vascular (7.5%) surgery mortality rate found in this study. While unstandardized overall mortality rates and general surgery mortality rates varied significantly across categories of RN skill mix ($P<.05$ and $P<0.001$, respectively), no conclusions can be drawn from these measures as they lack risk adjustment.

FTR was also found to differ among surgical categories, with the FTR rate ranging from 3.1% for patients undergoing orthopedic surgeries up to 11.2% for vascular surgery patients. FTR rates in patients undergoing emergent surgery have been reported up to 27% (Sheetz et al., 2013), which falls far above rates seen in this study. Again, while the unstandardized FTR rate for all surgeries and general surgery differed significantly across tertiles of RN skill mix, no conclusions can be drawn from these unstandardized ratios. Although only studied as a component of the FTR measure and not explored independently, it is of interest to note that the surgical patients in this study had a high burden of complications, ranging from 28.5-66.8% across surgical categories. Although the complication rate is consistent with published literature (Ghaferi et al., 2009a, 2009b; Symons et al., 2013), it reflects a high rate of morbidity for surgical patients, and perhaps an important area for future efforts to improve surgical patient care.

In addition to the main findings of decreased 30-day mortality and FTR with increasing proportions of RNs in the skill mix, interesting findings concerning the patient to RN ratio and the patient to all staff (RN + LPN/LVN + UAP) ratio were noted when comparisons across hospitals were made. When the 665 sample hospitals were divided into tertiles of RN skill mix, a significant difference between the mean patient per RN ratio in each group was noted ($P<0.001$), with almost two additional patients cared for by RNs in hospitals within the low RN skill mix category versus high RN skill mix hospitals (6.47 versus 4.72). However, the patient to all staff ratio remained fairly consistent across hospitals in all three categories of RN skill mix, with a mean of 3.66 patients per nursing staff ($P=0.4691$). The distribution of patient to all staff ratio versus patient to RN ratio found in this study lends support to the hypothesis that hospitals with low RN staffing are substituting less educated nursing providers (LPN/LVNs and UAPs) to maintain a consistent level of staffing.

Supporting this interpretation, when the correlation between proportion of RNs, proportion of LPN/LVNs, and proportion of UAPs in nursing skill mix are compared as separate variables in a Pearson correlation analysis, there is a moderate negative correlation between RN skill mix and proportion of LPN/LVNs (-0.57) and a strong negative correlation between RN skill mix and proportion of UAPs (-0.71). This provides statistical evidence of substitution of UAPs for RNs, and to a lesser extent LPN/LVNs for

RNs. Such substitution has clinical implications for surgical patients, as evidenced by this study.

With the exception of the patient to all staff (RN + LPN/LVN + UAP) ratio, all nursing variables studied in this analysis (RN skill mix, nursing education (%BSN), nurse practice environment (PES-NWI)) were found to be significant predictors of 30-day mortality and FTR in the fully adjusted final logistic model, which is consistent with previous published work examining these variables (Aiken et al., 2003; Aiken et al., 2009; Estabrooks et al., 2011). The lack of a significant association between the patient to all staff ratio and surgical patient 30-day mortality and FTR uncovered in this analysis calls into question the value of increased utilization of support staff. While a large body of literature underscores the importance of RN staffing (Aiken et al., 2014; Carthon et al., 2012; Kane et al., 2007), there is no such literature base exploring the association between patient to all staff ratios and surgical patient outcomes. The lack of significance between patient to all staff ratio and surgical patient outcomes found in this study may be due to the fact that additional support staff do not positively influence patient outcomes. Instead, this analysis suggests that adequate RN staffing is the driving force behind improved surgical patient outcomes, while increased proportions of assistive staff are associated with poor patient outcomes. Therefore, hospital administrators should not anticipate that adding assistive staff (UAP, LPN/LVN) will decrease patient mortality and FTR, and, based on these analyses, such staffing increases may even be associated with decreases in quality.

When comparing hospital characteristics across tertiles of RN skill mix, several significant differences were noted, including bed size (*P*=0.023), technology status (*P*=0.033), CBSA (*P*<0.001), and state *(P*<0.001). These differences suggest that hospitals with different RN skill mix levels may differ in systematic ways. For example, this study found that low RN skill mix hospitals were likely to have fewer beds, have lower technology capabilities, and be more likely to be located in rural areas. Of all hospitals located in Micropolitan (10,000-50,000 people) and Rural (<10,000 people) geographic locations, 50% and 60% were categorized as low RN skill mix, respectively. While this study did not look at variables such as the number of nursing education programs available in each state or geographic location, these results suggest that the supply of nurses may differ across regions, or alternatively, that market factors do not preferentially attract RNs to these areas. Mark and colleagues found that a significant amount of nursing skill mix variance at the unit level can be explained by market and hospital characteristics (Mark et al., 2000), which is consistent with significant differences that were noted across tertiles of skill mix in this analysis. Additionally, this result is consistent with a study examining factors impacting nurse staffing, which found that as the RN supply in an area decreased, so did the proportion of RNs in the nursing skill mix (Blegen, Vaughn, & Vojir, 2008).

A significant difference in average RN skill mix was noted across study states (California, Florida, New Jersey, Pennsylvania). Pennsylvania was noted to have the highest percentage of hospitals with low RN skill mix (50.3%), while California had the lowest percentage (23.6%). California is the only US state with legislation that specifies patient to nurse staffing ratios, and mandates nursing skill mix minimums (McHugh et al., 2012). Enacted in 2004, this legislation mandated that a maximum of 50% of all licensed nurses at the hospital-level could be comprised of LPN/LVNs, leading to concern that such legislation may cause “dilution” of the nursing skill mix (McHugh, Kelly, Sloane, & Aiken, 2011). However, the results of this study are consistent with previous published work that demonstrates maintenance of a skill mix with a high proportion of RNs in California (McHugh et al., 2012; McHugh et al., 2011).

Significant differences were also observed when comparing organizational nursing characteristics across hospitals in different tertiles of RN skill mix. In particular, the percentage of nurses educated at the baccalaureate level or above ($P<0.001$) and the designation of a hospital as having a good practice environment as measured by the PES-NWI ($P=0.004$) were found to differ significantly, with hospitals within the highest tertiles of skill mix having a greater proportion of BSN educated nurses as well as more likely to have a good nurse practice environment. These variables suggest that hospital-level policies are at play, with those hospitals that attract and retain RNs being more likely to also have good nurse practice environments, and more highly educated nurses. This underscores the importance of strong managerial policies that support the nursing workforce.

Discussion of Exploratory Analyses

The first exploratory analysis sought to identify whether the association between RN skill mix and surgical patient outcomes was moderated by staffing levels as measured by the patient to all staff (RN + LPN/LVN + UAP) ratio. A fully adjusted logistic regression model containing an interaction between continuous staffing and skill mix was not found to be statistically significant. However, when skill mix was examined at three different levels of staffing (low, medium, and high), there was evidence of a trend toward a different relationship between nursing skill mix and 30-day mortality and FTR as patient to all staff ratios varied. In hospitals with the poorest staffing ratios, no significant association was found between increases in nursing skill mix and the odds of 30-day mortality for surgical patients. However, in hospitals with medium or high levels of staffing, each 10% increase in the proportion of RNs was associated with an 8% decrease in the odds of 30-day mortality of adult surgical patients ($P<0.05$). A similar trend was seen with FTR, with only those hospitals with the best staffing seeing a 7% decrease in the odds of FTR ($P<0.05$) with increased RN skill mix. This lends support to the hypothesis that patient outcomes are influenced by both the proportion of RNs in the skill mix as well as prerequisite levels of adequate nurse staffing. In hospitals with poor overall staffing, RNs may be overly burdened and surveillance may be inadequate even as RN skill mix increases. To the author's knowledge no similar analysis examining the interaction between staffing and skill mix has been completed, and this exploratory evidence helps to address this gap.

Additionally, a second analysis to examine the crude and residual 30-day mortality rates of hospitals with varied staffing levels of each provider type (RN, LPN/LVN, UAP) was conducted. After classifying each hospital's staffing level of each provider type as above or below the median value, the analysis revealed that high RN staffing was associated with predicted decreases in both crude and residual 30-day mortality. These results are exploratory, and should be interpreted with caution, but seem to further underscore the importance of adequate RN staffing as compared to high staffing of any support staff (LPN/LVN or UAP). When RN staffing fell below the median, mortality rates for adult surgical patients remained elevated even if hospital LPN/LVN and UAP staffing was above the median.

Policy Implications

In the current climate of healthcare reform, hospitals are under increased pressure to reduce costs while simultaneously improving care quality. Initiatives within the Affordable Care Act aimed at improving patient outcomes are impacting hospital reimbursement, which may consequently place financial strain on hospital systems (James, 2012; Kurtzman et al., 2011). This study helps to provide evidence for an intervention to decrease surgical patient mortality that is not only feasible, but may also pose little additional cost to hospitals. Needleman and colleagues suggest that increased proportions of RNs in the skill mix would be offset by decreased costs from complications and length of stay (2006), while Martsolf and colleagues found that increasing the nursing skill mix lead to decreases in patient care costs (2014). Hospital administrators may use findings from this study in combination with data on cost associated with skill mix to provide evidence for their decision to hire and retain a nursing staff with a high proportion of RNs.

While the healthcare field has clearly acknowledged the challenges of providing safe patient care and responded through national and institutional initiatives (American College of Surgeons, 2014; World Health Organization, 2009), the majority of these programs have focused on hospital and physician factors. The findings of this study underscore the importance of a nursing staff with a high proportion of RNs for optimal patient outcomes, and suggest that a greater focus on nursing factors may play an important role in improving patient safety. RNs serve a critical surveillance role for surgical patients (Kutney-Lee, Lake, et al., 2009), and physicians should work with them as full and equal partners in the care of surgical patients. This includes the need for increased nurse representation on institution-level safety and quality committees, as well as inclusion in national discussions surrounding patient safety and healthcare reform.

It is also important to note that increases in RN skill mix did not have any significant association with FTR in hospitals with poor or medium staffing, and no significant association with 30-day mortality was observed in hospitals with poor staffing. However, in hospitals with the best staffing ratios, increases in the proportion of RNs in the nursing skill mix were associated with significant decreases in both 30-day mortality and FTR. This differential association of RN skill mix has policy implications for minimum staffing ratio recommendations, as both the absolute number of nursing staff as well as the mixture of nursing staff are necessary to address. California has begun to tackle this policy issue with the implementation of mandatory staffing minimums (McHugh et al., 2012). Although the staffing minimums are directed at patient to nurse ratios, guidelines also specify the minimum skill mix necessary, in order to avoid possible substitution and skill mix dilution. This study's findings support such a dual-pronged approach to any future staffing mandates.

Additionally, in order to ensure an adequate supply of RNs, it is critical that the proper educational systems and structures receive support. While there has been a shift toward employment of RNs over LPN/LVNs in the hospital setting over the last 30 years (Pope & Menke, 1990; US Department of Health and Human Services, 2013), the per capita supply of LPN/LVNs still varies substantially across states, with Midwest and Northeast states among those with the highest supply (US Department of Health and Human Services, 2013). A recent report on the Pennsylvania LPN/LVN workforce revealed that only one in five respondents were in the process of pursuing a higher nursing degree (identified as an associate's degree or higher)(Pennsylvania Department of Health Bureau of Health Planning, 2013). Institutions employing LPN/LVNs should encourage ongoing education and bridge programs in order to accelerate the educational pathway. Hospitals can support this transition through flexible scheduling, academic reimbursement, and preferential promotion of nurses with RN degrees.

In addition to improving surgical patient mortality and FTR, evidence continues to build that an educated and well-staffed nursing workforce has the ability to address multiple aspects of patient care simultaneously, including readmissions (Ma, McHugh, & Aiken, 2015; McHugh, Berez, & Small, 2013; Tubbs-Cooley et al., 2013), mortality (Kelly et al., 2014), and satisfaction (Aiken et al., 2012; Kutney-Lee, McHugh, et al., 2009; Potter et al., 2003; Seago, Williamson, & Atwood, 2006). As such, ensuring adequate nurse staffing with a high proportion of RNs may be one of the single most effective interventions in the hospital setting. While nursing skill mix is not currently a publically reported measure, such staffing information should be considered for public reporting as a marker of hospital quality in the future. Administrators who wish to improve the quality of care throughout the hospital should consider increased nurse staffing as one of the most comprehensive approaches.

Limitations

Although designed and implemented to the best of the author's ability, several study limitations are noted. The first major limitation is due to the observational, cross-sectional design of the study, which limits the ability to infer a causal relationship between nursing skill mix and surgical patient mortality and FTR. In order to support a causal relationship, longitudinal studies or specific staffing interventions with appropriate pre- and post-tests would be necessary.

Additionally, this study is a secondary data analysis, and as such, is limited to examination of variables that were already captured in the original survey. While the survey data used represents the largest and only data source of its kind, there are inevitably additional variables that may have helped to elucidate the concept of nursing skill mix and aid in the analysis of the impact of nursing skill mix on patient outcomes. For example, no data was available on the board certification of physicians, which is often cited as a control variable in studies examining patient mortality (Hartz et al., 1989). However, recent research suggests that most surgical deaths are not attributable to surgical error, and are instead secondary to system issues (Westaby, De Silva, Petrou, Bond, & Taggart, 2015).

The age of the data used in the study is also a limitation of the analysis. However, it can be argued that although the healthcare system itself has changed greatly since the data was collected, the relationship between nurse staffing and patient outcomes has not fundamentally changed. Additionally, there is no comparable data source that is more recent, and as such, the Multi-State Nursing Care and Patient Safety Survey represents the best data available to the researcher.

Another potential limitation of the analysis arises from the method in which the nursing skill mix variable was created. All nursing variables used in the analysis were created by aggregating nurse reports on staffing and workload. These reports were received from nurses working in many different units within the hospital, and were subsequently aggregated to the hospital level to create mean scores for use in analysis. As surgical patients are not necessarily limited to care in one particular type of unit, this presents a challenge in the analytical approach. It is possible that nurse staffing across all units surveyed could differ significantly from the units in which surgical patients received care. This limitation is addressed in the analysis by including a control variable for the percentage of nurse respondents at the hospital level who reported working in either a medical/surgical or intensive care unit, units that, in general, represent average and high staffing. By including this additional control variable, variations in the composition of units at the hospital level were partially accounted for. Additionally, surgical patients may be cared for in a variety of units during the course of a stay, and so it would not necessarily be appropriate to limit analysis to one type of unit.

Finally, as this study was based on the adult general, orthopedic, and vascular surgical patient population, the results may not be generalizable to other populations of interest. However, due to the large and diverse patient population, including over 1.2 million surgical patient admissions, as well as the large and geographically diverse hospital sample, these results are likely more generalizable than past studies on nursing skill mix. As no patient under the age of 18 was included in the sample, studies to examine the role of nursing skill mix on surgical patient outcomes would need to be replicated in the pediatric population, where care patterns may differ.

Strengths

Despite the stated limitations, this study represents an improvement over existing research examining nursing skill mix and has many strengths. As previously mentioned, the Multi-State Nursing Care and Patient Safety Survey is the only data source of its kind in the US, and it offers in-depth information on a wide range of nursing variables that are unavailable through other sources. Additionally, these data represent an improvement over nursing data drawn from administrative sources, as such data may overestimate the number of nurses involved in direct patient care or hospital care, and inadvertently inflate nurse staffing measures. This data represents a geographically diverse and large sample of hospitals, which addresses the limitation present in many past studies that focused on a small number of hospitals or units. Additionally, the patient sample is large (over 1.2 million), includes a wide range of ages (18-85 years), and a wide range of surgical procedures (general, orthopedic, vascular). This helps to strengthen the conclusions drawn from the analysis.

A limitation of many previous studies was addressed in this analysis through use of a robust risk-adjustment method. While past studies of skill mix have addressed risk by attempting to use patient-level risk scores (Hickey et al., 2010; Sasichay-Akkadechanunt et al., 2003; Yang et al., 2012) or case-mix index (Needleman et al., 2002), many studies lack a sophisticated risk adjustment framework encompassing patient, nurse and hospital characteristics. Previous studies on skill mix have led to unclear conclusions, as the impact of skill mix has not been found to be consistently associated with improved patient outcomes (Griffiths et al., 2014; Ridley, 2008). This discrepancy could be due to inadequate risk adjustment, or failure to account for confounding variables. Unique to this study, nursing characteristics, including nurse education at the hospital-level (%BSN), nurse staffing, and importantly, the practice environment as measured by the Practice Environment Scale of the Nursing Work Index

(PES-NWI), were also adjusted for in order to more discretely study the contribution of nursing skill mix to surgical patient outcomes. To the author's knowledge this is the first time the PES-NWI has been used in a study examining skill mix. The C-statistics from the full model underscore the high model discrimination, 0.89 and 0.82 for 30-day mortality and FTR respectively.

Future Research Directions

This study represents a significant addition to the existing literature on the role of RN skill mix on surgical patient mortality and FTR, and is the first to test for a possible interaction between nursing skill mix and staffing measures. While the association of nursing skill mix with decreased surgical patient mortality and FTR is strong, the causal mechanism behind this association remains unknown. It is hypothesized that the increased surveillance provided by RNs to surgical patients is likely responsible for the decrease in mortality observed, but further study is needed to isolate the mechanism. Future research should focus on providing a qualitative assessment of the functions of the RN, including the specific aspects of their training that enhance their ability to provide adequate surveillance.

An obvious concern that may be raised when discussing the importance of increasing RN skill mix in the hospital setting is cost. As nurses already represent a large part of hospital operating budgets, administrators may be unable or unwilling to increase costs associated with staffing. Therefore, an analysis of the associated cost of increasing RN skill mix would be an important future study. A 2006 study by Needleman and colleagues suggested that if the nurse to patient ratio was kept constant while proportion of total care provided by RNs was increased to the 75th percentile, a net reduction of $242 million could be realized. While this evidence provides a starting point, the literature on the cost-effectiveness of increased skill mix and nurse staffing remains limited, and existing research has not reached a clear consensus on the relationship of these measures to cost (Shekelle, 2013; Twigg, Myers, Duffield, Giles, & Evans, 2014; Unruh, 2008). A natural next step for this research trajectory is to examine costs associated with substitution of LPN/LVNs and UAPs for RNs, taking into consideration both financial as well as human burden.

While the surgical patient sample analyzed in this study is large and diverse, it is limited to adult patients. As such, these results are not generalizable to pediatric populations. There is a dearth of studies examining the impact of skill mix in the pediatric population. Similar to the surgical population, pediatric patients are at increased risk of adverse events while hospitalized (Mark, Harless, & Berman, 2007; Miller & Zhan, 2004), and comprise over 3 million admissions yearly (U.S. Department of Health and Human Services, 2011). The only identified study examining nursing skill mix and pediatric surgical patient outcomes did not find a significant association (Hickey et al., 2010), which may be due to inadequate risk adjustment for these models. Access to a large data set with patient physiological data could help to create risk adjustment models with greater discrimination, and help to address the role of nursing skill mix on pediatric surgical patient outcomes.

Conclusion

In conclusion, a nursing skill mix with a high proportion of RNs was associated with decreased 30-day mortality and FTR in the adult general, orthopedic, and vascular surgical patient population. Additionally, when the proportion of LPN/LVNs and UAPs providing care was increased, associated significant increases in both patient 30-day mortality and FTR were noted. Exploratory analyses point to a relationship of skill mix that was influenced by nurse staffing levels in the hospital setting, underscoring the importance of adequate staffing, and not simply a nursing skill mix with a high proportion of RNs. Preliminary predictive models suggest that the driving factor behind both crude and residual 30-day mortality rates in the surgical patient population was a nursing staff with a level of RN staffing.

Due to healthcare reform hospitals will continue to face cost and quality pressures, and these findings highlight the importance of maintaining an adequate RN skill mix to improve surgical patient outcomes. With over 50 million surgical procedures performed yearly (Centers for Disease Control and Prevention, 2010), a 7% decrease in the risk of 30-day mortality and FTR associated with a 10% increase in the RN skill mix represents a substantial number of potential lives saved. Administrators should use the evidence presented in this study to help support their decisions to hire a nursing staff with a high proportion of RNs.

APPENDIX A: List of DRGs used to create FTR measures (Silber et al., 2007)

DRG	Description
General Surgical Diagnosis-Related Groups	
Digestive System	
146	Rectal resection with complications
147	Rectal resection without complications
148	Major small & large bowel procedures with complications
149	Major small & large bowel procedures without complications
150	Peritoneal adhesiolysis with complications
151	Peritoneal adhesiolysis without complications
152	Minor small & large bowel procedures with complications
153	Minor small & large bowel procedures without complications
154	Stomach, esophageal & duodenal procedures age >17 with complications
155	Stomach, esophageal & duodenal procedures age >17 without complications
157	Anal & stomal procedures with complications
158	Anal & stomal procedures without complications
159	Hernia procedures except inguinal & femoral age >17 with complications
160	Hernia procedures except inguinal & femoral age >17 without complications
161	Inguinal & femoral hernia procedures age >17 with complications
162	Inguinal & femoral hernia procedures age >17 without complications
164	Appendectomy with complicated principal diagnosis with complications
165	Appendectomy with complicated principal diagnosis without complications
166	Appendectomy without complicated principal diagnosis with complications
167	Appendectomy without complicated principal diagnosis without complications
170	Other digestive system O.R. procedures with complications
171	Other digestive system O.R. procedures without complications
Hepatobiliary	
191	Pancreas, liver & shunt procedures with complications
192	Pancreas, liver & shunt procedures without complications
193	Biliary tract procedure except only cholecyst. With or without CDE with complications
194 195	Biliary tract procedure except only cholecyst. With or without CDE without complications Cholecystectomy with CDE with complications
196	Cholecystectomy with CDE without complications
197	Cholecystectomy except by laparoscope without CDE with complications
198	Cholecystectomy except by laparoscope without CDE without complications
199	Hepatobiliary diagnostic procedure for malignancy
200	Hepatobiliary diagnostic procedure for non-malignancy
201	Other hepatobiliary or pancreas O.R. procedures
493	Laparoscopic Cholecystectomy without CDE complications
494	Laparoscopic Cholecystectomy without CDE without complications
Skin, subcutaneous tissue, breast	
257	Total mastectomy for malignancy with complications
258	Total mastectomy for malignancy without complications

259	Subtotal mastectomy for malignancy with complications
260	Subtotal mastectomy for malignancy without complications
261	Breast procedures for non-malignancy except biopsy & local excision
262	Breast biopsy & local excision for non-malignancy
263	Skin graft &/or debridement for skin ulcer or cellulitis with complications
264	Skin graft &/or debridement for skin ulcer or cellulitis without complications
265	Skin graft &/or debridement except for skin ulcer or cellulitis with complications
266	Skin graft &/or debridement except for skin ulcer or cellulitis without complications
267	Perianal & pilonidal procedures
268	Skin, subcutaneous tissue & breast plastic procedures
Endocrine, nutritional, metabolic	
285	Amputation of lower limb for endocrine, nutritional & metabolic disorders
286	Adrenal & pituitary procedures
287	Skin grafts & wound debridement for endocrine, nutritional & metabolic disorders
288	O.R. procedures for obesity
289	Parathyroid procedures
290	Thyroid procedures
291	Thyroglossal procedures
292	Other endocrine, nutritional & metabolic OR procedures with complications
293	Other endocrine, nutritional & metabolic OR procedures without complications
493	Laparoscopic Cholecystectomy without C.D.E. with complication
494	Laparoscopic Cholecystectomy without C.D.E. without complications
Orthopedic Diagnosis-Related Groups	
210	Hip & femur procedures except major joint age > 17 with complications
211	Hip & femur procedures except major joint age > 17 without complications
213	Amputation for musculoskeletal system & connective tissue disorders
216	Biopsies of musculoskeletal system & connective tissue
217	Wound debridement & skin graft except hand, for musculoskeletal & connective tissue disorder
218	Lower extremities & humerus procedure except hip, foot, femur age >17 with complications
219	Lower extremities & humerus procedure except hip, foot, femur age >17 without complications
223	Major shoulder/elbow procedure, or other upper extremity procedure with complication
224	Major shoulder/elbow procedure, or other upper extremity procedure without complication
225	Foot procedures
226	Soft tissue procedure with complications
227	Soft tissue procedure without complications
228	Major thumb or joint procedure, or other hand or wrist procedure with complications
229	Major thumb or joint procedure, or other hand or wrist procedure without complications
230	Local excision & removal of interior fix devices of hip & femur

232	Arthroscopy
233	Other musculoskeletal system & connective tissue O.R. procedure with complications
234	Other musculoskeletal system & connective tissue O.R. procedure without complications
471	Bilateral or multiple major joint procedures of lower extremity
491	Major joint & limb reattachment procedures of upper extremity
496	Combined anterior/posterior spinal fusion
497	Spinal fusion except cervical with complications
498	Spinal fusion except cervical without complications
499	Back & neck procedures except spinal fusion with complications
500	Back & neck procedures except spinal fusion without complications
501	Knee procedures with prior diagnosis of infection with complications
502	Knee procedures with prior diagnosis of infection without complications
503	Knee procedures without prior diagnosis of infection
519	Cervical spinal fusion with complications
520	Cervical spinal fusion without complications
537	Local excision & removal of interior fix device except hip & femur with complications
538	Local excision & removal of interior fix device except hip & femur without complications
544	Major joint replacement or reattachment of lower extremity
545	Revision of hip or knee replacement
546	Spinal fusion except cervical with curvature of the spine or malignancy
Vascular Diagnosis-Related Groups	
110	Major cardiovascular procedures with complications
111	Major cardiovascular procedures without complications
113	Amputation for circulatory system disorders except upper limb & toe
114	Upper limb & toe amputation for circulatory system disorders
119	Vein ligation & stripping
120	Other circulatory system O.R. procedures

APPENDIX B: Definitions of complications used to create FTR measures (Silber et al., 2007)

	Inclusion criteria	**Exclusion criteria**
General Structure	1) General, orthopedic, and vascular surgery 2) Secondary diagnosis code and/or procedure code as specified below	Exclusion noted for each complication of care as specified in each row below
1. Cardiac Event	**Secondary diagnosis codes:** 9971 and any of (42612-3, 42689, 42731, 42781, 9) or 41189, 99601 **Secondary procedure codes:** 3778, 3780-3, 3606	
2. Cardiac Emergency	**Secondary diagnosis codes:** 4100, 41001, 4101, 41011, 4102, 41021, 4103, 41031, 4104, 41041, 4105, 41051, 4106, 41061, 4107, 41071, 4108, 41081, 4109, 41091, 4271, 42741, 7855, 78550-1 **Secondary procedure codes:** 3761, 3791, 8964, 9960-4, 9, 9961-2, or if 9363 or 996 and exclusion	**Principal diagnosis codes:** 4275, 7855, 78550-1, 9, 7991 **Principal procedure codes:** 9393, 996, 9963 **DRG** DRG = 75-145, 475 *1) Traumas as defined by principal diagnoses* 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 817, 818, 819, 820, 821, 822, 823, 824, 825, 827, 828, 829, 830, 831, 832, 833, 835, 836, 837, 838, 839, 850, 851, 852, 853, 854, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 884, 887, 890, 891, 892, 894, 896, 897, 900, 901, 902, 903, 904, 925, 926, 927, 928, 929, 940, 941,

		942, 943, 944, 945, 946, 947, 948, 949, 952, 953, 958 *2) Trauma DRGs* 002, 027, 028, 029, 031, 032, 072, 083, 084, 235, 236, 237, 440, 441, 442, 443, 444, 445, 446, 456, 457, 458, 459, 460, 484, 485, 486, 487, 491, 504, 505, 506, 507, 508, 509, 510, 511 *3) GI Hemorrhage as defined by principal diagnosis* 456.0, 456.20, 530.7, 531.00, 531.01, 531.20, 531.21, 531.40, 531.41, 531.60, 531.61, 532.00, 532.01, 532.20, 532.21, 532.40, 532.41, 532.60, 532.61, 533.00, 533.01, 533.20, 533.21, 533.40, 533.41, 533.60, 533.61, 534.00, 534.01, 534.20, 534.21, 534.40, 534.41, 534.60, 534.61, 535.01, 535.11, 535.21, 535.31, 535.41, 535.51, 535.61, 578.0, 578.1, 578.9
3. CHF	**Secondary diagnosis codes:** 5184, 42821, 42831, 42841, 42823, 42833, 42843, or 9971 and any of (428, 4280-1, 4289, 42820-1, 42823, 42830-1, 42833, 42840-1, 42843) or 428, 4280-1, 9, 4289, 42820, 1, 3, 42830-1, 3, 42840-1, 3 and exclusion	History of CHF defined as any of the following diagnoses during a look back period of 180 days: 39891, 40201, 40211, 40291, 40401, 3, 40411, 3, 40491, 3, 428, 4280, 4281, 42820-3, 42830-3, 42840-3, 4289, 5184
4. Hypotension/ Shock/ Hypovolemia	**Secondary diagnosis codes:** 2765, 4589, 78550-2, 78559, 7963, 9950, 9954, 9980	

5. Pulmonary embolus	**Secondary diagnosis codes:** 4151, 41511, 41519, 4539, 9581 **Secondary procedure codes:** 8843, 9215	
6. Deep Vein Thrombosis/ Arterial Clot	**Secondary diagnosis codes:** 4440-2, 4420-1, 4448, 44481, 9, 4449, 4538 **Secondary procedure codes:** 387, 8866, 8877	
7. Phlebitis	**Secondary diagnosis codes:** 4510-1, 45111, 9, 4512, 4518, 45181-2, 4, 9, 4519 **Secondary procedure codes:** 387, 8866, 8877	
8. Cerebrovascular Accident (CVA)/Stroke	**Secondary diagnosis codes:** 431, 432, 43301, 43311, 43321, 43331, 43381, 43391, 434, 4340-1, 4341, 43411, 4349, 43491, 436, 99702 **Secondary procedure codes:** 8703, 8891	History of CVA/stroke defined as any of the following diagnoses during a look back period of 180 days: 431, 432, 43301, 43311, 43321, 43331, 43381, 43391, 434, 4340, 43401, 4341, 43411, 4349, 43491, 436, 99702, 438, 4380, 4381, 43810, 43811, 43812, 43819, 4382, 43820, 43821, 43822, 4383, 43830, 43831, 43832, 4384, 43840, 43841, 43842, 4385, 43850, 43851, 43852, 43853, 4386, 4387, 4388, 43881, 43882, 43883, 43884, 43885, 43889, 4389, V1259
9. Transient Ischemic Attack (TIA)	**Secondary diagnosis codes:** 4350-3, 4358-9	
10. Coma	**Secondary diagnosis codes:** 3481, 5722, 7800, 78001, 9	
11. Seizure	**Secondary diagnosis codes:** 7803, 78031, 9 **Secondary procedure codes:**	History of seizure defined as any of the following diagnoses during a look back period of 180 days:

	8914, 8919	345, 3450, 34500, 34501, 3451, 34510, 34511, 3452, 3453, 3454, 34540, 34541, 3455, 34550, 34551, 3456, 34560, 34561, 3457, 34570, 34571, 3458, 34580, 34581, 3459, 34590, 34591, 7803
12. Psychosis	**Secondary diagnosis codes:** 292, 2920, 2921, 29211-2, 2922, 2928, 29281-4, 9, 2929, 2930, 2939, 2948, 2949	
13. Nervous System Complications	**Secondary diagnosis codes:** 9970 **Secondary procedure codes:** 0331, 8914, 8919	
14. Pneumonia-Aspiration	**Secondary diagnosis codes:** 5070-1, 5078 or 9973 and any of 4829, 485, or 486	
15. Pneumonia, other	**Secondary diagnosis codes:** 481, 4820-3, 48230-2, 9, 4824, 48240-1, 9, 4828, 48281-4, 9, 4829, 485, 486 or 9973, 514 and exclusion	**DRG** DRG=75-102, 475 **Any diagnosis codes:** *1) Viral Pneumonia* 480.0, 480.1, 480.2, 480.8, 480.9, 483, 483.0, 483.1, 483.8, 484.1, 484.3, 484.5, 484.6, 484.7, 484.8, 487.0, 487.1, 487.8 *2) Immuncompromised State* 042, 136.3, 279.00, 279.01, 279.02, 279.03, 279.04, 279.05, 279.06, 279.09, 279.10, 279.11, 279.12, 279.13, 279.19, 279.2, 279.3, 279.4, 279.8, 279.9
16. Pneumothorax	**Secondary diagnosis codes:** 5120, 5128, 5180	

	Secondary procedure codes: 3404, 3491	
17. Respiratory Compromise	DRG = 483 **Secondary diagnosis codes:** 5185, 51881, 9, 7991, 9604, 9670-2 **Secondary procedure codes:** 311, 312, 3121, 9, 390, 9671-2	
18. Bronchospasm	**Secondary diagnosis codes:** 5191 **Secondary procedure codes:** 8938, 9394	
19. Other Respiratory Complication	**Secondary procedure codes:** 3321, 3327, 9390	
20. Internal Organ Damage	**Secondary diagnosis codes:** 9981, 99811-3, 9982 **Secondary procedure codes:** 3941, 5412, 9 and exclusion	**Principal procedure codes:** 444, 4440-2, 4491
21. Perforation	**Secondary diagnosis codes:** 5304, 56983, 9982	
22. Peritonitis	**Secondary diagnosis codes:** 5670-2, 8, 9, 5695, 7894 **Secondary procedure codes:** 5491 and exclusion	Diagnosis of cancer as principal diagnosis or as a comorbidity of cancer defined in Appendix C, as secondary diagnoses or in a look back period of 180 days.
23. GI Bleed and Blood Loss	**Secondary diagnosis codes:** 2851 or 5780-1, 9 or 5307 or any of 4560, 45620, 53082, 53100-1, 53120-1, 53130-1, 53190-1, 53200-1, 53210-1, 53220-1, 53230-1, 53290-1, 53300-1, 53310-1, 53320-1, 53330-1, 53390-1, 53400-1, 53410-1, 53420-1, 53430-1, 53490-1, 53501, 53511, 53540-1, 53551, 53561, 53784, 56212-3, 5693, 56985, 5789 **Secondary procedure codes:** 4995	*1) Trauma as defined by principal diagnoses* 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 817, 818, 819, 820, 821, 822, 823, 824, 825, 827, 828, 829, 830, 831, 832, 833, 835, 836, 837, 838, 839, 850, 851, 852, 853, 854, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877,

		878, 879, 880, 881, 882, 884, 887, 890, 891, 892, 894, 896, 897, 900, 901, 902, 903, 904, 925, 926, 927, 928, 929, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 952, 953, 958 *2) Trauma DRGs* 002, 027, 028, 029, 031, 032, 072, 083, 084, 235, 236, 237, 440, 441, 442, 443, 444, 445, 446, 456, 457, 458, 459, 460, 484, 485, 486, 487, 491, 504, 505, 506, 507, 508, 509, 510, 511 *3) History of alcoholism defined as secondary diagnosis* 2910-5, 29181, 29189, 2919, 30300-3, 30390-2, 30500-2 **Principal procedure codes:** 444, 4440-2 if secondary diagnoses 5780-1, 9444, 4440-2 and 4491 if secondary procedure = 4995 **DRG** 1) *DRG* = 146-171 if secondary procedure = 5307 2) *DRG* = 146-167, 170-184, 188-208 if any of the secondary diagnoses in the inclusion are in the set of diagnoses 4560-5789
24. Sepsis	**Secondary diagnosis codes:**	

	0380-4, 03810-1, 03840-4, 9, 03819, 0388-9, 78552, 7907	
25. Deep Wound Infection	**Secondary diagnosis codes:** 9983, 99831-2, 9985, 99859, 9986, 99883 **Secondary procedure codes:** 5461, 8604, 8659, 8622, 8660-3, 8670, 8674	
26. Renal Dysfunction	**Secondary diagnosis codes:** 5845-9, 7885 **Secondary procedure codes:** 3995, 5494, 5498, 598, 8607, 8962 and exclusion	Comorbidity of renal failure defined as any of the following diagnoses 40301, 40311, 40391, 40402, 40403, 40412, 40413, 40492, 40493, 584, 5845, 5846, 5847, 5848, 5849, 585, 586, V420, V451, V560, V561, V562, V563, V5631, V5632, V568 or principal procedure 3995 during 180 day look back period:
27. Gangrene/ Amputation	**Secondary diagnosis codes:** 72886, 7854 **Secondary procedure codes:** 840, 8401-9, 841, 8410-9 and exclusion	**Principal procedure codes**: 840, 8401-9, 841, 8410-9
28. Intestinal Obstruction	**Secondary diagnosis codes:** 5570, 56081, 5609, 9974	**DRG** DRG = 148-153 **Principal diagnosis codes:** 5570, 56081, or 5609
29. Return to Surgery	**Secondary diagnosis codes:** 9984, 9987 **Secondary procedure codes:** 3403, 3409, 5411-2, 5492	
30. Decubitis Ulcer	**Secondary diagnosis codes:** 7070, 70700-7, 9 **Secondary procedure codes:** 8622	
31. Orthopedic	**Secondary diagnosis codes:**	**Principal procedure**

Complication	9964, 99666, 99677 and exclusion **Secondary procedure codes:** 7971, 7975-6, 7860, 7869 and exclusion	**codes:** 8153, 8155, 8183
32. Compartment Syndrome	**Secondary diagnosis codes:** 9588 or 99889 and **Secondary procedure codes:** 8314	
33. Hepatitis/Jaundice	**Secondary diagnosis codes:** 570, 5733	
34. Pancreatitis	**Secondary diagnosis codes:** 5770	
35. Necrosis of the Bone-Thermal or Aseptic	**Secondary diagnosis codes:** 73340-4, 9	
36. Osteomyelitis	**Secondary diagnosis codes:** 7300, 73000-9, 7302, 73020-9, 99667 and exclusion	**Primary diagnosis codes:** 7300, 73000-9, 7302, 73020-9
37. Disseminated Intravascular Coagulopathy (DIC)	**Secondary diagnosis codes:** 2866 **Secondary procedure codes:** 9907	
38. Pyelonephritis	**Secondary diagnosis codes:** 5901, 59010-1, 5902-3, 8, 59080, 5909	
39. Post Surgical Complication	**Secondary diagnosis codes:** 99700-1, 9972, 9975, 99851-2, 9988, 99881-2, 9, 9989, 9990-9	

APPENDIX C: Exclusion criteria for cancer in peritonitis complication definition (Silber et al. 2007)

Diagnosis of cancer as principal diagnosis or as a comorbidity of cancer:

140, 1400, 1401, 1403, 1404, 1405, 1406, 1408, 1409, 141, 1410, 1411, 1412, 1413, 1414, 1415, 1416, 1418, 1419, 142, 1420, 1421, 1422, 1428, 1429, 143, 1430, 1431, 1438, 1439, 144, 1440, 1441, 1448, 1449, 145, 1450, 1451, 1452, 1453, 1454, 1455, 1456, 1458, 1459, 146, 1460, 1461, 1462, 1463, 1464, 1465, 1466, 1467, 1468, 1469, 147, 1470, 1471, 1472, 1473, 1478, 1479, 148, 1480, 1481, 1482, 1483, 1488, 1489, 149, 1490, 1491, 1498, 1499, 150, 1500, 1501, 1502, 1503, 1504, 1505, 1508, 1509, 151, 1510, 1511, 1512, 1513, 1514, 1515, 1516, 1518, 1519, 152, 1520, 1521, 1522, 1523, 1528, 1529, 153, 1530, 1531, 1532, 1533, 1534, 1535, 1536, 1537, 1538, 1539, 154, 1540, 1541, 1542, 1543, 1548, 155, 1550, 1551, 1552, 156, 1560, 1561, 1562, 1568, 1569, 157, 1570, 1571, 1572, 1573, 1574, 1578, 1579, 158, 1580, 1588, 1589, 159, 1590, 1591, 1598, 1599, 160, 1600, 1601, 1602, 1603, 1604, 1605, 1608, 1609, 161, 1610, 1611, 1612, 1613, 1618, 1619, 162, 1620, 1622, 1623, 1624, 1625, 1628, 1629, 163, 1630, 1631, 1638, 1639, 164, 1640, 1641, 1642, 1643, 1648, 1649, 165, 1650, 1658, 1659, 170, 1700, 1701, 1702, 1703, 1704, 1705, 1706, 1707, 1708, 1709, 171, 1710, 1712, 1713, 1714, 1715, 1716, 1717, 1718, 1719, 172, 1720, 1721, 1722, 1723, 1724, 1725, 1726, 1727, 1728, 1729, 173, 1730, 1731, 1732, 1733, 1734, 1735, 1736, 1737, 1738, 1739, 174, 1740, 1741, 1742, 1743, 1744, 1745, 1746, 1748, 1749, 175, 1750, 1759, 176, 1760, 1761, 1762, 1763, 1764, 1765, 1768, 1769, 179, 180, 1800, 1801, 1808, 1809, 181, 182, 1820, 1821, 1828, 183, 1830, 1832, 1833, 1834, 1835, 1838, 1839, 184, 1840, 1841, 1842, 1843, 1844, 1848, 1849, 185, 186, 1860, 1869, 187, 1871, 1872, 1873, 1874, 1875, 1876, 1877, 1878, 1879, 188, 1880, 1881, 1882, 1883, 1884, 1885, 1886, 1887, 1888, 1889, 189, 1890, 1891, 1892, 1893, 1894, 1898, 1899, 190, 1900, 1901, 1902, 1903, 1904, 1905, 1906, 1907, 1908, 1909, 191, 1910, 1911, 1912, 1913, 1914, 1915, 1916, 1917, 1918, 1919, 192, 1920, 1921, 1922, 1923, 1928, 1929, 193, 194, 1940, 1941, 1943, 1944, 1945, 1946, 1948, 1949, 195, 1950, 1951, 1952, 1953, 1954, 1955, 1958, 196, 1960, 1961, 1962, 1963, 1965, 1966, 1968, 1969, 197, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 198, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 19881, 19882, 19889, 199, 1990, 1991, 200, 2000, 20000, 20001, 20002, 20003, 20004, 20005, 20006, 20007, 20008, 2001, 20010, 20011, 20012, 20013, 20014, 20015, 20016, 20017, 20018, 2002, 20020, 20021, 20022, 20023, 20024, 20025, 20026, 20027, 20028, 2008, 20080, 20081, 20082, 20083, 20084, 20085, 20086, 20087, 20088, 201, 2010, 20100, 20101, 20102, 20103, 20104, 20105, 20106, 20107, 20108, 2011, 20110, 20111, 20112, 20113, 20114, 20115, 20116, 20117, 20118, 2012, 20120, 20121, 20122, 20123, 20124, 20125, 20126, 20127, 20128, 2014, 20140, 20141, 20142, 20143, 20144, 20145, 20146, 20147, 20148, 2015, 20150, 20151, 20152, 20153, 20154, 20155, 20156, 20157, 20158, 2016, 20160, 20161, 20162, 20163, 20164, 20165, 20166, 20167, 20168, 2017, 20170, 20171, 20172, 20173, 20174, 20175, 20176, 20177, 20178, 2019, 20190, 20191, 20192, 20193, 20194, 20195, 20196, 20197, 20198, 202, 2020, 20200, 20201, 20202, 20203, 20204, 20205, 20206, 20207, 20208, 2021, 20210, 20211, 20212, 20213, 20214, 20215, 20216, 20217, 20218, 2022, 20220, 20221, 20222, 20223, 20224, 20225, 20226, 20227, 20228, 2023, 20230, 20231, 20232, 20233, 20234, 20235, 20236, 20237, 20238, 2024, 20240, 20241, 20242, 20243, 20244, 20245, 20246, 20247, 20248, 2025, 20250, 20251, 20252, 20253, 20254, 20255, 20256, 20257, 20258, 2026, 20260, 20261, 20262, 20263, 20264, 20265, 20266, 20267, 20268, 2028, 20280, 20281, 20282, 20283, 20284, 20285, 20286, 20287, 20288, 2029, 20290, 20291, 20292, 20293, 20294, 20295, 20296, 20297, 2028, 203, 2030, 20300, 20301, 2031, 20310, 20311, 2038, 20380, 20381, 204, 2040, 20400, 20401, 2041, 20410, 20411, 2042, 20420, 20421, 2048, 20480, 20481, 2049, 20490, 20491, 205, 2050, 20500, 20501, 2051, 20510, 20511, 2052, 20520, 20521, 2053, 20530, 20531, 2058, 20580, 20581, 2059, 20590, 20591, 206, 2060, 20600, 20601, 2061, 20610, 20611, 2062, 20620, 20621, 2068, 20680, 20681, 2069, 20690, 20691, 207, 2070, 20700, 20701, 2071, 20710, 20711, 2072, 20720, 20721, 2078, 20780, 20781, 208, 2080, 20800, 20801, 2081, 20810, 20811, 2082, 20820, 20821, 2088, 20880, 20881, 2089, 2386, 2733, V10, V100, V1000, V1001, V1002, V1003, V1004, V1005, V1006, V1007, V1009, V101, V1011, V1012, V102, V1020, V1021, V1022, V1029, V103, V104, V1040, V1041, V1042, V1043, V1044, V1045, V1046, V1047, V1048, V1049, V105, V1050, V1051, V1052, V1053, V1059, V106, V1060, V1061, V1062, V1063, V1069, V107, V1071, V1072, V1079, V108, V1081, V1082, V1083, V1084, V1085, V1086, V1087, V1088, V1089

APPENDIX D: Institutional Review Board Exemption

University of Pennsylvania
Office of Regulatory Affairs
3624 Market St., Suite 301 S
Philadelphia, PA 19104-6006
Ph: 215-573-2540/ Fax: 215-573-9438
INSTITUTIONAL REVIEW BOARD
(Federalwide Assurance # 00004028)

09-Mar-2015

Ann M Kutney Lee
Attn: Danielle Sarik
altares@nursing.upenn.edu
akutney@nursing.upenn.edu

PRINCIPAL INVESTIGATOR	: Ann M Kutney Lee
TITLE	: The Impact Of Nursing Skill Mix On The Outcomes Of Hospitalized Adult Surgical Patients
SPONSORING AGENCY	: No Sponsor Number
PROTOCOL #	: 822056
REVIEW BOARD	: IRB #8

Dear Dr. Kutney Lee:

The above-referenced research proposal was reviewed by the Institutional Review Board (IRB) on 06-Mar-2015. It has been determined that the proposal meets eligibility criteria for IRB review exemption authorized by 45 CFR 46.101, category 4.

This does not necessarily constitute authorization to initiate the conduct of a human subject research study. You are responsible for assuring other relevant committee approvals.

Consistent with the federal regulations, ongoing oversight of this proposal is not required. No continuing reviews will be required for this proposal. The proposal can proceed as approved by the IRB. This decision will not affect any funding of your proposal.

Please Note: The IRB must be kept apprised of any and all changes in the research that may have an impact on the IRB review mechanism needed for a specific proposal. You are required to notify the IRB if any changes are proposed in the study that might alter its IRB exempt status or HIPAA compliance status. New procedures that may have an impact on the risk-to-benefit ratio cannot be initiated until Committee approval has been given.

If your study is funded by an external agency, please retain this letter as documentation of the IRB's determination regarding your proposal.

Please Note: You are responsible for assuring and maintaining other relevant committee approvals.

If you have any questions about the information in this letter, please contact the IRB administrative staff. Contact information is available at our website: http://www.upenn.edu/IRB/directory.

Thank you for your cooperation.

Sincerely,

Stephanie Lesage

Digitally signed by Stephanie Lesage
DN: cn=Stephanie Lesage, o=ORA, ou=IRB, email=lesages@upenn.edu, c=US
Reason: I attest to the accuracy and integrity of this document
Date: 2015.03.09 13:49:32 -04'00'

IRB Administrator

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