2018

The Impact Of Hospital Nursing On Postsurgical Sepsis

Andrew Michael Dierkes
University of Pennsylvania, adierkes@upenn.edu

The Impact Of Hospital Nursing On Postsurgical Sepsis

Abstract

Sepsis is common, deadly, and costly. Over 1 million patients are affected each year, and as many as half of them die. The cost of care exceeds that of any hospital admission. Early diagnosis and rapid response are essential elements of effective treatment. Nurses providing direct patient care have the patient contact and clinical knowledge to make them critical components of inpatient sepsis prevention, surveillance, and response. There is a large research literature on sepsis. Many studies evaluate clinical interventions and examine patient risk factors. These studies inform evidence-based guidelines, such as the Surviving Sepsis Campaign. Despite the international expert consensus on sepsis treatment that this campaign represents, sepsis incidence and mortality varies by hospital. The Quality Health Outcomes Model posits that system (and patient) characteristics mediate the relationship between interventions and outcomes such that in actual practice, clinical guidelines often do not have their intended effects. Hospital nursing characteristics are system-level features that may help explain institutional differences in sepsis incidence and mortality. This study explored the relationship between hospital nursing characteristics and sepsis. Specifically, it determined the impact of nurse staffing, education, and the work environment among postsurgical patients on the odds of sepsis (Aim 1), and on mortality among septic patients (Aim 2). This was a cross-sectional, secondary analysis of nurse survey responses, patient discharge abstracts, and hospital administrative data from hospitals in four states. The sample included 1,435,919 patients who were hospitalized for general, orthopedic, or vascular surgeries from 2005 through 2007, 23,603 nurse survey respondents, and the 503 hospitals associated with these subjects. Logistic regression was used to model the relationship between hospital nursing characteristics and patient outcomes. There was a significant association between hospital work environment and postsurgical sepsis and between nurse education and death after sepsis. Surgical patients in hospitals with better nurse work environment experienced lower odds of sepsis (OR 0.93; p=0.002). Postsurgical septic patients in hospitals with a higher percentage of BSN-prepared nurses had lower odds of death (OR 0.94; p<0.001). Nursing resources were associated with patient outcomes and may be a mechanism for administrators to reduce sepsis incidence and mortality.

Degree Type

Dissertation

Degree Name

Doctor of Philosophy (PhD)

Graduate Group

Nursing

First Advisor

Matthew D. McHugh

Keywords

Nurse Education, Nurse Staffing, Nursing, Patient Outcomes, Practice Environment, Sepsis

Subject Categories

Health and Medical Administration | Nursing | Organizational Behavior and Theory

THE IMPACT OF HOSPITAL NURSING ON POSTSURGICAL SEPSIS

Andrew Michael Dierkes

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

2018

Supervisor of Dissertation

____

Matthew D. McHugh, Professor of Nursing

Graduate Group Chairperson

____

Salimah H. Meghani, Professor of Nursing

Dissertation Committee:

Linda H. Aiken, Professor of Nursing and Sociology

Ann M. Kutney-Lee, Adjunct Associate Professor of Nursing

THE IMPACT OF HOSPITAL NURSING ON POSTSURGICAL SEPSIS

DEDICATION

ad majorem Dei gloriam

Catherine Imms

ACKNOWLEDGEMENT

While a dissertation must represent the author's original, unique contribution to the science and literature, it would be disingenuous to say that I did this alone. I remain grateful to so many people for their contributions – large and small – to my education, personal and professional development, and overall wellbeing during my time at Penn. I owe immediate thanks to my dissertation chair, Dr. McHugh, my committee members, Dr. Aiken and Dr. Kutney-Lee, and to my readers, Dr. Lasater and Dr. Cimiotti. For your time and attention to my work, your polite and constructive critiques, and for affirming a new investigator, I am grateful. Likewise, I am indebted to Tim Cheney for patiently fielding analytical questions and to Doug Sloane for his wit and wisdom in all things, but especially in reviewing the results of this dissertation. Herb Smith, too, provided guidance in his characteristically wise, generous, and insightful manner.

I owe much to all of my CHOPR colleagues who have enriched my pre-doctoral experience. Working with smart, talented people is a profound privilege. A special thank you goes to Dr. Margo Brooks-Carthon for trusting me with the data analysis for the clinical scholars' patient safety paper. The hands-on experience was invaluable and prepared me for the analysis in this dissertation. I have not forgotten the patient mentorship of Aparna Kumar and Hailey Germack during my earliest days at CHOPR. Thank you for including me in work that would become my first conference poster presentation and journal article.

I have grown increasingly appreciative of all the support I received throughout my doctoral program that allowed me to focus on my research and education, including the administrative assistance of Andrea Barol and Irene Hung, the statistical support of Jesse Chittams, and for T-32 funding from the National Institutes of Health. Even so, without the support and integrated program offered by the Hillman Foundation, it is unlikely that I would not have pursued a doctoral degree. Likewise, in the absence of Ahrin Mishan, I may not have persevered in my studies. His vision to train "kickass" nurses by equipping them with the tools and skills to change the world of healthcare and beyond was perennially grounding, inspirational, and seemed a worthy endeavor. I hope to prove his concept.

I have been privileged to share this academic journey with many good and generous colleagues. I treasure the friendship of Jennifer Toth, Lydia Felter, and all “The Ladies”. I owe much to their support during my undergraduate years and beyond. Many doctoral student colleagues were also key players in my pre-doc years. Nick Giordano and Stefanie Zavodny accompanied me throughout the program – from NURS 101 to my dissertation defense – Betsy White, Elizabeth Schierholz, and Ashley Ritter were reliable sounding boards and provided astute peer mentorship, and I look forward to continuing collaborative work with Amelia Schlak and Colin Plover.

I am grateful to Pennsylvania Hospital for offering a clinical fellowship and per-diem position to a new nurse. My work at the bedside grounded my research and gave me the experience needed to understand first-hand how key nurses are in effectively preventing and treating sepsis. I am indebted to all the nurses and patient care technicians on 5 Cathcart for their support and encouragement. A special note of thanks goes to my first nurse manager, Debbie Drayton, and to my preceptor, Trish Maguire.

My time at Penn has been especially blessed by the parish community of Saint Agatha-Saint James and the Newman Center. In particular, I am grateful to my pastor and spiritual father, Fr. Carlos, the SCV, my dear friend Dr. Marisa March, and all members of the “Breakfast Club”! To Sean Daru, Arthur Tsoi, and Pearl Lo: few are those who could match your persistence in maintaining relationships; I am humbled by your friendship.

Last, but far from least, I am immeasurably indebted to my family: Mom and Dad, Peter, Catherine, Elizabeth, Theresa, Stephen, Maria, and Thomas. Each of you contributed to the success of this endeavor in your own way, including setting high standards by modeling excellence in your own lives, acknowledging hard work and a job well-done, and providing comic relief and a space to de-stress all while maintaining in subtle ways that my worth and your love were never contingent upon academic success. To each of you and to the multitude whose contributions remain anonymous, a most sincere thank you.

ABSTRACT

THE IMPACT OF HOSPITAL NURSING ON POSTSURGICAL SEPSIS

Andrew M. Dierkes

Matthew D. McHugh

Sepsis is common, deadly, and costly. Over 1 million patients are affected each year, and as many as half of them die. The cost of care exceeds that of any hospital admission. Early diagnosis and rapid response are essential elements of effective treatment. Nurses providing direct patient care have the patient contact and clinical knowledge to make them critical components of inpatient sepsis prevention, surveillance, and response. There is a large research literature on sepsis. Many studies evaluate clinical interventions and examine patient risk factors. These studies inform evidence-based guidelines, such as the *Surviving Sepsis Campaign*. Despite the international expert consensus on sepsis treatment that this campaign represents, sepsis incidence and mortality varies by hospital. The Quality Health Outcomes Model posits that system (and patient) characteristics mediate the relationship between interventions and outcomes such that in actual practice, clinical guidelines often do not have their intended effects. Hospital nursing characteristics are system-level features that may help explain institutional differences in sepsis incidence and mortality. This study explored the relationship between hospital nursing characteristics and sepsis. Specifically, it determined the impact of nurse staffing, education, and the work environment among postsurgical patients on the odds of sepsis (Aim 1), and on mortality among septic patients (Aim 2). This was a cross-sectional, secondary analysis of nurse survey responses, patient discharge abstracts, and hospital administrative data from hospitals in four states. The sample included 1,435,919 patients who were hospitalized for general, orthopedic, or vascular surgeries from 2005 through 2007, 23,603 nurse survey respondents, and the 503 hospitals associated with these subjects. Logistic regression was used to model the relationship between hospital nursing characteristics and patient outcomes. There was a significant association between hospital work environment and postsurgical sepsis and between nurse education and death after sepsis. Surgical patients in hospitals with better nurse work environment experienced lower odds of sepsis (OR 0.93; p=0.002). Postsurgical septic patients in hospitals with a higher percentage of BSN-prepared nurses had lower odds of death (OR 0.94; $p<0.001$). Nursing resources were associated with patient outcomes and may be a mechanism for administrators to reduce sepsis incidence and mortality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION AND SPECIFIC AIMS

The Problem

Sepsis is a leading cause of death in the United States (Angus et al., 2001) and the most expensive condition treated in U.S. hospitals (Torio & Andrews, 2013). For decades, researchers have contributed to the evidence base that informs the guidelines for responding to suspected sepsis as established by the *Surviving Sepsis Campaign* (Rhodes et al., 2017). Despite the global expert consensus on sepsis treatment that this campaign represents, sepsis incidence and mortality among postsurgical patients varies greatly by hospital (Ghaferi, Birkmeyer, & Dimick, 2009; Vogel, Dombrovskiy, Carson, Graham, & Lowry, 2010). Nurses' position and clinical responsibilities at the bedside place them at the forefront of sepsis surveillance, prevention, and early response. A growing body of literature suggests that the hospital context in which nurses operate may mediate the effectiveness of clinical interventions and thereby contribute to the variation in outcomes across institutions. Nursing resources, including staffing (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002), education (Aiken, Clarke, Cheung, Sloane, & Silber, 2003), and the work environment (Aiken et al., 2012), are all associated with patient outcomes.

Infection prevention and early recognition and treatment are key to improving septic patient outcomes (Esper et al., 2006; Rhodes et al., 2017; Seymour et al., 2017; Torsvik et al., 2016). Many common nursing responsibilities are at the service of these goals. Abnormal vital signs are among the initial indications of sepsis (Chong, Dumont, Francis-Frank, & Balaan, 2015; Kenzaka et al., 2012) and collecting blood culture specimens and administering intravenous fluids and antibiotics are among the evidence-based guidelines for responding to suspected sepsis (Rhodes et al., 2017). The leading infection sources of sepsis are respiratory and genitourinary (Esper et al., 2006). Nurses have a shared responsibility to help prevent and treat these and other healthcare acquired infections (HAIs) (Boev & Kiss, 2017), and nursing resources are important factors in HAI prevention (Zingg et al., 2015).

Nurse staffing, education, and the hospital work environment help explain variation in death following the development of complications, a measure known as failure to rescue (FTR)

(Aiken, Clarke, Cheung, Sloane, & Silber, 2003; Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Boyle, 2004; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002; Schmid, Hoffman, Happ, Wolf, & DeVita, 2007). Sepsis is just one of many complications included in a FTR analysis (Silber et al., 2007). *The magnitude of the sepsis problem warrants an individual analysis of death after sepsis as well as an exploration of the value of nursing resources in terms of sepsis prevention*. The aims of this study investigated both sepsis prevention and treatment. While improvements in nursing resources have been associated with a decrease in FTR (Aiken et al., 2003; Aiken et al., 2002; Boyle, 2004; Needleman et al., 2002; Schmid et al., 2007), **the relationship between nursing resources and sepsis incidence and mortality is unknown.**

Study Overview, Aims, and Hypotheses

This study aims to determine the effect of modifiable hospital nursing resources on the odds of developing sepsis and the odds of death after sepsis in a surgical patient population using a large sample of hospitals and patients. Aggregated responses from individual direct-care registered nurses responding to the NINR-funded Multi-State Nursing Care & Patient Safety Study survey provided valid measures of hospital resources. These data were linked to patient discharge abstracts and administrative hospital data for a cross-sectional analysis. This study is a natural extension of the failure to rescue literature and work on nurse-sensitive patient outcomes. Some complications and subsequent deaths may be unavoidable, but hospitals should be able to prevent, or at least identify and treat many more complications before they result in death.

The central hypothesis of this study was that patients cared for in hospitals with more favorable nursing resources would be less likely to develop sepsis and would experience better outcomes even if they were to become septic. Specifically, better nurse staffing, education, and practice environments would be associated with lower odds of sepsis and death after sepsis. Improvements in staffing, education, and the work environment may facilitate the mechanisms of sepsis prevention, early recognition, and treatment, improving outcomes. Better staffing (i.e. fewer patients per nurse) divides a nurse's time and attention among fewer patients. More time at the bedside may provide the contact a nurse needs to assess, identify, and respond to signs and symptoms of sepsis. Higher education (i.e. a bachelor's degree or higher) could equip a nurse with the critical thinking and evidence-based judgement needed to synthesize that information and accurately identify the signs of sepsis in a timely manner. Finally, the work environment (as reported by nurses using a validated scale) represents the extent to which an institution supports and engages its nurses, which in turn enhances their effectiveness.

The overall objective of this study was to inform institution-level workforce interventions to reduce the odds of sepsis and improve patient outcomes when sepsis does occur. This study aimed to achieve this objective by examining modifiable hospital nursing characteristics, such as staffing, education, and elements of the work environment that are hypothesized to be associated with lower odds of sepsis and better septic patient outcomes.

Specifically, this study aimed to:

1. **Determine the relationship between hospital nursing resources (staffing, education, and the work environment) and the odds of sepsis among surgical patients, controlling for patient and hospital characteristics.**

   H1: Surgical patients in hospitals with better nursing resources will experience lower odds of sepsis.

2. **Determine the relationship between hospital nursing resources and 30-day mortality among surgical patients who develop sepsis, controlling for patient and hospital characteristics.**

   H2: Postsurgical patients who develop sepsis in hospitals with better nursing resources will experience lower odds of death within 30 days of admission.

Significance

In a healthcare system seeking to deliver value, sepsis is a significant obstacle to improving quality and reducing costs. A hospital's ability to prevent deaths in patients who develop complications may be a better indicator of care quality than standard mortality or complication metrics alone (Silber et al., 2007). The Surviving Sepsis Campaign, last updated in 2016, indicates that "substantial agreement exists among a large cohort of international experts regarding many strong recommendations for the best care of patients with sepsis" (Rhodes et al., 2017). Despite uniformity in practice recommendations, postsurgical sepsis incidence and mortality varies significantly by hospital, even after accounting for patient severity of illness (Vogel et al., 2010).

Existing research has shown that differences in hospital nursing resources, including staffing (Aiken et al., 2002; Needleman et al., 2002; Needleman et al., 2001), education (Kutney-Lee et al., 2013), and the work environment (Silber et al., 2016), helped explain patient death after complications. The effect of these nursing resources on sepsis incidence and mortality has not been studied directly, but may represent key factors mediating the effectiveness of clinical sepsis interventions. This study contributes to the science on the impact a hospital's organizational structure has on patient outcomes. While many hospital characteristics (such as urban/rural location, bed size, and teaching status) are difficult, if not impossible, to change, hospital nursing resources are modifiable. The results of this study can inform the structuring of hospital nursing to better prevent and treat postsurgical sepsis.

CHAPTER 2: BACKGROUND AND SIGNIFICANCE

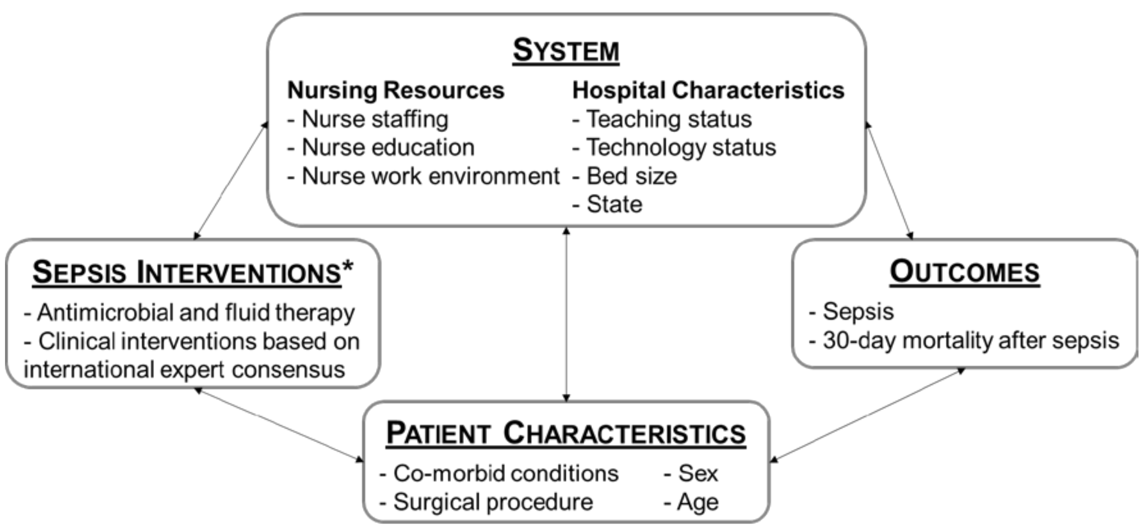
Introduction

The purpose of this study was to examine the impact of hospital nurse staffing, education, and work environment on 1) the odds of developing sepsis after surgery, and 2) the odds of death among postsurgical sepsis patients. This chapter presents the conceptual framework for this study, an overview of sepsis, and a comprehensive literature review.

Conceptual Framework

The American Academy of Nursing's Quality Health Outcomes Model (QHOM) (Mitchell, Ferketich, & Jennings, 1998) guided the development of this study. The QHOM was developed by nursing academics, building upon Donabedian's linear structure-process-outcomes model (Donabedian, 1966, 1988), and has since been used and cited in national and international nursing research (Mitchell & Lang, 2004). It proposes that **system and patient characteristics mediate the success of clinical interventions.** In other words, the same intervention affects equivalent patients differently when implemented in different system contexts; s**ystems can either support or diminish interventions**. **FIGURE 2.1** represents the QHOM as adapted for this study.

FIGURE 2.1:
Conceptual Model



Notes: Adapted from the Quality Health Outcomes Model (Mitchell et al., 1998)
*The conceptual model includes examples of "Sepsis Interventions", but the regression models did not include any specific intervention variables.

The focus of this study was on the impact of hospital nursing resources (system context) on postsurgical sepsis incidence and mortality (patient outcomes). Hospital administrators can shape this context of care through various mechanisms, including hiring decisions, policymaking, and choosing a governance structure. System modifications do not replace clinical interventions, but they can mediate their effectiveness in terms of achieving desired patient outcomes. Clinical interventions are also modifiable, but a large body of sepsis literature already addresses this mechanism of improving outcomes and evidence-based clinical guidelines are well established (Rhodes et al., 2017). Nurses affect patient outcomes through these direct clinical interventions, but they also influence formal policy development and informal cultural norms, both of which shape the context in which other hospital personnel act and influence patient outcomes. The organizational context (the hospital in which nurses practice) mediates the extent to which these channels of influence operate (Aiken, Sochalski, & Lake, 1997).

To effectively isolate the impact of hospital nursing resources on postsurgical sepsis incidence and mortality, this study included several controls. Patient characteristics that increase the risk of developing sepsis are well documented (Mayr, Yende, & Angus, 2014). This study accounted for patient comorbidities using validated risk adjustment methods. The controls also included hospital characteristics with conceptual and empirical associations with sepsis. This study did not include any direct controls of clinical interventions. As the two-way arrows in the model suggest, the system may influence how well clinicians implement these guidelines. Allowing this variation preserves a more complete picture of how differences in nursing resources are associated with patient outcomes.

This study responds to the call for a closer consideration of “health-care system factors” in sepsis research by examining how the organizational context of nursing affects patient outcomes (Cohen et al., 2015). Examples of system-level predictor variables in existing sepsis research include case volume (Gaieski et al., 2014; Ofoma, Dahdah, Kethireddy, Maeng, & Walkey, 2017) and hospital characteristics such as teaching status and bed size (Banta, Joshi, Beeson, & Nguyen, 2012; Vogel et al., 2010). Unlike nursing resources, these factors are generally *not* modifiable, which limits the ability to translate these findings into actionable interventions. Two landmark reports by The Institute of Medicine (IOM), *To Err is Human: Building a Safer Health System* (Donaldson, Corrigan, & Kohn, 2000) and its subsequent companion, *Keeping Patients Safe: Transforming the Work Environment of Nurses* (Page, 2004), also recognize the role of hospital systems in shaping the delivery of care and affecting patient outcomes, but they include a specific look at nursing. There is evidence to support the association of nursing characteristics and patient outcomes. Magnet® recognition, which acknowledges excellence in hospital nursing, is associated with better patient outcomes (McHugh et al., 2013). Some of these outcomes relate to sepsis, including bloodstream infections (Barnes, Rearden, & McHugh, 2016; Brennan et al., 1991) and failure to rescue (Friese, Xia, Ghaferi, Birkmeyer, & Banerjee, 2015; Henneman et al., 2013). Nursing characteristics also help explain quality of care in non-Magnet® hospitals (McHugh, Aiken, Eckenhoff, & Burns, 2016). The hospital is an ideal setting for exploring these associations, as nurses are extensively involved in the full continuum of surgical patient care.

Sepsis Background

The meaning of sepsis has changed over time. The word “sepsis” has Greek roots that reference rot and decay. The modern formalization of sepsis in a medical context came in 1989 when Roger Bone et al. (1989) introduced “sepsis syndrome” as a systemic response to infection involving inflammation and organ failure – the foundation for today’s systemic inflammatory response syndrome (SIRS). A series of International Consensus Conferences held in 1991 ("American College of Chest Physicians/Society of Critical Care Medicine Consensus Conference: definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis," 1992), 2001 (Levy et al., 2003), and 2014-15 (Singer, Deutschman, Seymour, & et al., 2016) further refined the definition. **TABLE 2.1** presents the criteria for each iteration. A maladaptive response to infection (with organ dysfunction and hypotension determining severity) is at the core of all three versions. The development over the years reveals an evolution in how experts viewed the relationship between Systemic Inflammatory Response Syndrome (SIRS) and sepsis. In 1991, SIRS was fundamental to sepsis at every level of severity. In 2001, the inflammatory response was still key, but the objective SIRS criteria from 1991 (see

“SIRS” note in **TABLE 2.1**) were abandoned in favor of “the physical and laboratory findings that prompt an experienced clinician to conclude that an infected patient ‘looks septic’” (Levy et al., 2003). The 2015 conference, in the interest of identifying more severe cases, made organ dysfunction in response to infection the entry-level definition for sepsis.

Even after 25 years of work by experts across the globe, there is dissatisfaction with the subjective nature of the sepsis definition and the consequential loose use of the term in the clinical setting. Patients meet sepsis criteria at the intersection of infection and inflammatory response. As **FIGURE 2.2** illustrates, there are infectious and inflammatory states that are not sepsis. Clinicians may use the term casually to describe an acutely ill patient without carefully considering the criteria. The Global Sepsis Alliance hosted the Merinoff Symposium in 2010 and produced a “molecular definition” of sepsis, which highlighted the host response to infection as a way to distinguish sepsis from other inflammatory states (Czura, 2011), but there is no definitive test for sepsis. The physiology is complex, involving countless cells, cascades, receptors, signals, and inflammatory mediators. Various tests can detect these molecular processes and may even contribute to a diagnosis, but sepsis is ultimately a syndrome. Clinicians make sepsis diagnoses based on a constellation of signs and symptoms, which are subject to clinical judgement.

TABLE 2.1

International Consensus Definitions for Sepsis

Severity	Conference Year		
	1991	2001	2015
Sepsis	SIRS[A] + infection	a systemic inflammatory response[F] + infection	"life-threatening organ dysfunction[B] caused by a dysregulated host response to infection" (Singer et al., 2016)
Severe Sepsis	Sepsis + organ dysfunction[B] OR hypoperfusion abnormality[C] OR sepsis-induced hypotension[D]	*definition from 1991*	*term discontinued – former definition of severe sepsis is now this year's "sepsis" definition.*
Septic Shock	Severe Sepsis + persisting hypotension[E]	*definition from 1991*	Sepsis + persisting hypotension[E] requiring vasopressors to maintain MAP ≥65mmHg + having a serum lactate level >2mmol/L (18mg/dL)

[A] **SIRS** (Systemic Inflammatory Response Syndrome) criteria are met in patients with any two of the following:

1. respiratory rate >20 breaths per min OR a PaCo2 <32 mmHg
2. heart rate >90 beats per minute
3. temperature >38 °C or <36 °C
4. white blood cell count >12,000/mm3 OR <4000/mm3 OR >10% bandemia

[B] **Organ dysfunction:** no single definition. An acute change of 2 or more points in total Sequential Organ Failure Assessment (SOFA) score was given as an example in (Singer et al., 2016).

[C] **Hypoperfusion abnormalities** include, but are not limited to, lactic acidosis, oliguria, and acute altered mental status

[D] **Hypotension**:

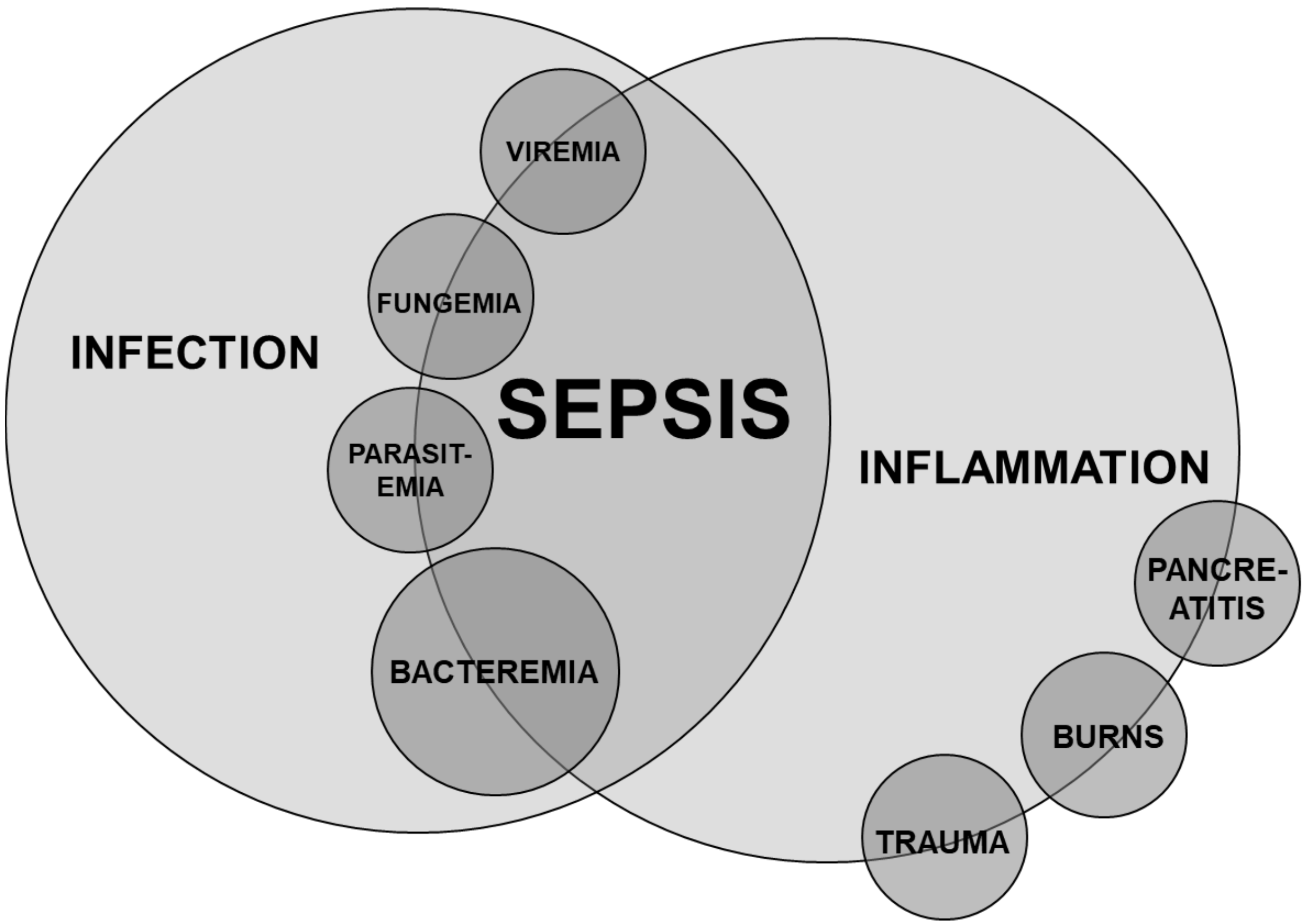
1. systolic blood pressure of <90mmHg OR
2. drop in systolic blood pressure of ≥40mmHg OR
3. mean arterial pressure <60 (*this criteria added in 2001*)

"in the absence of other causes for hypotension (e.g. cardiogenic shock)" ("American College of Chest Physicians/Society of Critical Care Medicine Consensus Conference: definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis," 1992)

[E] **Persisting hypotension:** hypotensive despite "adequate" fluid resuscitation (Levy et al., 2003; Physicians, 1992; Singer et al., 2016)

[F] **A Systemic Inflammatory Response**: "the physical and laboratory findings that prompt an experienced clinician to conclude that an infected patient 'looks septic'" (Levy et al., 2003). Examples given in publication, but the list is not exhaustive and the term remains largely subjective.

FIGURE 2.2
Sepsis at the Intersection of Infection and Host Inflammatory Response



Notes: Figure adapted from Bone et al. (1992)

Review of the Literature

Sepsis Overview

Each year, *more than 1 million patients* are treated for sepsis (Torio & Andrews, 2013), making up over 4 percent of all hospitalized patients (Elixhauser, 2011). While sepsis discharges have increased over time, inpatient mortality after sepsis has decreased (Banta et al., 2012; Elixhauser, 2011). The increase in the number of sepsis cases is expected to outpace projected population growth as the elderly, who have a higher risk of sepsis, make up an increasingly larger proportion of society (Angus et al., 2001). In addition to being common, sepsis is *a leading cause of death* in the United States, exceeding the in-hospital mortality rate for all other admissions by a factor of 8 (Elixhauser, 2011). While the in-hospital mortality rate for all septic patients is approximately 16 percent (Elixhauser, 2011), among the most severe septic cases, mortality approaches 50 percent (Mayr et al., 2014). The estimated mean hospital cost per septic patient varies by study between $13,292 and $75,015 (Arefian et al., 2017). As this wide range suggests, many variables affect the actual and estimated costs of sepsis treatment. However, the conclusion is consistent: sepsis is expensive. In 2011, sepsis cost U.S. hospitals $20.3 billion – 5.3 percent of the costs for all hospitalizations – making it *the most expensive condition* treated (Torio & Andrews, 2013).

Surgical sepsis etiology. Sepsis may develop outside the hospital or as a complication of inpatient care. Secondary diagnoses of sepsis have increased over time, and among the most common principal diagnoses associated with these cases are complications related to surgical procedures, devices, implants, and/or grafts (Elixhauser, 2011). While only a small portion (1%) of surgical patients develop sepsis (Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2001; Unruh & Zhang, 2012), they make up more than 20% of all sepsis cases (Angus et al., 2001). Sepsis incidence and mortality varies widely by procedure. In a study of patients undergoing elective surgical procedures, the rate of sepsis ranged from 0.3% (breast surgery) to 3.8% (esophageal surgery). Mortality with sepsis in the same patient population ranged from 7.3% (thyroidectomy) to 45.9% (thoracic surgery) (Vogel et al., 2010).

Postsurgical Sepsis and Nursing

Nurses' proximity to the bedside places the success of sepsis prevention, surveillance, recognition, and treatment within their domain (Kleinpell, Aitken, & Schorr, 2013). In surgical patients, sepsis is more often a preventable complication that develops while the patient is under continual nursing care.

HAI prevention. Nursing resources help prevent a broad set of hospital acquired infections (HAIs), including respiratory and genitourinary infections, which are the leading source infections for sepsis (Esper et al., 2006; Zingg et al., 2015). Common perioperative nursing clinical responsibilities also contribute to infection prevention. Oral hygiene, early ambulation and other forms of exercise or mobilization, patient positioning, and prophylactic probiotics help prevent respiratory infection (Yokoe et al., 2014). Catheter-associated genitourinary and bloodstream infections are reduced by general patient hygiene and catheter-specific care, catheter surveillance for appropriate indication and signs of infection, and advocating for removal of nonessential catheters (Yokoe et al., 2014). Nurses contribute to the prevention of surgical site infections (SSIs) through their involvement in antimicrobial prophylaxis, blood glucose control, maintaining patient normothermia, preoperative skin prep, surgical site wound care, SSI surveillance, and educating patients and families about SSI prevention (Yokoe et al., 2014). Infection prevention is one mechanism of sepsis prevention.

"Potentially sensitive to nursing". In the early 2000s, the Agency for Healthcare Research and Quality (AHRQ) established "Postoperative Sepsis" as a "Patient Safety Indicator" (PSI) for benchmarking hospital quality and safety (*Guide to Patient Safety Indicators* 2003). Needleman, Buerhas, Mattke, Stewart, and Zelevinsky (2001) conducted the primary research to develop and validate several PSIs. Their study originally conceptualized hospital-acquired sepsis as one of several "Outcomes Potentially Sensitive to Nursing" (OPSNs) (Needleman et al., 2001). While they found no strong or consistent relationship between nurse staffing and sepsis in medical or surgical patients, they did identify an association with related measures, including failure to rescue (FTR) and infections (Needleman et al., 2001). FTR was higher among surgical patients than among medical patients, and stood out as the only OPSN with a strong and consistent relationship with staffing among surgical patients. They found a weaker relationship for staffing with UTIs and pneumonia. The current study approached the impact of nursing on sepsis in a more robust way. It used a more direct measure of staffing and included nurse education and the work environment.

Nursing Resources and Postsurgical Sepsis

Staffing. Since Needleman and colleagues' (2001) publication, subsequent research has reexamined the impact of nurse staffing on postsurgical sepsis with mixed results. Some have reported decreases in sepsis associated with an increase in nurse staffing, in a postsurgical population (Mark, Harless, & Berman, 2007; Unruh & Zhang, 2012), and among patients in high- (but not low-) dependency units (Shuldham, Parkin, Firouzi, Roughton, & Lau-Walker, 2009). Others found no effect of nursing staffing on sepsis (Cho, Ketefian, Barkauskas, & Smith, 2003), or even reported higher odds of sepsis associated with an increase in LPN staffing and higher percent ratios of LPN to total nurse staffing time (Glance et al., 2012). Related research found higher rates of postsurgical sepsis in Magnet® versus non-Magnet hospitals, while noting that staffing was also poorer in Magnet® hospitals in their sample (Goode, Blegen, Park, Vaughn, & Spetz, 2011). These findings were contrary to the larger body of literature and to the researchers' hypothesis. It is possible for non-Magnet hospitals to have Magnet® characteristics, which may confound the analysis. Magnet® recognition is a signal of hospital nursing quality and, in other more recent work, has been associated with lower odds of mortality and failure to rescue in surgical patients, which was largely attributed to their better work environments and higher-educated staff (McHugh et al., 2013).

Work environment. This review yielded one study (Manojlovich & DeCicco, 2007) that examined the impact of the work environment on sepsis. The Practice Environment Scale of the Nursing Work Index (PES-NWI) maintained a significant, negative relationship with nurse-reported frequency of catheter-associated sepsis in regression models. While this study included nurse education level among its controls, this review found no studies that examined the impact of a nursing bachelor's degree on sepsis directly.

Hospital Characteristics and Postsurgical Sepsis

Not unlike the current study, Vogel and colleagues (2010) studied postsurgical sepsis incidence and outcomes in a large administrative dataset using ICD-9 codes. Large, urban, and non-teaching hospitals were associated with higher postsurgical sepsis rates, suggesting that hospital system factors impact the development of sepsis after surgery (Vogel et al., 2010). The current study contributes to this knowledge base. Specifically, it sought to examine the impact of hospital nursing characteristics on the odds and outcomes of postsurgical sepsis.

Summary

This study was timely and important. In May 2017, the World Health Assembly (WHA) of the World Health Organization (WHO) passed a resolution to advance the global "prevention, diagnosis and treatment of sepsis" (Assembly, 2017, p. 2). For decades, researchers have contributed to the evidence base that informs the experts' consensus on how to respond, clinically, to sepsis (Rhodes et al., 2017). *While more favorable nursing resources are associated with improved infection prevention and lower FTR, the effect of nurse staffing, education, and the work environment on sepsis prevention and outcomes is unknown.* Whereas existing research informs the clinical pathway in response to sepsis, **this study aimed to inform how hospital administrators can shape the context in which these interventions take place to optimize patient outcomes**.

CHAPTER 3: METHODS

Introduction

The purpose of this study was to examine how nursing resources may partly explain the variation across hospitals in the development of sepsis and death after sepsis in postsurgical patients. This chapter presents this study's design and methods, including its datasets, sample, variables and an outline of the analysis plan.

Datasets

This observational study was a cross-sectional analysis of secondary data to explore the association of nurse staffing, education, and work environment with the odds of developing sepsis (Aim 1) and death after sepsis (Aim 2) within a postsurgical population. Data from three sources were merged using hospital identifiers common to all three datasets. Patients, nurses, and their associated hospitals included in this study are from four states: California, Pennsylvania, New Jersey, and Florida. These four states are geographically diverse and represent a large and approximately representative sample of the US population.

Specifically, these data sources are:

1. Multi-State Nursing Care & Patient Safety Study (2005-2008). This NINR-funded survey was sent to registered nurses in four states: California, Pennsylvania, New Jersey, and Florida. The protocol used for sampling and surveying nurses was introduced in 1999 (Aiken et al., 2003; Aiken et al., 2002), and repeated between 2005 and 2008 (Aiken et al., 2011). The Multi-State Nursing Care & Patient Safety Study researchers used a modified Dillman method (Dillman, 1978) to survey a random sample of licensed registered nurses in each state, drawing from state-based licensure records among nurses with an active license and a mailing address. Surveys were mailed to the home address with the option to reply by mail or online. This study used the nurse responses from the 2005-2008 survey. The response rate was 39%. A focused survey of non-responders with a 91% response rate found no significant difference in how responders and non-responders reported on hospital nursing characteristics (Aiken et al., 2011; Smith, 2009).

Nurse respondents were asked to provide place of employment information, including hospital name, so results could be aggregated to the hospital level. Because responses were used in aggregate to assess hospital characteristics, more important than the overall response rate is the distribution of respondents across an unbiased sample of hospitals. The average hospital in the final analytical dataset for this study had an average of 47 nurse respondents. Nursing resources data (staffing, education, and the work environment) were aggregated to the hospital level (as described later under "Explanatory Variables") and linked to patient administrative data and hospital characteristics from the same four states.

2. American Hospital Association (AHA) Annual Survey (2006)*.* This census of US hospitals provides facility-level data including geographic location (state as well as urban/rural setting), size, teaching status, and technology status. It is widely cited in peer-reviewed journal publications and used in government agency and industry reports, and policy papers. The survey methodology is rigorous and focused on maximizing participation and accuracy. The response rate historically exceeds 75% (The American Hospital Association (AHA), 2017). This study uses the survey responses from 2006.

3. Patient Discharge Data (2005-2007). Clinical patient information, including diagnosis-related groups (DRGs), International Classification of Diseases (ICD) diagnosis codes, mortality, and the information needed for risk adjustment come from hospital discharge abstracts, which were collected by each state in the study. This study used patient data from patients hospitalized in CA, PA, & NJ in 2005 and 2006, and from patients hospitalized in Florida in 2006 and 2007. The choice of a later timeframe for patients in Florida is made to mirror the timeline of the Multi-State Nursing Care & Patient Safety Study survey, which surveyed Florida nurses later than nurses in CA, PA, & NJ.

Sample

Hospitals*.* This study included 503 adult nonfederal acute care hospitals in four states (CA, FL, NJ, PA). It is common practice among studies aggregating Multi-State Nursing Care & Patient Safety Study survey data to exclude hospitals with fewer than 10 nurse survey respondents. This is to improve the reliability of hospital-level variables reported by individual nurses (Aiken et al., 2011; Aiken et al., 2003; Aiken et al., 2002; Lasater & McHugh, 2016; McHugh et al., 2013). This method was empirically evaluated and supported by intraclass correlation statistical analysis (McHugh et al., 2013). When aggregating nurse responses to create a nurse staffing variable, this study excludes responses from nurses working in the emergency room, psychiatric and labor/delivery units, and the outpatient setting – areas where staffing and patient assignments are atypical compared to the rest of the hospital. This study adopted the precedent of a minimum of 10 nurse respondents per hospital, but took the conservative approach of ensuring those individuals worked on units that qualified for the staffing measure.

Nurses. This study included 23,603 individual nurses distributed across 503 hospitals, with an average of 47 nurses per hospital. Nurses must have worked in a hospital that meets inclusion criteria (as outlined above) and provide direct-patient care.

Patients. This study included adult patients 18-85, who were hospitalized for general, orthopedic, or vascular surgical procedures as identified by diagnosis related groups (DRGs) (see **APPENDIX A**, **TABLE A1**). These surgical groups capture procedures common in most general acute care hospitals, have established risk-adjustment methods, and have a history of use in published research (Aiken et al., 2011, 2012; Aiken et al., 2003; Aiken, Clarke, Sloane, Lake, & Cheney, 2008; Aiken et al., 2002; Aiken, Sloane, Bruyneel, Van den Heede, Griffiths, Busse, Diomidous, Kinnunen, Kozka, et al., 2014; Carthon, Kutney-Lee, Jarrin, Sloane, & Aiken, 2012; Jane E. Ball, 2017; Kutney-Lee, Sloane, & Aiken, 2013; McHugh et al., 2013). The rate of sepsis and death after sepsis varies significantly by surgical group, with implications for risk adjustment, which is outlined in the "Data Analysis" section of this chapter.

Variables and Instruments

This study aimed to determine the impact of hospital nursing characteristics on postsurgical sepsis and mortality after sepsis. Hospitals, patients, and nurses are the units of observation. The units of analysis are patients clustered within hospitals. **TABLE 3.1** summarizes the major study variables and the text that follows provides a more in-depth description of each variable.

TABLE 3.1
Study Variables

Category	Title	Description	Variable Type	Level	Database
Explanatory	Staffing	Mean patients/nurse	Continuous	Hospital	RN Survey
	Education	Proportion of nursing staff BSN-prepared (or higher)	Continuous	Hospital	RN Survey
	Work Environment	Average nurse response to PES-NWI	Continuous	Hospital	RN Survey
Outcome	Sepsis	Indicator of sepsis as a secondary diagnosis	Dichotomous	Patient	Discharge Abstracts
	30-day mortality	Indicator of death within 30 days of hospital admission	Dichotomous	Patient	Discharge Abstracts
Control	Bed size	1=≤100 beds 2=101-250 beds 3=>250 beds	Categorical	Hospital	AHA
	Technology Status	0=Low-tech 1=High-tech	Dichotomous	Hospital	AHA
	Teaching Status	0=Non-teaching 1=Minor teaching 2=Major teaching	Categorical	Hospital	AHA
	State	Dummy variables for each state	Dichotomous	Hospital	RN Survey
	ICU Nurses	Proportion of RN Survey respondents – ICU nurses	Continuous	Hospital	RN Survey
	Med/Surg Nurses	Proportion of RN Survey respondents – med-surg nurses	Continuous	Hospital	RN Survey
	Patient Sex	0=Female 1=Male	Dichotomous	Patient	Discharge Abstracts
	Patient Age	Age in years	Continuous	Patient	Discharge Abstracts
	Elixhauser comorbidities	Indicator variables for each of 31 comorbidities	Dichotomous	Patient	Discharge Abstracts
	DRGs	Dummy variables for each surgical procedure	Dichotomous	Patient	Discharge Abstracts

RN Survey: Multi-State Nursing Care & Patient Safety Study; **AHA:** American Hospital Association Annual Survey of hospitals; **Discharge Abstracts:** Hospital discharge abstracts collected by each state; **PES-NWI:** Practice Environment Scale of the Nursing Work Index

Explanatory Variables*.* The data for each explanatory variable came from the Multi-State Nursing Care & Patient Safety Study survey and was aggregated to the hospital level. Compared to administrative data, this method of constructing hospital-level variables has the advantage of including only inpatient, direct-care nurses (McHugh et al., 2013). Nurses have first-hand knowledge of hospital nursing resources and direct experience caring for patients in hospitals. Aggregating individual reports improves the reliability and accuracy of institution-level variables. Each of these variables has a strong record of use and predictive validity in existing research (Aiken et al., 2003; Aiken, Sloane, Bruyneel, Van den Heede, Griffiths, Busse, Diomidous, Kinnunen, Kózka, et al., 2014; Cho et al., 2015; Kutney-Lee et al., 2013; Lasater & McHugh, 2016; Silber et al., 2016).

1. *Nurse Staffing.* Survey respondents reported the number of nurses providing direct patient care and the number of patients on their unit during their last shift. Responses were aggregated to the hospital level and a staffing metric was generated by dividing the mean number of patients by the mean number of nurses on the unit as reported by nurses in each institution. A one-unit increase in the resulting variable represents an additional patient per nurse in the average workload of that hospital. The responses of nurses who identified working in the emergency room, psychiatric and labor/delivery units, and the outpatient setting were not used in the creation of the staffing variable. Nurse responses that were excluded from the staffing variable still contributed to other variables.
2. *Nurse Education.* Nurses self-reported their highest level of education by degrees in nursing and in fields other than nursing. Responses were aggregated by hospital to reflect the percent of nurses in an institution with a baccalaureate degree in nursing (BSN) or higher degree. For regression analyses, education was recoded so that a one-unit increase represents a 10% increase in BSN-prepared nursing staff.
3. *Nurse Work Environment.* The Multi-State Nursing Care & Patient Safety Study survey included the 31-item Practice Environment Scale (PES) from the Nursing Work Index (NWI). The National Quality Forum endorses the PES-NWI as a hospital-level structural performance measure (National Quality Forum (NQF), 2017). It is a version of the Nursing Work Index,

which was developed from interviews with nurses in hospitals known for attractive work environments, and was conceived as a measure that would be aggregated to the hospital level and used in outcomes research (Lake, 2002). Questions are divided across five subscales, each assessing a different nursing domain: 1) Nurse Participation in Hospital Affairs; 2) Nursing Foundations for Quality of Care; 3) Nurse Manager Ability, Leadership, and Support of Nurses; 4) Staffing and Resource Adequacy; 5) Collegial Nurse-Physician Relations. Nurse responses were aggregated to the mean response by hospital within each subscale. The global measure is the mean of these hospital-level subscale responses. For regression analyses, hospitals were divided into three ordinal categories by quartile: "poor" (first quartile), "mixed" (second and third quartile), and "good" (fourth quartile).

Outcome Variables. Patient-level outcomes were retrieved from the patient discharge abstracts each state collects.

Sepsis. The primary patient outcome variable was whether a patient developed sepsis during their inpatient surgical admission. Most studies identify sepsis using either established clinical criteria or ICD codes (Arefian et al., 2017). Both methods are imperfect, but they identify similar patient cohorts (Angus et al., 2001). As presented in Chapter 2 and summarized in **TABLE 2.1**, the term sepsis, along with an understanding of the disease, has evolved significantly. Diagnoses rely on clinician judgement and the severity of sepsis remains subjective with poor agreement among physicians observing the same case (Rhee et al., 2016). Identifying sepsis in a patient discharge abstract database presents its own challenges (Cohen et al., 2015). Sepsis incidence and mortality varies by abstraction method (Gaieski, Edwards, Kallan, & Carr, 2013) and ICD-9-CM codes have a poor negative predictive value, missing as many as one quarter of all sepsis cases (Martin , Mannino , Eaton , & Moss 2003; Ollendorf, Fendrick, Massey, Williams, & Oster, 2002). However, they remain a widely used method of abstraction in the literature both in the United States and internationally (Arefian et al., 2017; Fleischmann et al., 2016).

The patient data available for this study were from discharge abstracts, precluding the use of clinical presentation in sepsis criteria. This study used ICD-9 codes to identify septic patients. As noted in Chapter 2, published sepsis research uses several different sets of ICD-9 codes to detect subjects. This study aligned itself in Aim 2 with the work of Silber and colleagues on failure to rescue. The earliest FTR studies identified complications through chart review (Silber, Williams, Krakauer, & Schwartz, 1992), but subsequent studies abstracted complications from administrative data (Aiken et al., 2003; Aiken et al., 2002; Silber et al., 2000). At least two alternatives to the original FTR abstraction method have been proposed. Each excludes a large portion of deaths (as much as 41.5%) otherwise included in the original FTR (Silber et al., 2007). These newer methods are less stable and reliable than the original FTR, and may yield weaker associations with some hospital characteristics of interest (Silber et al., 2007). This study used the original FTR construction using the ICD-9 codes listed in **TABLE A2** (**APPENDIX A**) and searched across the first 24 secondary diagnoses to identify septic patients.

30-Day Mortality. Whether or not the patient died within 30 days of admission, in or out of the hospital.

Additional Hospital Characteristics. Existing research has identified the association of hospital size, urban/rural location, and teaching status with postsurgical sepsis (Vogel et al., 2010) and that age-adjusted sepsis mortality rates vary significantly by US state (Wang, Devereaux, Yealy, Safford, & Howard, 2010).

Hospital size was determined by number of beds as reported in the AHA annual survey. Small hospitals have up to and including 100 beds. Medium hospitals have 101-250 beds. Large hospitals have more than 250 beds. *Location.* Urban or non-urban location as reported in the AHA annual survey. *State.* This is a control variable indicating the state in which the hospital is located. *Teaching status* reflects the ratio of medical residents and fellows to beds. Non-teaching hospitals have no residents/fellows. Minor teaching hospitals have a ratio of 1:4 or smaller. Major teaching hospitals have ratios greater than 1:4. *Technology status* refers to the procedures a facility can accommodate. High-technology hospitals have facilities for open-heart surgery and/or major organ transplants. Low-technology hospitals do not have facilities for either.

Staffing ratios may differ by unit, reflecting patient acuity and intensity of nursing care required. Nurses on medical/surgical units may care for several times the number of patients assigned to a nurse in the intensive care unit (ICU). The staffing variable is a ratio of nurse-reported numbers of patients and nurses on the unit during their last shift. Disproportionate response rates of ICU and medical/surgical nurses could lead to a misrepresentation of overall hospital staffing. For example, if ICU nurses are overrepresented in the survey sample, the average number of patients assigned to a nurse would be artificially low. To adjust for this possibility, two variables were included in the fully adjusted models: 1) *Percent ICU nurses:* the percent of nurse respondents by hospital who worked their last shift in the ICU, and 2) *Percent medical/surgical nurses*: the percent of nurse respondents by hospital who worked their last shift on a medical/surgical unit.

Preliminary Analyses

A statistical power analysis helped inform the feasibility of this study prior to initiation. A review of the literature provided the sample-size and effect-size estimates. Both aims analyze data from multi-level observations: patients, hospitals, and nurses. The analysis was The Tests for Two Proportions in a Repeated Measures Design (Liu & Wu, 2005) and it accounts for clustering of individuals within hospitals. A conservative estimate of 500 hundred hospitals was divided into two unequal groups (55/445) reflecting the proportion of Magnet® and non-Magnet hospitals found in the last iteration of the Multi-State Nursing Care & Patient Safety Study survey (McHugh et al., 2013). Magnet® recognition here is a proxy for obtaining estimates of the number of hospitals with good nursing characteristics versus those with poor nursing characteristics. Published research (Aiken et al., 2011) using these same data sources averages 1,898 total general, orthopedic, and vascular surgical patients per hospital. These are the estimates used for powering Aim 1. As displayed in **TABLE 3.2**, these sample sizes are adequate to detect odds ratios as low as 1.103 (80% power; 0.05 alpha; 0.100 rho). Computations were performed using PASS 15.0.3 and used an autoregressive covariance structure (PASS 15 Power Analysis and Sample Size Software (2017).). This assumed that patient outcomes were more highly correlated to one another the closer in time their admissions took place relative to one another.

TABLE 3.2
Power Analysis Results

Rho	Odds Ratio
0.100	1.103
0.200	1.114
0.300	1.127

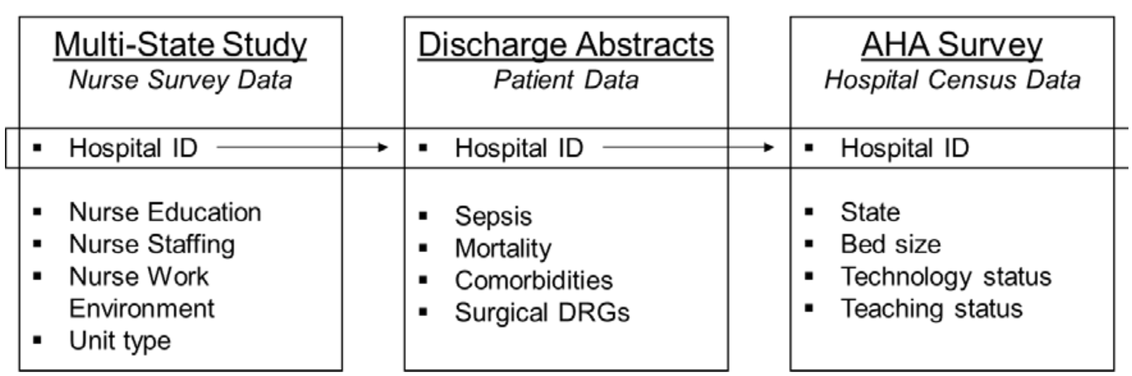
Notes: power: 80%; alpha: 0.05

Aim 2 is an exploratory aim. Prior research using the same data sources as in this study demonstrate that the large sample of patients and hospitals generate adequate power to detect differences in surgical patient outcomes associated with hospital nursing characteristics (Aiken et al., 2011, 2012).

Data Analysis

This study used cross-sectional data to examine the impact of hospital nursing resources (staffing, education, and the work environment) on the odds of sepsis and death after sepsis among postsurgical patients. Nurse survey, patient discharge, and American Hospital Association data sets from 2007 were linked using common hospital identifiers. **FIGURE 3.1** shows each dataset, its main variables of interest, and the common identifier used to merge each to the other. The resulting dataset included hospital-level measures of nursing resources, hospital characteristics, and patient-level demographics, comorbidities, procedures, and outcomes.

FIGURE 3.1
Construction of Analytical File



The steps for constructing the analytic dataset were as follows:

Nurse Survey. (1) The Multi-State Nursing Care & Patient Safety Study survey data were cleaned for staff nurses working in the hospital setting and providing direct patient care. Nurses who reported that their last shift and permanent unit was outpatient were excluded. **(2)** Hospitals with fewer than 10 nurse respondents on units included in the staffing variable (everything but the emergency department, psychiatric and labor/delivery units, and the outpatient setting) were dropped. **(3)** Hospital-level variables for nurse education, staffing, and the work environment were created from nurses' responses to survey questions.

AHA Survey. (1) Hospital census data were cleaned for adult, nonfederal, acute care hospitals. **(2)** Variables for bed size, technology status, and teaching status were created, as well as dummy variables for hospital state.

Patient Discharge Abstracts*.* Starting with a dataset containing only patients in general, orthopedic, and vascular surgery groups with DRG coding as outlined in **TABLE A1** (**APPENDIX A**), **(1)** the data were cleaned for ages 18-85 years, inclusive. **(2)** A new dichotomous variable to identify patients with sepsis was generated using the ICD-9 codes outlined in **TABLE A2**. **(3)** Patient comorbidities for Elixhauser's risk adjustment were identified using ICD-9 codes.

Merge*.* The three datasets were merged into one patient-level analytical file using a hospital identifier common to all datasets. Only the 503 hospitals with information in all three datasets were retained in the final analytical file.

Risk Adjustment*.* AHRQ notes the importance of risk adjustment for its postsurgical sepsis PSI (*Guide to Patient Safety Indicators* 2003), and controlling for patient characteristics is essential in order to effectively isolate the influence of hospital nursing on postsurgical sepsis. Risk adjustment in administrative data is limited, but Elixhauser controls are designed specifically "for use with administrative data" (Elixhauser, Steiner, Harris, & Coffey, 1998). The Elixhauser model is well-established with validated performance in ICD-9 data (Li, Evans, Faris, Dean, & Quan, 2008).

In addition to controlling for comorbidities, other patient characteristics with empirical relationships to sepsis as demonstrated in published research were included in the analyses: **sex** (Mokart et al., 2005; Sakr et al., 2013), and **age** (Mayr et al., 2014). To control for variation by procedure in postsurgical sepsis incidence and mortality (Vogel et al., 2010), the 98 DRGs in this study were collapsed to combine DRGs with and without complications in the same group, an approach used by Silber and colleagues (Silber, Gleeson, & Zhao, 1999). A total of 61 collapsed DRG groups were used in the risk adjustment. In the Aim 2 analyses, all patients in the sample have the same complication (sepsis), providing uniformity of illness, which is considered a strength in FTR analyses.

Analytic Approach

Descriptive Statistics. The first level of analysis was descriptive. This included examining the distribution of hospitals by each institutional characteristic (state, teaching and technology status, & bed size) and nursing characteristic (staffing, education, and the work environment). Similarly, the distribution of patients by age, sex, and surgical group were analyzed as a full surgical patient population and a postsurgical sepsis population. Pearson chi-square analysis generated p-values to assess significance of differences in frequencies across categories. The distribution of patients and nurses across hospitals was also examined. Two-sample t-tests assessed the differences in comorbidities between postsurgical patients with and without sepsis. The distribution of hospital-level rates of postsurgical sepsis and death after sepsis was analyzed for all surgical patients – in aggregate and stratified by surgical group. An initial descriptive look at Aim 1 and Aim 2 tabulated hospital sepsis and mortality rates by each nursing resource at three quality levels (poor, mixed, and good). One-way analysis of variance (ANOVA) tested the degree of significance in difference between means across quality levels.

Specific Aim 1. Aim 1 examined the impact of hospital nurse staffing, education, and work environment on the odds of sepsis among postsurgical patients. Multivariate logistic regression modelled these associations and accounted for clustering of individual patients within hospitals. Bivariate models of each nursing resource separately were followed by multivariate models incorporating patient and hospital characteristics, respectively:

1. $\log\left(\frac{P_{ij}}{1-P_{ij}}\right) = \alpha + \mathbf{N}'j\boldsymbol{\beta}N + \varepsilon$

Where…

a. $\frac{P_{ij}}{1-P_{ij}}$ is the probability of sepsis (a binary outcome) for the i^{th} patient in the j^{th} hospital

b. α is the constant intercept term
c. $\mathbf{N}'j$ represents a vector of the nursing characteristics for the j^{th} hospital
d. $\boldsymbol{\beta}N$ is a vector of coefficients representing the effect of the nursing characteristics
e. ε is a random error term

2. $\log\left(\frac{P_{ij}}{1-P_{ij}}\right) = \alpha + \mathbf{N}'j\boldsymbol{\beta}N + \mathbf{X}'ij\boldsymbol{\beta}X + \varepsilon$

Where, in addition to those variables already described above…
a. $\mathbf{X}'ij$ represents a vector of the characteristics of patient *i* for the j^{th} hospital
b. $\boldsymbol{\beta}X$ is a vector of coefficients representing the effect of the patient characteristics

3. $\log\left(\frac{P_{ij}}{1-P_{ij}}\right) = \alpha + \mathbf{N}'j\boldsymbol{\beta}N + \mathbf{X}'ij\boldsymbol{\beta}X + \mathbf{H}'j\boldsymbol{\beta}H + \varepsilon$

Where, in addition to those variables already described above…
a. $\mathbf{H}'j$ represents a vector of the hospital characteristics for the j^{th} hospital
b. $\boldsymbol{\beta}H$ is a vector of coefficients representing the effect of the hospital characteristics

For all three models, nursing, patient, and hospital characteristics were defined as follows:

Nursing characteristics: hospital nurse staffing, education, and work environment. Each model was used four separate times: once for each nursing resource (for a total of three iterations), and once with all three nursing resources included jointly in the same model. Because the work environment variable included a subscale ("Staffing and Resource Adequacy") that is conceptually similar to the direct staffing variable, the joint models used a modified work environment variable based on the remaining four subscales.

Patient characteristics: patient age, patient sex, 31 dummy variables for Elixhauser comorbidities, and 61 dummy variables for surgical DRGs.

Hospital characteristics: hospital state, bed size, teaching status, technology status, and a variable for the percent of nurse survey respondents reporting from the ICU and medical/surgical units, respectively.

Specific Aim 2. Using the same cross-sectional dataset as *Aim 1*, this aim analyzed a subset of the larger sample: only those surgical patients who developed sepsis. While *Aim 1* examined the relationship between nursing resources and the occurrence of sepsis, *Aim 2* explored the relationship between occurrence of death among septic patients and nursing resources. The association between nursing resources and patient-level 30-day mortality (a dichotomous variable), was modeled using logistic regression following the same pattern as outlined above for *Aim 1* (1-3).

Protection of Human Subjects

This study used secondary data from patient discharge abstracts, a survey of nurses, and a survey of hospitals. *Nurses*. The Multi-State Nursing Care & Patient Safety Study protocol was NINR-funded and approved by the University of Pennsylvania IRB. Nurses were selected at random from their state licensure databases. The data for this study did not include personal identifiers, and responses were aggregated to the hospital level, further protecting the identity of individual nurse respondents. *Patients.* This study included patients of ages 18 to 85 years and who were hospitalized for general, orthopedic, or vascular surgical procedures. Administrative claims data are retrospective and de-identified. Patients were not recruited for this study. *Data Security*. A secure server at the University of Pennsylvania School of Nursing stored all study data. *Risk-Benefit Analysis*. This study represents a minimal risk to patients, nurses, and hospitals. The results will advance an understanding of how hospital nursing affects postsurgical sepsis. These findings will inform how hospital administrators shape their nursing workforce to achieve better patient outcomes. Sepsis is major problem in terms of morbidity, mortality, and costs. System-level interventions, such as those informed by this study, have the potential to impact a broad set of patients. There is no burden on study participants when using secondary data. The strong benefits of this study outweigh its minimal risks. The University of Pennsylvania IRB determined that this study was exempt from review on March 8, 2018 (protocol #829457).

Summary

This study merged data on nurses, patients, and hospitals to investigate whether modifiable hospital nursing characteristics help explain why sepsis outcomes vary by hospital. The results will inform actionable system-level interventions as potential solutions to improve postsurgical patient outcomes.

CHAPTER 4: RESULTS

Introduction

The purpose of this study was to expand the understanding of the relationship between hospital nursing-related structural characteristics and patient outcomes. Specifically, the aims were to determine the relationship between hospital nursing resources and postsurgical patient outcomes. The impact of nurse staffing, education, and the work environment, on the odds of and outcomes from sepsis was the focus of analyses. This chapter presents the results of that work, beginning with descriptive statistics and progressing to regression analyses. The principal hypothesis was that patients cared for in hospitals with better nurse staffing, education, and the work environment would experience lower odds of postsurgical sepsis and lower odds of 30-day mortality after sepsis.

Characteristics of the Samples

TABLE 4.1 presents a summary of hospital characteristics. The largest number of hospitals (37%) were located in California and the least (14%) in New Jersey. Most were non-teaching (49%) or minor teaching (42%) hospitals, and the sample evenly represented high- and low-technology institutions. In terms of size, about half (51%) were large hospitals having at least 250 beds. Hospital nursing resources varied by institution. The average nurse in the average hospital cared for 5 patients on any given shift, but this value ranged from 2 to 13 across all hospitals. In the average hospital, 39% of registered nurses had a BSN or higher, but this value ranged from 0-77% across all hospitals. Finally, the average hospital work environment received a score of 2.7 on the PES-NWI, with a range of 2.1 to 3.4 (possible range: 1-4).

TABLE 4.1
Hospital Characteristics (n=503)

State	**n (%)**
California	186 (37)
Florida	135 (27)
Pennsylvania	113 (22)
New Jersey	69 (14)
Teaching Status	
Non-teaching	248 (49)
Minor teaching	212 (42)
Major teaching	43 (9)
Technology Status	
High technology	253 (50)
Low technology	250 (50)
Hospital Size	
Small (≤100 beds)	31 (6)
Medium (101-250 beds)	214 (43)
Large (≥250 beds)	258 (51)
Staffing (*mean patients/nurse*)	
<4	107 (21)
4-<5	192 (38)
5-<6	114 (23)
6-<7	56 (11)
≥7	34 (7)
Mean (SD)	5 (1.3)
Range	2-13
Education (*% nursing staff with a BSN or higher*)	
0-<20%	35 (7)
20-<30%	88 (18)
30-<40%	151 (30)
40-<50%	134 (27)
≥50	95 (19)
Mean (SD)	39 (13)
Range	0-77
Work Environment*	
Poor	126 (25)
Mixed	252 (50)
Good	125 (25)
Mean (SD)	2.7 (0.2)
Range	2.1-3.4

Notes: *Work Environment: the average response of nurses by hospital to the PES-NWI (possible range, 1-4)

TABLE 4.2 presents the distribution of patients and nurses across hospitals. Aim 1 analyzed all 1,435,919 surgical patients. These patients were distributed across all hospitals with an average of 2,855 patients per hospital. Aim 2 analyzed a subgroup of this population: those 25,135 patients with a secondary diagnosis of sepsis. The average hospital had 50 surgical sepsis patients. A total of 23,603 nurse responses to the Multi-State Nursing Care & Patient

Safety Study nurse survey informed hospital nursing resource characteristics. Hospitals, on average, had 47 nurse respondents.

TABLE 4.2
Patients and Nurses per Hospital by State

	Patients		
State (hosp. n)	**All Surgical** (n=1,435,919)	**Surgical Sepsis** (n=25,135)	**Nurses** (n=23,603)
California (186)	3,211 (1,876) 102-12,817	59 (34) 0-189	39 (23) 13-131
Florida (135)	2,281 (1,391) 163-7,378	38 (26) 0-138	39 (30) 11-151
Pennsylvania (113)	3,180 (3,014) 220-21,705	44 (43) 0-326	52 (37) 12-206
New Jersey (69)	2,484 (1,935) 454-11,423	57 (36) 8-206	75 (49) 23-237
All (503)	2,855 (2,128) 102-21,705	50 (36) 0-326	47 (35) 11-237

Format: mean (standard deviation)
minimum-maximum

Notes: Hospitals with <10 nurse respondents on non-emergency room, -outpatient, -psychiatric, and -labor & delivery units were excluded from the study.

TABLE 4.3 presents the characteristics of patients in this study, comparing those with sepsis to the full surgical patient sample. The demographic composition of surgical sepsis patients differed significantly from the overall sample. In terms of age, the distribution of septic patients shifted to the oldest age categories compared to the overall surgical patient population. Over half (52.7%) of septic patients were 66 years or older, compared to 37.4% in the full sample. While more than a quarter (25.6%) of all surgical patients were ages 18-45, patients in this age category comprised only 12.2% of septic patients. The overall population was mostly male (56%), but septic patients were disproportionately female (54.7%).

The distribution of patients across surgical groups is significantly different among all surgical patients compared to surgical sepsis patients. While just over half (51%) of all patients had undergone an orthopedic surgical procedure, only 18% of those with surgical sepsis were orthopedic patients. Conversely, vascular patients represented only 5% of all surgical cases in the study, but 22% of all surgical sepsis patients. General surgery patients represented 45% of all surgical patients, but composed 60% of surgical sepsis patients.

TABLE 4.3
Characteristics of All Surgical and Surgical Sepsis Patients

		All Surgical Patients (n=1,435,919)	Surgical Sepsis Patients (n=25,135)	p-value
Demographics				
Age	18-45	368,233 25.6%	3,055 12.2%	<0.001
	46-55	253,780 17.7%	3,740 14.9%	
	56-65	276,861 19.3%	5,095 20.3%	
	66-75	279,699 19.5%	6,151 24.5%	
	76-85	257,346 17.9%	7,094 28.2%	
Sex	Male	804,222 56.0%	11,396 45.3%	<0.001
	Female	631,664 44.0%	13,739 54.7%	
Surgical Group				
General		633,023 44.9%	15,049 59.9%	<0.001
Orthopedic		712,436 50.5%	4,609 18.3%	
Vascular		65,325 4.6%	5,477 21.8%	

Format: number
percent

Notes: p-values were calculated using Pearson chi-square.

There is a higher rate of sepsis among vascular and general surgery patients than among orthopedic surgery patients. A look at the specific procedures in each group begins to explain some of this difference. The most common surgical procedures within each surgical group are presented in **APPENDIX A (TABLE A3)**. Of the 98 DRGs included in this study (see **TABLE A1**), the 14 listed in **TABLE A3** represent over half of the total patient population. A third (34%) of all orthopedic procedures involved the replacement or reattachment of major joints or limbs of the lower extremity. These are typically scheduled, elective procedures and, especially in large hospitals, are likely performed by surgeons who see large volumes of these types of patients. Nearly half (49%) of all vascular patients underwent major cardiovascular procedures with complications. These are not necessarily planned, elective procedures and, by definition, they involve complications.

TABLE 4.4 presents the Elixhauser comorbidity profile of the overall surgical patient sample, as well as a side-by-side comparison of septic and non-septic patients in the study. On average, septic patients had significantly more – over twice as many – comorbidities than non-septic patients (3.6 vs. 1.6 comorbidities). A quarter or more of all septic patients had fluid and electrolyte disorders (45%), cardiac arrhythmias (30%), uncomplicated hypertension (27%), renal failure (26%), and/or congestive heart failure (25%). Septic patients had significantly higher rates of these and every comorbidity, except four: uncomplicated hypertension, obesity, hypothyroidism, and depression.

Some of the comorbidities are synonymous with certain elements of sepsis. For example, hypotension is a component of septic shock and may very well register among “Fluid and Electrolyte Disorders” (which in turn may generate cardiac arrhythmias). Similarly, “Renal Failure” would be present in virtually every case of severe sepsis as kidney function is particularly susceptible to hypotension. Finally, several comorbidities (metastatic cancer, solid tumor, lymphoma, and AIDS/HIV) imply an immunocompromised state and may increase the risk of infection.

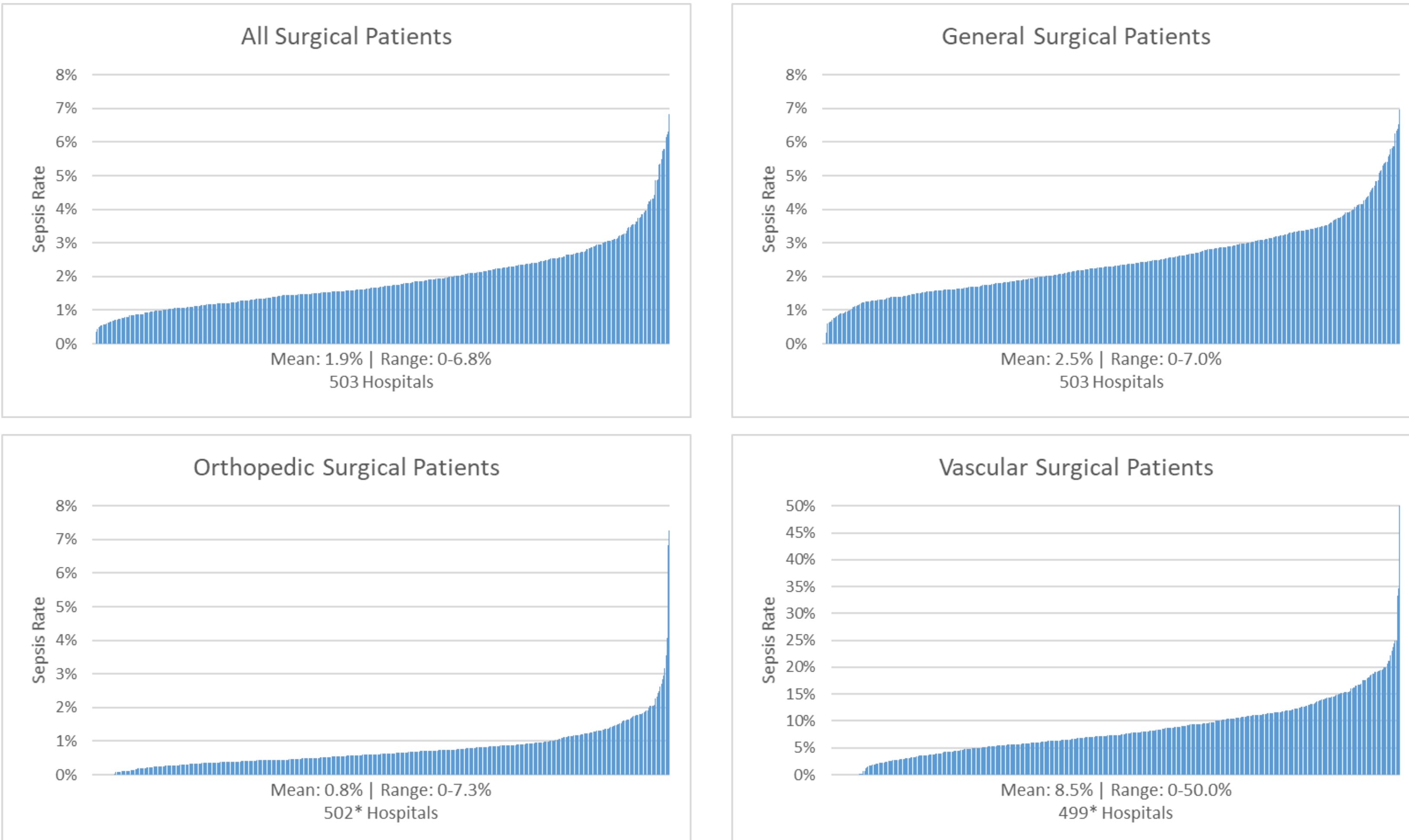
TABLE 4.4
Elixhauser Comorbidities among all Patients and with/without Sepsis

		Sepsis		
		Yes (n=25,135)	No (n=1,410,784)	Overall (n=1,435,919)
Number of Comorbidities	Mean (SD)	3.6 (2.2)	1.6 (1.6)	1.7 (1.6)
	Range	0-13	0-14	0-14
Fluid and Electrolyte Disorders		44.5%	9.2%	9.8%
Cardiac Arrhythmias		30.0%	10.3%	10.7%
Hypertension, Uncomplicated		27.1%	40.3%	40.0%
Renal Failure		25.5%	4.2%	4.5%
Congestive Heart Failure		25.2%	5.3%	5.7%
Chronic Pulmonary Disease		22.6%	13.9%	14.1%
Hypertension, Complicated		22.1%	4.1%	4.4%
Diabetes, Uncomplicated		17.5%	14.0%	14.1%
Weight Loss		14.6%	1.3%	1.5%
Coagulopathy		13.7%	1.7%	1.9%
Diabetes, Complicated		11.2%	2.8%	3.0%
Peripheral Vascular Disorders		10.2%	3.5%	3.6%
Liver Disease		9.6%	2.6%	2.7%
Other Neurological Disorders		9.3%	2.8%	2.9%
Valvular Disease		8.5%	4.4%	4.5%
Metastatic Cancer		8.2%	3.3%	3.4%
Obesity		7.4%	8.5%	8.5%
Depression		7.1%	7.5%	7.5%
Hypothyroidism		6.7%	8.7%	8.7%
Alcohol Abuse		5.4%	2.2%	2.3%
Solid Tumor Without Metastasis		4.9%	1.7%	1.8%
Blood Loss Anemia		3.9%	1.2%	1.2%
Drug Abuse		3.9%	1.6%	1.7%
Pulmonary Circulation Disorders		3.7%	1.0%	1.1%
Rheumatoid Arthritis/Collagen Vascular		2.9%	2.3%	2.3%
Deficiency Anemia		2.8%	1.2%	1.2%
Paralysis		1.9%	0.7%	0.7%
Psychoses		1.6%	0.6%	0.7%
Peptic Ulcer Disease Excluding Bleeding		1.3%	0.6%	0.6%
Lymphoma		1.2%	0.4%	0.4%
AIDS/HIV		0.6%	0.1%	0.2%

Notes: Two-sample t-tests examined the difference between septic and non-septic patients for each comorbidity. All were highly significant ($p<0.001$) except for "Depression", which, while still significant, had a p-value of 0.0434.

As presented in **FIGURE 4.1**, hospital-level rates of sepsis vary widely across hospitals and within all surgical groups. The average hospital rate of sepsis for all surgical patients was 1.9%, but some hospitals in each surgical group category had no septic patients, while the maximum sepsis rate for all surgical patients reached 6.8%. Hospital rates of sepsis among vascular patients were the highest on average (8.5%) and varied across the greatest range (0 to 50%), requiring a y-axis of a different scale than the other groups to accommodate the data. Mean hospital rates of sepsis were lowest among orthopedic patients (0.8%).

FIGURE 4.1
Variation in Postsurgical Sepsis Rates across Hospitals



Notes: 1 hospital had no orthopedic patients, and 4 hospitals lacked vascular patients, resulting in lower hospital ns for these two surgical groups (502 & 499, respectively). The y-axis for vascular patients is of a different scale than that of the other three graphs presented.

Similarly, hospital-level rates of mortality among postsurgical sepsis patients also vary by hospital across all surgical groups. **TABLE 4.5** presents hospital-level rates of 30-day mortality among all surgical patients, as well as stratified by septic and non-septic patients. Mortality is much higher among septic (22.3%) than among non-septic (1.4%) patients in all surgical groups. The difference in mortality between septic and non-septic patients is least among vascular patients, who experience a high mortality rate even without sepsis. However, even here, septic patients experience mortality at a rate (22.2%) that is nearly three times that of their non-septic counterparts (8.4%).

TABLE 4.5
Hospital-Level Rates of 30-day Mortality by Sepsis and Surgical Group

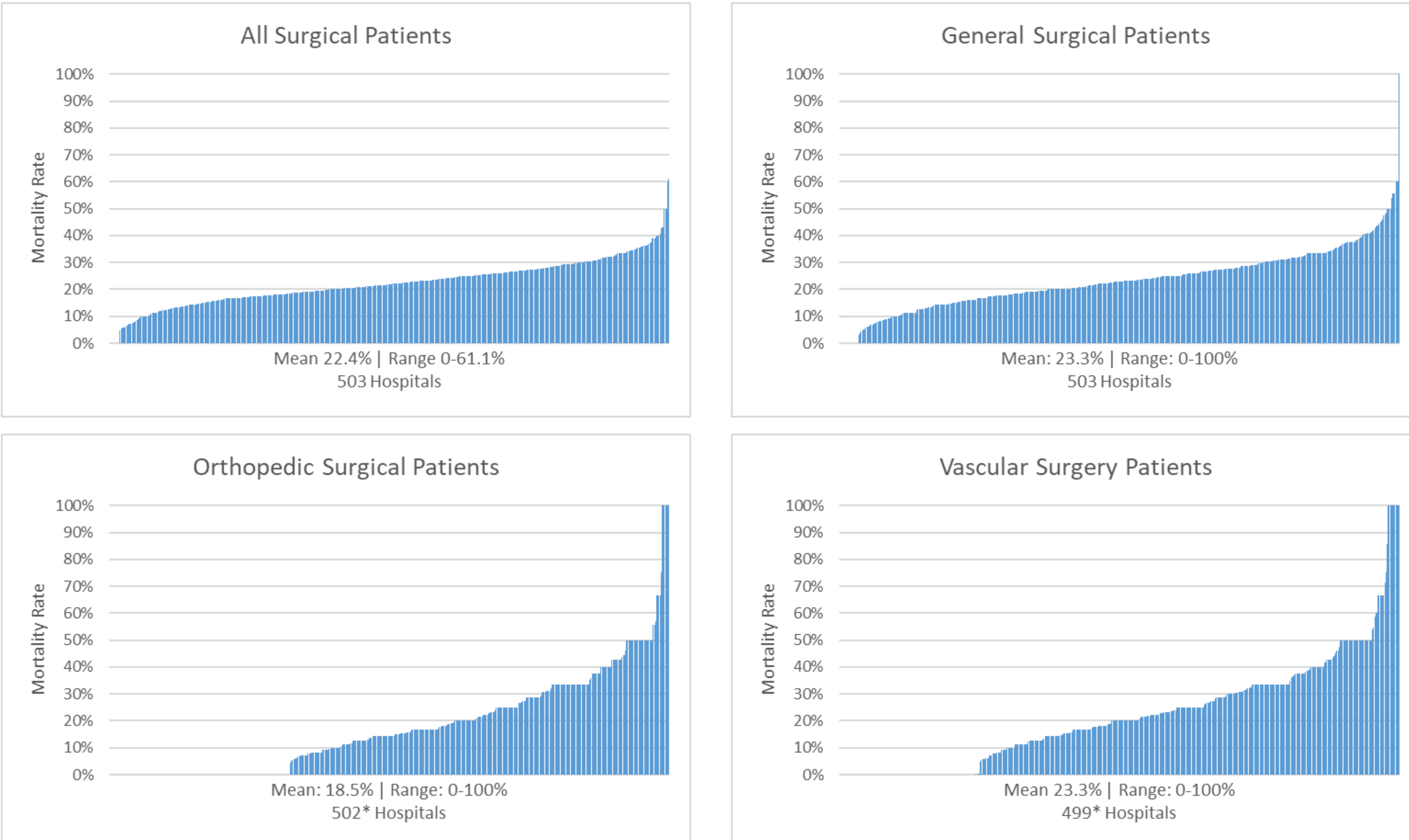
Surgical Group (hosp. n)	Sepsis		All Surgical Patients
	Yes	No	
General (503)	23.3% (11.3) 0.0-100.0	1.4% (0.7) 0.0-5.3	2.0% (0.8) 0.0-7.1
Orthopedic (502*)	17.8% (18.8) 0.0-100.0	0.9% (0.9) 0.0-16.7	1.0 (1.0) 0.0-16.7%
Vascular (499*)	22.2% (20.5) 0.0-100.0	8.4% (5.2) 0.0-50.0	9.5% (5.0) 0.0-40.0
All Surgical Groups (503)	22.3% (8.5) 0.0-61.1	1.4% (0.6) 0.0-4.1	1.8% (0.7) 0.0-5.1

Format: mean (standard deviation)
minimum-maximum

Notes: *1 hospital had no orthopedic patients, and 4 hospitals lacked vascular patients, resulting in lower hospital n's for these two surgical groups.

FIGURE 4.2 presents the institution-level sepsis patient 30-day mortality rate for each hospital and for all surgical patients and by each surgical group. Not unlike the hospital-level rates of sepsis shown in **FIGURE 1**, there is a range of mortality rates and hospitals fall on a continuum. What is striking among both orthopedic and vascular surgery patients are the hospitals on the extreme high and low ends of the graph. A quarter to a third of all hospitals registered no deaths among postsurgical sepsis patients (among vascular and orthopedic patient, respectively). And yet, in other hospitals, 50% or more of all postsurgical septic patients died.

FIGURE 4.2
Variation in Rates of Mortality after Sepsis across Hospitals



Notes: 1 hospital had no orthopedic patients, and 4 hospitals lacked vascular patients, resulting in lower hospital ns for these two surgical groups.

Analysis of Specific Aims

Chapter 3 details the methods and approach for the following sequence of analyses. **TABLE 4.6** and **TABLE 4.7** present the results of these analyses. In both tables, Model 1 includes just the primary independent and dependent variables of interest. When the nursing resources are modelled separately, this is a bivariate model. Each subsequent model adds to the previous model's structure. Model 2 adjusts for patient characteristics (age, sex, 31 comorbidities, and 61 collapsed surgical DRGs), and Model 3 adds hospital and nursing characteristics.

Specific Aim 1: Determine the relationship between hospital nursing resources (staffing, education, and the work environment) and the odds of sepsis among surgical patients.

***Hypothesis 1*:** Surgical patients in hospitals with better nursing resources will experience lower odds of sepsis.

As shown previously in **FIGURE 4.1**, the rate of postsurgical sepsis varies greatly by hospital. Aim 1 explores whether and to what extent hospital nursing resources explain this variation using logistic regression to model the impact of hospital nurse staffing, education, and the work environment on the odds of sepsis.

TABLE 4.6 presents the results of logistic regression indicating the unadjusted and adjusted impact of nursing resources on the odds of sepsis. Even after adjusting for patient, hospital, and nursing characteristics (model 3), the work environment had a significant association with odds of sepsis. Each one-unit increase in the work environment (from "poor" to "mixed", or "mixed" to "good") was associated with a 7% decrease in the odds of sepsis (OR 0.93 p=0.002). A 2-unit increase in the work environment (an improvement from "poor" to "good") would be associated with a 14% decrease in odds of sepsis ($0.93^2 = 0.86$). The average hospital with a poor work environment in this study cared for 1,946 surgical patients, 37 of whom developed sepsis. Had they been cared for in a good work environment, the reduced probability of sepsis translates to 4 fewer cases of sepsis, a reduction of 11%. If all the patients in both the poor and mixed work environments had been cared for in good work environments, 1,336 cases of sepsis could have been averted (5.3% fewer sepsis cases). Whether work environment was modelled separately from or jointly with staffing and education had a negligible impact on the effect size and significance in the fully adjusted (model 3) models. Both staffing (in models 1 and 2) and education (in model 2) achieve a statistically significant effect size, but in a direction opposite that of the stated hypothesis. The additional controls in model 3 nullify this effect and, in the case of staffing, reverse the direction of impact on odds of sepsis, but without achieving significance.

TABLE 4.6

Unadjusted and Adjusted Impact of Nursing Resources on the ODDS OF SEPSIS (patient n=1,435,919)

	Staffing		Education		Work Environment	
Model	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Nursing Resources Modelled Separately						
Model 1	0.96 (0.93-0.99)	0.013	1.02 (0.99-1.06)	0.201	0.91 (0.86-0.97)	0.003
Model 2	0.97 (0.95-1.00)	0.026	1.04 (1.01-1.06)	0.007	0.96 (0.92-1.01)	0.086
Model 3	1.01 (0.99-1.04)	0.285	1.01 (0.98-1.03)	0.551	0.93 (0.89-0.97)	0.002
Nursing Resources Modelled Jointly						
Model 1	0.95 (0.91-0.99)	0.007	1.02 (0.98-1.06)	0.297	0.90 (0.84-0.96)	0.003
Model 2	0.97 (0.95-1.00)	0.042	1.04 (1.01-1.06)	0.012	0.94 (0.89-0.99)	0.014
Model 3	1.01 (0.98-1.04)	0.569	1.01 (0.99-1.04)	0.321	0.93 (0.90-0.99)	0.010

Notes: Model 1: nursing resource(s) and outcome variables only
Model 2: adjusted for patient age, sex, 31 comorbidities, & 61 surgical patient DRGs
Model 3: adjusted for Model 2 + hospital characteristics (state, bed size, teaching status, and technology status) and nursing characteristics (proportion med-surg and ICU unit type).
All models adjusted for clustering of patients within hospitals.

Specific Aim 2: Determine the relationship between hospital nursing resources and septic patient 30-day mortality among surgical patients who develop sepsis.

***Hypothesis 2*:** Surgical patients in hospitals with better nursing resources will experience lower odds of 30-day mortality after sepsis.

The analysis of Aim 2 followed the same pattern as Aim 1, but with a different population and outcome. Aim 2 examined the impact of hospital nursing resources on 30-day mortality among those patients who developed sepsis. This analysis helped explain the significant variation in postsurgical sepsis mortality across hospitals as shown in **FIGURE 4.2**.

TABLE 4.7 presents the results of logistic regression indicating the unadjusted and adjusted impact of nursing resources on the odds of 30-day mortality among postsurgical patients with sepsis. Education had an association with odds of death after sepsis that was consistently statistically significant across all models. Each one-unit increase in education (an additional 10% BSN-prepared nursing staff) was associated with a 6% decrease in odds of death (OR 0.94; $p<0.001$) in fully-adjusted models with and without staffing and work environment modelled jointly. A 2- and 3-unit increase (20% and 30% increase in BSN-prepared staff) would be associated with a 12% and 17% decrease in odds of death after sepsis, respectively ($0.94^2 = 0.88$; $0.94^3 = 0.83$). The average hospital nursing staff in this study was 39% BSN-prepared and they cared for 50 surgical sepsis patients, 11 of whom died. Had these patients been cared for in a hospital where all of the nurses were BSN-prepared, the corresponding 31% reduction in odds of death after sepsis ($0.94^{5.9} = 0.69$) could have averted at least 2 deaths (18% decrease).

TABLE 4.7

Unadjusted and Adjusted Impact of Nursing Resources on the ODDS OF DEATH after Sepsis (patient n=25,135)

	Staffing		Education		Work Environment	
Model	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Nursing Resources Modelled Separately						
Model 1	1.02 (0.99-1.05)	0.225	0.96 (0.93-0.98)	<0.001	1.01 (0.95-1.06)	0.823
Model 2	1.04 (1.01-1.08)	0.023	0.94 (0.92-0.97)	<0.001	0.95 (0.90-1.01)	0.121
Model 3	1.03 (0.99-1.07)	0.192	0.94 (0.91-0.97)	<0.001	0.98 (0.92-1.04)	0.484
Nursing Resources Modelled Jointly						
Model 1	1.01 (0.98-1.04)	0.601	0.96 (0.93-0.98)	0.001	1.02 (0.97-1.07)	0.497
Model 2	1.02 (0.98-1.05)	0.279	0.95 (0.92-0.98)	0.002	0.97 (0.92-1.03)	0.367
Model 3	1.01 (0.97-1.05)	0.641	0.94 (0.92-0.97)	<0.001	0.99 (0.93-1.05)	0.640

Notes: Model 1: nursing resource(s) and outcome variables only
Model 2: adjusted for patient age, sex, 31 comorbidities, & 61 surgical patient DRGs
Model 3: adjusted for Model 2 + hospital characteristics (state, bed size, teaching status, and technology status) and nursing characteristics (proportion med-surg and ICU unit type).
Mortality estimated among septic patients only.
All models adjusted for clustering of patients within hospitals.

Sensitivity Analyses

Given the variety of sepsis definitions and variation in sepsis incidence and mortality, the following sensitivity analyses helped verify the main findings of this study using two approaches: 1) an alternate, more conservative, definition of sepsis, and 2) an alternate risk adjustment method.

1. Alternate Sepsis Definition. This study was aligned with existing failure to rescue research. Conceptually, it is an analysis of odds of death after developing a complication (in this case, sepsis), and the patient population (general, orthopedic, and vascular surgery groups) matches that of published failure to rescue literature (Aiken et al., 2012; Carthon et al., 2012; Kendall-Gallagher, Aiken, Sloane, & Cimiotti, 2011). This study, therefore, employs Silber and colleague's definition of sepsis from their failure to rescue work (Silber et al., 2007). However, the clinical criteria for sepsis have evolved with time and likewise there is variation in definitions of sepsis used in research. Even among studies using ICD-9 codes, as this one does, there is a lack of consensus as to the authoritative list of sepsis codes, and different methods yield different estimates of sepsis incidence and mortality (Gaieski et al., 2013).

*PSI Sepsis***.** To substantiate the findings outlined earlier in this chapter, the regression analyses were repeated using an alternate postsurgical sepsis definition based on a measure developed by the Agency for Healthcare Research and Quality (AHRQ) as a "patient safety indicator" for hospital quality benchmarking (*Guide to Patient Safety Indicators* 2003). **APPENDIX B** contains the results of these analyses. **TABLE B1** displays side-by-side the ICD-9 codes for both Silber's failure to rescue (FTR) sepsis and AHRQ's patient safety indicator (PSI) sepsis definitions, highlighting areas where they differ. One of the primary differences in ICD-9 coding is that PSI sepsis includes infection-related SIRS and postoperative shock, whereas FTR sepsis does not. While FTR sepsis uses fewer codes, PSI is the more conservative definition, identifying a smaller patient population as shown in **TABLE B2**, (2,840 fewer patients or 11% smaller than the FTR sepsis population).

TABLE B3 and **TABLE B4** present the results of logistic regression estimating the impact of hospital nursing resources on the odds of PSI sepsis and death after PSI sepsis, respectively. The format mirrors **TABLE 4.6** and **TABLE 4.7** but the analysis employs an alternative sepsis definition using the ICD-9 codes from AHRQ (PSI sepsis). Overall, the definition makes little difference in terms of how nursing resources broadly impact odds of postsurgical sepsis and odds of death among these septic patients. The few areas of difference generally strengthened the associations presented with FTR sepsis and were more consistent with the stated hypotheses. Changes in statistical significance between sepsis definitions were primarily in model 2 across all nursing resources. The adjustments in these cases often made achieving significance (or not) consistent across models 1, 2, and 3 in the PSI sepsis analysis where it varied in the FTR sepsis analysis. Poor staffing was significantly associated with a higher odds of PSI sepsis in model 3. Each additional patient per nurse assignment was associated with a 3% increase in odds of PSI sepsis (OR: 1.03; p=0.049). This association was not significant in the FTR sepsis analysis.

2. Alternate Risk Adjustment. Risk adjustment is an essential element of postsurgical sepsis analyses (*Guide to Patient Safety Indicators* 2003). Effectively controlling for patient characteristics helps to isolate the impact of hospital nursing. This study adjusted for patient age and sex, 61 collapsed surgical DRGs, and 31 Elixhauser comorbidities (Elixhauser et al., 1998). As noted previously, some of these comorbidities are synonymous with elements of the sepsis definition, or they contribute to determining the severity of sepsis, which influences mortality rates (Mayr et al., 2014). Including some of these comorbidities may diminish the apparent impact of nursing.

In the absence of a lookback period and/or ICD coding that notes whether a condition was present on admission, it is difficult to distinguish true comorbidities from complications. Glance et al. (2006) found that 43% of coagulopathies and 25% of fluid and electrolyte disorders were misclassified as comorbidities (Glance, Dick, Osler, & Mukamel, 2006). On these grounds, some studies have excluded these two comorbidities from their risk adjustment when examining the impact of nursing on surgical patient outcomes (Aiken et al., 2011, 2012; Kutney-Lee et al., 2013; McHugh et al., 2013). This sensitivity analysis goes a step further, using an even more restricted set of comorbidities along with additional controls based on the AHRQ methodology for Patient Safety Indicator #13: Postoperative Sepsis Rate.

In addition to controlling for patient age, sex, and diagnosis, PSI #13 controls for whether a patient was transferred to the hospital and for 13 comorbidities: congestive heart failure (CHF), valvular disease, pulmonary circulation disorders, paralysis, chronic pulmonary disease, hypothyroidism, renal failure, liver disease, obesity, weight loss, alcohol abuse, depression, and complicated hypertension (Battelle, 2012). This is less than half of the comorbidities present in the full Elixhauser method (Elixhauser et al., 1998). The PSI #13 criteria exclude patients with 1) a coded principal diagnosis for infection or pressure ulcer, 2) any listed code for immunocompromised state or cancer, and/or 3) patients with length of stay less than 4 days (AHRQ, 2015). They also exclude patients with a primary diagnosis of sepsis and those in MDC 14 (pregnancy, childbirth, and puerperium), but these criteria did not apply to any of the patients in this study sample.

These exclusion criteria reflect the purpose of PSIs as quality benchmark indicators. Excluding these patients helps avoid penalizing or rewarding hospitals for spurious outcomes that are the product of case mix, not quality of care. The purpose of this study is different, and the impact of nursing on these patients is important, too. Rather than exclude them from the study, this sensitivity analysis accounts for them in the risk adjustment. The set of indicators includes 1) patient controls (age, sex, surgical DRGs), 2) an indicator for patients admitted from another facility, and 3) an indicator for each condition in the exclusion criteria (infection/pressure ulcer, immunocompromised state, and cancer).

***Sepsis Readmissions*.** The exclusion of patients with length of stay less than 4 days raises an important point. Hospitals that discharge their patients quickly may be sending patients away before sepsis fully develops and manifests. This would result in an artificially low rate of sepsis in these hospitals. **TABLE C2** (**APPENDIX C)** present the number of postsurgical patients readmitted with a principal diagnosis of sepsis within 30 days of discharge. Over a quarter (28%) of all patients who returned to the hospital within this period were readmitted within the first 5 days. Nearly 7% of all patients admitted within 30 days were readmitted on the day of discharge (day 0). Nearly one quarter (23.9%) of patients readmitted with sepsis as a primary diagnosis within 5 days had been coded for sepsis as a secondary diagnosis during their index hospitalization (**TABLE C3**).

Instead of dropping patients with length of stay less than 4 days, this sensitivity analysis added those 739 patients who were readmitted within 5 days with a principal diagnosis of sepsis to the septic patient population. **TABLE C4** and **TABLE C5** present the results of these analyses. There are no substantial differences in the fully adjusted models. A few coefficients from model 2 lost significance with the alternative risk adjustment, but in all cases, this improved consistency in significance across models.

CHAPTER 5: DISCUSSION AND CONCLUSION

Introduction

The origins of sepsis as a syndrome are quite literally ancient, but the problems sepsis presents are of immediate relevance in the modern world. Sepsis is a problem of grave importance to clinicians, patients, administrators, researchers, and policymakers. Despite capturing the attention of a diversity of stakeholders and generating expert consensus on clinical intervention recommendations, the rate of sepsis and mortality among septic patients varies significantly by hospital. From the patient's perspective, hospital choice is important and may represent a life-and-death situation. Such variation at the institutional level in the context of uniform practice recommendations calls to question how hospital characteristics impact the effectiveness of clinical interventions. The quality health outcomes model conceptualizes this relationship.

Hospital administrators are in charge of shaping institutional characteristics, including nursing resources. The Quality Health Outcomes Model proposes that the system context mediates the effectiveness of clinical interventions. In the context of this study, this means that the same sepsis intervention affects comparable surgical patients differently depending on the hospital's quality of nursing resources. Specifically, better nurse work environments were associated with lower odds of sepsis, and higher proportions of BSN-prepared nurses were associated with decreased odds of mortality among those patients who did develop sepsis. These resources are effective levers of change that do not require administrators to micromanage complex behavioral changes at the level of individual clinicians. Effective prevention and treatment are discrete mechanisms, as are the impacts of the work environment and nurse education. A comprehensive approach to creating hospital structures that foster and facilitate nursing excellence may help reduce cases of postsurgical sepsis and achieve better septic patient outcomes.

Discussion of Principal Findings: Specific Aim 1

Specific Aim 1 examined the impact of hospital nurse staffing, education, and work environment on the odds of sepsis among postsurgical patients. The hypothesized relationship was that improvements in nursing resources (higher proportions of BSN-prepared nursing staff, fewer patients per nurse on the average shift, and better work environments as measured by the PES-NWI) would be associated with lower odds of sepsis. Chapter 4 presents the full results of these analyses. While staffing and education were not significantly associated with postsurgical sepsis in the fully adjusted models, the work environment was significant in the fully adjusted models both when nursing resources were modelled separately and jointly. Each unit increase in the work environment variable (from “poor” to “mixed” or “mixed” to “good”) was associated with a 7% decrease in odds of postsurgical sepsis (OR 0.93; p=0.002).

The work environment composite score represents a multifaceted concept that reflects how well a hospital engages and supports its nursing staff. The Quality Health Outcomes Model proposes that these structural elements support or hinder nursing interventions, with implications for patient outcomes. Each of the PES-NWI’s 5 subscales – 1) Nurse Participation in Hospital Affairs, 2) Nursing Foundations for Quality of Care, 3) Nurse Manager Ability, Leadership, and Support of Nurses, 4) Collegial Nurse-Physician Relations, and 5) Staffing and Resource Adequacy – maintains a conceptual relationship with infection (and sepsis) prevention:

1. Nurse Participation in Hospital Affairs. This subscale evaluates opportunities for career development and advancement, the attentiveness of administrators to nurses, and the power and authority both clinical and administrative nurses have in shaping hospital policy and procedure. Hospital nurses are numerous and distributed throughout the hospital. They are intimately involved in patient care and know firsthand where hospital policies and procedures help or hinder their work. The relationship this study presents between the work environment and odds of sepsis suggests that nurses have valuable insight on patient care. Administrators who structure their hospital governance to listen and incorporate nurses’ perspectives benefit patients.

2. Nursing Foundations for Quality of Care. This subscale assesses the presence, strength, and clarity of a hospital’s nursing philosophy and care model, and how that sets standards of care and drives staff development. That a hospital has a nursing-specific care model and philosophy signals a recognition of the importance of nursing care and its impact. Hospitals that set the standard of care high and encourage the professional development of their nursing staff can expect higher quality outcomes, including lower odds of sepsis.

3. Nurse Manager Ability, Leadership, and Support of Nurses. This subscale focuses on the competencies of nursing supervisory staff and whether their management style is supportive and constructive. Managers, especially those in direct supervisory positions, can bring out the best in their staff through positive reinforcement and recognition of quality work, and a nondisparaging approach to addressing errors. They may also empower nurses to exercise full authority within their scope of practice by supporting appropriate decision-making. Nurses may know what to do and have the scope of practice to act accordingly, but a lack of confidence in leadership support engenders hesitancies, especially if there is a chance of generating conflict. Speed is a key characteristic of a successful response to sepsis. Delays are detrimental to the patient's wellbeing. Furthermore, nurses need to unreservedly contribute to septic patient care, not just by following physician orders, but also by expressing their clinical judgement and assessment with other members of the care team with complete confidence in the support of their supervisors.

4. Collegial Nurse-Physician Relations. This subscale assesses the state of nurse-physician working relationships, teamwork, and collaboration. When a nurse recognizes the signs of sepsis, good nurse-physician rapport facilitates open and honest communication and a collaborative response aided by effective team work. Early recognition and response are key pillars of successful sepsis interventions. If a nurse suspects sepsis, he/she should feel comfortable contacting the physician immediately, even if he/she is uncertain of his/her assessment. Any uncertainty as to how the physician will receive the nurse's call may encourage nurses to wait until sepsis presents more clearly before alerting the physician. This precious time wasted counts against the patient's wellbeing.

5. Staffing and Resource Adequacy. This subscale is the closest to a subjective equivalent of the nurse-to-patient ratio this study uses as its staffing variable. The analysis identified a mixed relationship between the staffing ratio variable and the odds of sepsis. In models 1 and 2, the association opposed the hypothesis, with additional patients per nurse associated with lower odds of sepsis. The direction of the effect reversed in model 3, but fell short of achieving statistical significance. The conceptual relationship between staffing and odds of sepsis is strong. Additional patients per nurse translates to less nursing time at each bedside and increasingly divided attention. This creates a situation of potential missed nursing care and cutting corners to expedite care processes. In this rushed setting, nurses are less likely to detect the signs of infection, and even if they do suspect something is wrong with the clinical picture, they may not have the presence of mind and luxury of time to connect the dots.

Despite the cogency of this hypothesis, the fact remains that this study did not find a relationship between its direct measure of staffing and odds of sepsis in the fully adjusted models. Whether and in what direction the "Staffing and Resource Adequacy" subscale contributes to the effect the overall work environment variable has on odds of sepsis is unclear from the primary analysis using a composite score of all five subscales. The analysis shown in **TABLE D1** (**APPENDIX D**) models each subscale as a discrete variable. In the fully adjusted models with each subscale modelled independently (Model 3), all subscales but "Collegial Nurse-Physician Relations" achieved significance. "Nurse Participation in Hospital Affairs" had the largest effect size (OR 0.92, $p<0.001$) and was the only subscale to retain a significant effect when all five subscales were modelled jointly in Model 4 (OR 0.92, $p=0.020$).

There are a few potential reasons for this apparent discrepancy in significance between the PES-NWI "Staffing and Resource Adequacy" subscale and the "Staffing" patient-to-nurse ratio variable. First, they are not identical variables. The PES-NWI subscale is subjective and encompasses more than staffing, while "Staffing" is an objective ratio. Second, and more likely the source of difference, a unit increase in the work environment variable is not equivalent to a unit increase in the staffing variable. The range for the PES-NWI score was 2.1-3.4, whereas the range for staffing was 2-13 (**TABLE 4.1**). Even after recoding the work environment variable as a 3-category ordinal variable, the difference in magnitude of a 1-unit increase in each variable remained substantially different. Finally, existing research demonstrates that nursing characteristics interact with one another. For example, in general surgical patients, reductions in patient mortality and FTR are associated with better nurse staffing, but not in hospitals with poor work environments. (Aiken et al., 2012). Similarly, the value of nurse specialty certification in reducing mortality and failure to rescue in general surgical patients is only realized in BSN-prepared nurses (Kendall-Gallagher, Aiken, Sloane, & Cimiotti, 2011). The impact of staffing on sepsis may be contingent on other variables, including education and the work environment. An analysis of how these variables interact with one another may provide a more nuanced understanding of the role staffing plays in sepsis prevention.

Application

Sepsis is a response to infection. Therefore, infection prevention *is* sepsis prevention. The means of preventing the spread of infections are well known. The most important measures are also the most basic: hand hygiene and the use of personal protective equipment. Specific interventions for postsurgical patients are also not complicated. Encouraging ambulation and incentive spirometer use reduces the risk of pneumonia, and timely discontinuation of indwelling urinary catheters helps prevent urinary tract infections (UTIs). Together, these interventions prevent the most common sources of sepsis. Given how straightforward these interventions are, the obstacles to implementing them are likely practical hurdles rather than dependent on expertise.

A good work environment helps remove these obstacles and supports nursing care activities. Consistent with the QHOM, the environment in which this vital workforce operates mediates their effectiveness in terms of achieving good patient outcomes. Valuing quality nursing care, supporting day-to-day nursing operations and long-term development, engaging nurses in hospital decision-making, and including them in the interdisciplinary care team are all interventions within administrators' realm of influence. Administrators may implement tested and effective nurse-driven protocols (NDPs), such as for discontinuing indwelling urinary catheters to reduce the catheter-associated UTIs (and sepsis). A more ambitious hospital-level nursing intervention with demonstrated success in improving patient outcomes is the Magnet® recognition program. Magnet® designation not only recognizes existing nursing excellence, the process of achieving Magnet® status is itself an intervention (Kutney-Lee et al., 2015).

Nurses represent a large expense on every hospital's budget. Applying for Magnet® recognition is an added expense, but it may help extract value from the initial hiring investment.

Improving the work environment may generate a return on investment through lower sepsis rates. Chapter 4 included an example of the average hospital with a poor work environment developing a good work environment and potentially averting 4 cases of sepsis. Among general surgery patients, the average added cost of sepsis per patient is $63,824, for a total of $255,296 for all 4 cases (Vaughan-Sarrazin, Bayman, & Cullen, 2011). This is a conservative estimate of the cost savings related to sepsis prevention only. System-level interventions, such as improving the work environment, affect all patients treated in the hospital setting and likely generate savings among other conditions as well.

Discussion of Principal Findings: Specific Aim 2

Specific Aim 2 explored the impact of hospital nurse staffing, education, and work environment on the odds of death among those postsurgical patients who developed sepsis. The hypothesized relationship was that improvements in nursing resources (higher proportions of BSN-prepared nursing staff, fewer patients per nurse on the average shift, and better work environments as measured by the PES-NWI) would be associated with lower odds of death. Chapter 4 presents the full results of these analyses. While staffing and the work environment were not significantly associated with postsurgical sepsis in the fully adjusted models, education stood out for its consistent and strong statistical significance across all models. Each unit increase in education (representing a 10% increase in BSN-prepared nursing staff) was associated with a 6% decrease in odds of death after postsurgical sepsis (OR 0.94; $p < 0.001$).

In Aim 1, the work environment impacts sepsis *prevention* in a way that education does not. In Aim 2, education mediates sepsis *treatment* in a way that the work environment does not. The fundamental difference in outcomes between the two aims is sepsis prevention vs. sepsis treatment. The key to effective sepsis treatment is early intervention. Hospitals increasingly have protocol-driven sepsis responses in place. However, a timely response depends on timely recognition of sepsis signs and symptoms. Nurses in direct-patient care roles have the patient exposure and scope of practice needed to collect and interpret these signals. The sooner they suspect sepsis, the sooner they can activate the appropriate response. Critical thinking informed by physical assessment and knowledge of pathophysiology aid nurses in collecting and interpreting clinical data. Baccalaureate programs emphasize these foundations, and nurse managers and Chief Nursing Officers notice the difference, especially in critical thinking skills (Goode et al., 2001; Weinberg, Cooney-Miner, Perloff, & Bourgoin, 2011).

The case for BSN-prepared nurses is not new. Decades of health services research have revealed the impact of baccalaureate education on patient outcomes (Aiken et al., 2003; Blegen, Goode, Park, Vaughn, & Spetz, 2013). Other countries have made BSN the entry-level nursing education, but the United States has been slower to respond in this way (Aiken, 2014). While it is still possible to become a registered nurse without a baccalaureate degree, recent policies and recommendations have indicated a preference for baccalaureate education in nursing. For example, in 2011 the Institute of Medicine called for more BSN-prepared nurses, targeting 80% of the workforce by 2020 (IOM, 2011) and, most recently, New York State passed legislation requiring nurses to earn a bachelor’s degree within 10 years of initial licensure. Achieving this 80% BSN benchmark among the hospitals in this study could have averted 15% of septic patient deaths, saving 818 lives. This number grows to 1,110 lives (20%) saved when the bachelor’s degree becomes the entry-level requirement and 100% of nurses are BSN-prepared.

The estimated savings through reduced readmissions and related charges more than compensate for the anticipated costs of achieving this goal (Yakusheva, Lindrooth, & Weiss, 2014). Nurse managers acknowledge that a BSN is value-added in a nurse (Weinberg et al., 2011) and the findings of this current study support hiring a BSN-prepared nursing workforce.

Limitations

As a cross-sectional analysis, this study is limited to identifying associations among variables and cannot assert causation. The results are still valuable insofar as nursing resources are indicative of postsurgical risk of sepsis and death after sepsis. However, it is unclear from this study alone whether improving nursing resources represents an intervention to lower postsurgical sepsis incidence and mortality, although the conceptual underpinnings suggest this direction of effect. A longitudinal study could help clarify this question.

The definition of sepsis has changed since the subjects in the current study were in the hospital. As discussed in Chapter 2, the 2015 definition made organ dysfunction the minimum severity level for an inflammatory response to infection to be sepsis. Sepsis under this new definition is equivalent to the former definition for severe sepsis (a term that is no longer in use). In effect, it is harder to qualify as septic and the resultant patient population this definition identifies is sicker. The findings of this study may or may not apply under this narrower definition. However, parsing the language is of secondary importance when considering this study's importance in its own right. The fact remains that the patients this study calls 'septic' experienced a complication of care and that the odds of these negative outcomes were lower for patients in hospitals with better nursing resources. The large, representative sample of hospitals in this study further diminish concerns regarding generalizability.

The impacts of hospital nursing may be larger than estimated in this study. The risk adjustment of individual patients using Elixhauser comorbidities, as mentioned in Chapter 4, may inadvertently control for sepsis severity and diminish the impact of nursing, especially on reducing the odds of mortality. Furthermore, this study uses patient discharge abstracts, which exist primarily for billing and administrative purposes. Coders may not enter details from patient charts that are unlikely to affect reimbursement, but could be relevant to the analysis. The reduced level of detail limits the capacity to adjust for severity of illness or comorbidities, and increases the risk of underestimating postsurgical complications. While this limits our capacity to quantify with more precision the estimated effect size, it is a 'good problem' in that resolving this limitation would only reveal a stronger impact of hospital nursing on postsurgical sepsis.

Implications

There are several paths to becoming a registered nurse. This study suggests that not all roads are equal when it comes to patient outcomes. Hospitals must consider an individual's educational background when hiring. When a hospital hires more BSN-prepared nurses, its patients benefit. This is not the first study to demonstrate the value of an educated workforce in terms of patient outcomes. The accumulation of evidence is already influencing policy and practice, as the discussion of Aim 2 noted. In order to meet the demand generated by translation of the value of BSN-prepared nurses, nursing programs will need to identify and help students overcome barriers to the attaining bachelor's degrees. Healthcare employers can be partners in this mission by incentivizing and facilitating further education through clinical ladder programs and tuition benefits. Many hospitals, including those of the University of Pennsylvania Health System (UPHS), now only hire BSN-prepared nurses. The findings of this study support this trend insofar as it helps patients.

The work environment depends less on the supply of nurses and more on how administrators organize their hospital and foster a culture that values professional nursing. Of the two nursing resources with significant effects, the work environment is more fundamental as it is associated with decreased odds of sepsis. In the absence of sepsis, there can be no death from sepsis. Whereas state and national policies play a role in the ongoing transition to a BSN-prepared nursing workforce, the agents of change for hospital work environments are more likely at the level of the hospital or health-system, where interventions can correspond with institutional needs and culture.

Directions for Future Research

Sepsis is a monumental problem with many stakeholders and continues to be an important subject of research. In the decade since this study's data were generated, sepsis management has become more systematic and highly scrutinized. Dedicated clinical pathways and early warning scores are more common and increasingly integrated with electronic medical records (EMRs). The National Quality Forum has endorsed a "Severe Sepsis and Septic Shock: Management Bundle" measure, which the Centers for Medicare and Medicaid Services (CMS) have since adopted to assess sepsis care quality in hospitals. The effectiveness of EMRs, clinical pathways, and management bundles in achieving better sepsis outcomes, and the ability of hospitals to extract the full value from these interventions, likely depends on nursing resource quality.

ICD coding. Just as the definition of sepsis has changed over time, the identification of septic cases in administrative data continues to evolve. Future research will have the benefit of using ICD-10 codes, which are more comprehensive and have improved quality in coding of postoperative complications over the ICD-9 codes used in this study (CDC/National Center for

Health Statistics, 2015). Better coding may improve the positive and negative predictive value of ICD codes identifying sepsis patients.

Risk adjustment. This study employs Elixhauser's comorbidities for risk adjustment, a common and appropriate method in adminstrative data. However, the particular application in this case may warrant some adjustments. In the absence of indicators for conditions present on admission, it is unclear whether the secondary diagnoses are true comorbidities or rather complications of care. If the latter, some of the conditions could end up controlling for sepsis severity rather than patient risk, and perhaps diminish the estimated effect of nursing on sepsis mortality. This study provides a parallel analysis using an alternative risk adjustment method, but there is room for further refining the risk adjustment of septic patients. Future approaches may exclude certain comorbidities with intrinsic connections to sepsis or employ a look back period to differentiate comorbidities and complications (Glance et al., 2006)

The risk adjustment model for this study did not include a direct measure of sepsis severity, such as differentiating between sepsis and septic shock. This was by design; hospitals should prevent sepsis or, if prevention is somehow impossible, at least act to mitigate its severity. This study demonstrates that better educated nurse workforces are associated with lower odds of death after postoperative sepsis. Sepsis severity may be the key mechanism of this effect. It is possible that BSN-prepared nurses deliver better mortality outcomes among postoperative sepsis patients by attenuating sepsis severity. Future studies analyzing the impact of BSN-prepared nurses on sepsis severity could help answer this question.

Interactions. Sepsis severity may also be an interaction term. A recent study of the impact of the nursing work environment on mortality among general surgical patients found that sicker patients benefitted more from a good nurse work environment (Silber et al., 2016). Whether nursing resources impact sepsis incidence and mortality differently across severity levels is unknown. This study modelled nursing resources separately and jointly, but staffing, education, and the work environment likely interact with one another. A study of general, orthopedic, and vascular surgery patients found that the impact of nurse staffing depended on the quality of the work environment. Patients in hospitals with poor work environments received little to no benefit from better staffing, while patients in the best work environments experienced the greatest reduction in odds of death and failure to rescue (Aiken et al., 2011). The impact of staffing on sepsis incidence and mortality may act similarly across different levels of work environment quality.

Additional patient outcomes. In addition to refining risk adjustment techniques for sepsis and exploring interactions between staffing, education, and the work environment, future research may explore the impact of these nursing resources on additional patient outcomes. This study identified that nearly a quarter of patients readmitted with sepsis within 5 days of discharge had been diagnosed with sepsis during their index hospitalization. This suggests that patients were discharged from the hospital too soon. Readmissions and length of stay are outcomes for future studies with great impact on healthcare costs and hospital reimbursement. Hospital nursing is costly and, as such, an easy target for budget cuts. Demonstrating the impact that nursing has on these factors that impact a hospital's bottom line adds an economic argument in addition to the patient outcomes evidence in a case for maintaining and/or advancing investments in nursing.

Summary

Despite expert consensus informing best practice recommendations for sepsis treatment, hospital-level rates of sepsis and mortality after sepsis vary significantly across hospitals. The context of care matters as much as the care itself. For a patient, this translates into the importance of hospital choice. Our findings suggest that the same patient undergoing the same surgery may experience different outcomes depending on the hospital in which the procedure takes place. In one hospital the patient develops sepsis and dies. In another, the patient is discharged infection-free with no additional risk of mortality beyond that which the procedure itself imposes. This study examined the extent to which hospital nursing resources explain this variation. Specifically, it analyzed the impact of hospital nurse staffing, education, and the work environment on the odds of sepsis and death after sepsis among postsurgical patients. Better work environments were associated with lower odds of sepsis, and higher proportions of BSN-prepared nurses on staff were associated with lower odds of mortality. The implications of this study are distinct. Existing research largely informs clinical interventions. This study addresses the context in which those interventions takes place, which mediates their effectiveness. The principle agents of these changes are hospital administrators. They direct hiring practices and have the capacity to invest in nurses and make nursing care an institutional priority. System-level interventions have system-wide impacts. Hospital characteristics impact (positively or negatively) the care of every patient admitted. Improvements in hospital nursing resources are likely to improve postsurgical patient outcomes throughout the hospital and across providers.

APPENDIX A

Patient Data Abstraction

TABLE A1
CMS Diagnosis Related Groups (DRGs)

General Surgical Procedures
146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 157, 158, 159, 160, 161, 162, 164, 165, 166, 167, 170, 171, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 285, 286, 287, 288, 289, 290, 291, 292, 293, 493, 494
Orthopedic Surgical Procedures
209, 210, 211, 213, 216, 217, 218, 219, 223, 224, 225, 226, 227, 228, 229, 230, 232, 233, 234, 471, 491, 496, 497, 498, 499, 500, 501, 502, 503, 519, 520, 537, 538, 544, 545, 546
Vascular Surgical Procedures
110, 120, 113, 111, 114, 119

TABLE A2
International Classification of Diseases 9 (ICD-9) Codes for Sepsis

0380, 0381, 0382, 0383, 0384, 03840, 03841, 03842, 03843, 03844, 03849, 0388, 0389, 7907, 03819, 03810, 03811, 78552

Notes: These codes are for Silber and colleague's definition of sepsis as a complication for failure to rescue, and this study's primary sepsis definition.

TABLE A3
Most Common Surgical Procedures by Surgical Group (n=1,435,919 patients)

DRG	Description	Frequency	Percent within-group (cumulative)	Percent Overall
	General (n=648,224)			
148	Major Small & Large Bowel Procedures w cc	63,741	9.8%	4.4%
494	Laparoscopic Cholecystectomy w/o Common Duct Exploration w/o cc	62,345	9.6% (19.5)	4.3%
167	Appendectomy w/o Complicated Principal Diagnoses w/o cc	55,775	8.6% (28.1)	3.9%
493	Laparoscopic Cholecystectomy w/o Common Duct Exploration w cc	52,556	8.1% (36.2)	3.7%
288	Operating Room Procedures for Obesity	45,456	7.0% (43.2)	3.2%
290	Thyroid Procedures	26,431	4.1% (47.3)	1.8%
149	Major Small & Large Bowel Procedures w/o cc	23,105	3.6% (50.8)	1.6%
	Orthopedic (n=717,110)			
544	Major Joint Replacement or Reattachment of Lower Extremity	161,588	22.5%	11.3%
209	Major Joint & Limb Reattachment Procedures of Lower Extremity	80,606	11.2% (33.8)	5.6%
500	Back & Neck Procedures except Spinal Fusion w/o cc	61,649	8.6% (42.4)	4.3%
219	Lower Extremity & Humerus Procedures except Hip, Foot, Femur Age >17 w/o cc	41,147	5.7% (48.1)	2.9%
210	Hip & Femur Procedures except Major Joint Age >17 w cc	39,482	5.5% (53.6)	2.7%
	Vascular (n=70,802)			
110	Major Cardiovascular Procedures w cc	34,455	48.7%	2.4%
120	Other Circulatory System Operating Room Procedures	14,891	21.0% (69.7)	1.0%

Notes: "Percent within-group" represents the each procedure's frequency as a percent of all procedures within that particular surgical group.
"Percent Overall" represents each procedure's frequency as a percent of all 1,436,136 surgical patients.
Within each surgical group, the DRGs are listed in descending order of frequency until 50% or more of all cases within each group are represented.

APPENDIX B

Sensitivity Analysis – Alternate Sepsis Definition

TABLE B1
Comparing Sepsis Definitions: Failure to Rescue (FTR) vs. Patient Safety Indicator (PSI) 13

ICD-9 Code	Description	AHRQ PSI	Silber FTR
0380	STREPTOCOCCAL SEPTICEMIA	X	X
0381	STAPHYLOCOCCAL SEPTICEMIA	X	X
03810	STAPHYLOCOCCAL SEPTICEMIA, UNSPECIFIED	X	X
03811	METH SUSC STAPH AUR SEPT	X	X
03812	MRSA SEPTICEMIA	X	
03819	OTHER STAPHYLOCOCCAL SEPTICEMIA	X	X
0382	PNEUMOCOCCAL SEPTICEMIA (STREPTOCOCCUS PNEUMONIAE SEPTICEMIA)	X	X
0383	SEPTICEMIA DUE TO ANAEROBES	X	X
0384	SEPTICEMIA DUE TO OTHER GRAM-NEGATIVE ORGANISMS		X
03840	GRAM-NEGATIVE ORGANISM, UNSPECIFIED	X	X
03841	HEMOPHILUS INFLUENZAE	X	X
03842	ESCHERICHIA COLI	X	X
03843	PSEUDOMONAS	X	X
03844	SERRATIA	X	X
03849	SEPTICEMIA DUE TO OTHER GRAM-NEGATIVE ORGANISMS	X	X
0388	OTHER SPECIFIED SEPTICEMIAS	X	X
0389	UNSPECIFIED SEPTICEMIA	X	X
78552	SEPTIC SHOCK	X	X
78559	SHOCK W/O TRAUMA NEC	X	
7907	BACTEREMIA		X
99591	SYSTEMIC INFLAMMATORY RESPONSE SYNDROME DUE TO INFECTIOUS PROCESS WITHOUT ORGAN DYSFUNCTION	X	
99592	SYSTEMIC INFLAMMATORY RESPONSE SYNDROME DUE TO INFECTIOUS PROCESS WITH ORGAN DYSFUNCTION	X	
9980	POSTOPERATIVE SHOCK	X	
99800	POSTOPERATIVE SHOCK, UNSPECIFIED	X	

Notes: FTR: Failure to Rescue; PSI: Patient Safety Indicator (version 5)

TABLE B2
Comparing FTR and PSI Sepsis Terms

FTR	PSI: Yes	PSI: No	Total
Yes	19,955 89.5%	5,180 0.4%	25,135 1.8%
No	2,340 10.5%	1,408,444 99.6%	1,410,784 98.3%
Total	22,295 100%	1,413,624 100%	1,435,919 100%

Format: number
percent

Notes: Postsurgical sepsis is a secondary diagnosis of sepsis during the index hospitalization.
Sepsis readmissions represent all patients readmitted with a primary diagnosis of sepsis within 5 days of discharge.

ALTERNATE SEPSIS DEFINITION

TABLE B3

Unadjusted and Adjusted Impact of Nursing Resources on the ODDS OF PSI 13 SEPSIS (patient n=1,435,919)

	Staffing		Education		Work Environment	
Model	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Nursing Resources Modelled Separately						
Model 1	0.96 (0.93-1.00)	0.042	1.00 (0.96-1.03)	0.836	0.91 (0.85-0.97)	0.003
Model 2	0.98 (0.95-1.01)	0.175	1.00 (0.97-1.03)	0.833	0.94 (0.89-0.99)	0.021
Model 3	1.03 (1.00-1.06)	0.049	0.98 (0.95-1.01)	0.139	0.90 (0.86-0.95)	<0.001
Nursing Resources Modelled Jointly						
Model 1	0.94 (0.91-0.98)	0.006	0.99 (0.95-1.03)	0.716	0.90 (0.84-0.97)	0.004
Model 2	0.97 (0.94-1.00)	0.044	1.00 (0.97-1.03)	0.852	0.93 (0.88-0.98)	0.006
Model 3	1.01 (0.98-1.05)	0.414	0.99 (0.96-1.01)	0.343	0.92 (0.87-0.96)	0.001

Notes: Model 1: nursing resource(s) and outcome variables only
Model 2: adjusted for patient age, sex, 31 comorbidities, & 61 surgical patient DRGs
Model 3: adjusted for Model 2 + hospital characteristics (state, bed size, teaching status, and technology status) and nursing characteristics (proportion med-surg and ICU unit type).
All models adjusted for clustering of patients within hospitals.

ALTERNATE SEPSIS DEFINITION

TABLE B4

Unadjusted and Adjusted Impact of Nursing Resources on the ODDS OF DEATH after PSI 13 Sepsis (patient n=22,295)

	Staffing		Education		Work Environment	
Model	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Nursing Resources Modelled Separately						
Model 1	1.01 (0.98-1.05)	0.404	0.97 (0.94-1.00)	0.041	1.00 (0.95-1.06)	0.942
Model 2	1.03 (0.99-1.06)	0.147	0.96 (0.93-0.99)	0.012	0.96 (0.90-1.02)	0.149
Model 3	1.01 (0.97-1.06)	0.575	0.95 (0.93-0.98)	0.002	0.98 (0.92-1.04)	0.560
Nursing Resources Modelled Jointly						
Model 1	1.01 (0.97-1.04)	0.681	0.97 (0.94-1.00)	0.055	1.01 (0.95-1.06)	0.818
Model 2	1.01 (0.97-1.05)	0.594	0.97 (0.94-1.00)	0.036	0.96 (0.91-1.02)	0.207
Model 3	1.00 (0.96-1.04)	0.934	0.95 (0.93-0.98)	0.003	0.98 (0.92-1.04)	0.483

Notes: Model 1: nursing resource(s) and outcome variables only
Model 2: adjusted for patient age, sex, 31 comorbidities, & 61 surgical patient DRGs
Model 3: adjusted for Model 2 + hospital characteristics (state, bed size, teaching status, and technology status) and nursing characteristics (proportion med-surg and ICU unit type).

Mortality estimated among septic patients only.

All models adjusted for clustering of patients within hospitals.

APPENDIX C

Sensitivity Analysis – Alternate Risk Adjustment

TABLE C1
PSI #13 Criteria Informing Alternative Risk Adjustment

PSI #13 Exclusion Criteria[1]	Corresponding Risk Adjustment
Excludes cases with a principal diagnosis (or secondary diagnosis present on admission*) of sepsis.	Study did not have any patients with a principal diagnosis of sepsis. All secondary diagnoses of sepsis were considered complications of care.
Excludes cases with a principal diagnosis (or secondary diagnosis present on admission*) of infection† or pressure ulcer	Indicator variable for principal diagnosis of infection or pressure ulcer.
Excludes cases with an immunocompromised state.	Indicator variable for any diagnosis or procedure of an immunocompromised state
Excludes cases with cancer.	Indicator variable for any diagnosis of cancer.
Excludes obstetric discharges (MDC 14: pregnancy, childbirth, and puerperium).	Study did not have any patients in MDC 14.
Excludes cases with stays less than four (4) days	Include patients readmitted with a principal diagnosis of sepsis within 5 days of discharge as having developed sepsis as complication of care during the index hospitalization.
Excludes cases with missing values for gender, age, quarter, year, or principal diagnosis	Study did not have subjects with missing values for gender, age, or principal diagnosis. The design was cross-sectional, so quarter and year were not included among the controls.
PSI #13 Risk Adjustments[2]	**Corresponding Risk Adjustment**
Patient age, sex, MDRG, MDC.	Patient age, sex, and 61 DRG categories indicating surgical procedure.
Indicator for whether a patient was transferred in to the hospital.	Indicator for admission from another facility.
Comorbidities: congestive heart failure (CHF), valvular disease, pulmonary circulation disorders, paralysis, chronic pulmonary disease, hypothyroidism, renal failure, liver disease, obesity, weight loss, alcohol abuse, depression, and complicated hypertension	Comorbidities: congestive heart failure (CHF), valvular disease, pulmonary circulation disorders, paralysis, chronic pulmonary disease, hypothyroidism, renal failure, liver disease, obesity, weight loss, alcohol abuse, depression, and complicated hypertension

Notes: *the data for this study did not include an indication for whether secondary diagnoses were present on admission.
†excludes cases with a secondary diagnosis of infection present on admission only if they also have a secondary diagnosis of sepsis.
[1](AHRQ, 2015); [2](Battelle, 2012)

TABLE C2

Patients Readmitted with Sepsis as a Primary Diagnosis within 30 Days

Days to Readmission	n	%	Cum. n	Cum. %
0	243	6.9	243	6.9
1	134	3.8	377	10.8
2	147	4.2	524	15.0
3	156	4.5	680	19.4
4	153	4.4	833	23.8
5	138	3.9	971	27.7
6	169	4.8	1,140	32.5
7	166	4.7	1,306	37.3
8	138	3.9	1,444	41.2
9	132	3.8	1,576	45.0
10	139	4.0	1,715	48.9
11	131	3.7	1,846	52.7
12	118	3.4	1,964	56.0
13	121	3.5	2,085	59.5
14	129	3.7	2,214	63.2
15	106	3.0	2,320	66.2
16	96	2.7	2,416	68.9
17	95	2.7	2,511	71.6
18	91	2.6	2,602	74.2
19	89	2.5	2,691	76.8
20	83	2.4	2,774	79.1
21	78	2.2	2,852	81.4
22	93	2.7	2,945	84.0
23	86	2.5	3,031	86.5
24	69	2.0	3,100	88.5
25	70	2.0	3,170	90.4
26	58	1.7	3,228	92.1
27	86	2.5	3,314	94.6
28	74	2.1	3,388	96.7
29	67	1.9	3,455	98.6
30	50	1.4	3,505	100

Notes: Sepsis is FTR sepsis

TABLE C3
Index Hospitalizations of Patients Readmitted with/without Sepsis

Index Sepsis	Readmissions with Sepsis		
	Yes	No	Total
Yes	232 23.9%	2709 2.8%	2,941 3.0%
No	739 76.1%	93821 97.2%	94,560 97.0%
Total	971 100%	96,530 100%	97,501 100%

Format: number
percent

Notes: Readmissions were within 5 days of discharge from the index hospitalization. Sepsis is FTR sepsis.

ALTERNATE RISK ADJUSTMENT

TABLE C4

Unadjusted and Adjusted Impact of Nursing Resources on the ODDS OF SEPSIS (patient n=1,435,919)

	Staffing		Education		Work Environment	
Model	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Nursing Resources Modelled Separately						
Model 1	0.96 (0.93-0.99)	0.012	1.02 (0.99-1.05)	0.229	0.91 (0.86-0.97)	0.002
Model 2	0.97 (0.95-0.99)	0.012	1.03 (1.00-1.05)	0.034	0.97 (0.92-1.01)	0.142
Model 3	1.02 (0.99-1.04)	0.208	1.00 (0.98-1.03)	0.412	0.93 (0.89-0.97)	0.002
Nursing Resources Modelled Jointly						
Model 1	0.95 (0.91-0.98)	0.006	1.02 (0.98-1.06)	0.327	0.90 (0.84-0.96)	0.002
Model 2	0.97 (0.94-0.99)	0.017	1.02 (1.00-1.05)	0.077	0.95 (0.90-0.99)	0.030
Model 3	1.01 (0.98-1.04)	0.498	1.01 (0.98-1.03)	0.607	0.94 (0.90-0.99)	0.012

Notes: Model 1: nursing resource(s) and outcome variables only

Model 2: adjusted for patient age, sex, 13 comorbidities*, 61 surgical patient DRGs, and indicators for 1) principal diagnosis of infection or pressure ulcer, 2) any listed code for immunocompromised state, 3) any listed code for cancer, and 3) transfer from another facility.

Model 3: adjusted for Model 2 + hospital characteristics (state, bed size, teaching status, and technology status) and nursing characteristics (proportion med-surg and ICU unit type).

Includes patients readmitted with a principal diagnosis of sepsis within 5 days of discharge.

All models adjusted for clustering of patients within hospitals.

*Comorbidities: congestive heart failure (CHF), valvular disease, pulmonary circulation disorders, paralysis, chronic pulmonary disease, hypothyroidism, renal failure, liver disease, obesity, weight loss, alcohol abuse, depression, and complicated hypertension

ALTERNATE RISK ADJUSTMENT

TABLE C5

Unadjusted and Adjusted Impact of Nursing Resources on the ODDS OF DEATH after Sepsis (patient n=25,874)

	Staffing		Education		Work Environment	
Model	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Nursing Resources Modelled Separately						
Model 1	1.01 (0.98-1.04)	0.378	0.96 (0.93-0.98)	0.001	1.01 (0.96-1.07)	0.558
Model 2	1.03 (1.00-1.06)	0.081	0.94 (0.92-0.97)	<0.001	0.98 (0.93-1.04)	0.511
Model 3	1.02 (0.98-1.06)	0.300	0.94 (0.91-0.97)	<0.001	1.00 (0.931-1.06)	0.901
Nursing Resources Modelled Jointly						
Model 1	1.00 (0.97-1.04)	0.789	0.96 (0.93-0.98)	0.001	1.03 (0.97-1.08)	0.338
Model 2	1.01 (0.98-1.05)	0.466	0.95 (0.92-0.97)	<0.001	1.00 (0.95-1.06)	0.949
Model 3	1.01 (0.97-1.05)	0.776	0.94 (0.91-0.97)	<0.001	1.00 (0.95-1.06)	0.887

Notes: Model 1: nursing resource(s) and outcome variables only

Model 2: adjusted for patient age, sex, 13 comorbidities*, 61 surgical patient DRGs, and indicators for 1) principal diagnosis of infection or pressure ulcer, 2) any listed code for immunocompromised state, 3) any listed code for cancer, and 3) transfer from another facility.

Model 3: adjusted for Model 2 + hospital characteristics (state, bed size, teaching status, and technology status) and nursing characteristics (proportion med-surg and ICU unit type).

Includes patients readmitted with a principal diagnosis of sepsis within 5 days of discharge.

All models adjusted for clustering of patients within hospitals.

*Comorbidities: congestive heart failure (CHF), valvular disease, pulmonary circulation disorders, paralysis, chronic pulmonary disease, hypothyroidism, renal failure, liver disease, obesity, weight loss, alcohol abuse, depression, and complicated hypertension

APPENDIX D

Practice Environment Scale of the Nursing Work Index (PES-NWI) Subscales

TABLE D1

Adjusted and Unadjusted Impact of the PES-NWI Subscales on the ODDS OF SEPSIS (patient n=1,435,919)

	Model 1		Model 2		Model 3		Model 4	
Subscale	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
1. Nurse Participation in Hospital Affairs	0.92 (0.87-0.98)	0.007	0.95 (0.90-0.99)	0.018	0.92 (0.88-0.96)	<0.001	0.92 (0.85-0.99)	0.020
2. Nursing Foundations for Quality of Care	0.94 (0.88-1.00)	0.044	0.96 (0.92-1.01)	0.130	0.94 (0.90-0.98)	0.008	1.00 (0.93-1.09)	0.904
3. Nurse Manager Ability, Leadership, and Support of Nurses	0.94 (0.88-1.00)	0.040	0.95 (0.91-0.99)	0.028	0.95 (0.91-0.99)	0.027	1.00 (0.95-1.06)	0.876
4. Collegial Nurse-Physician Relations	0.92 (0.86-0.98)	0.006	0.99 (0.94-1.04)	0.640	0.96 (0.92-1.01)	0.096	1.01 (0.95-1.06)	0.815
5. Staffing and Resource Adequacy	0.93 (0.87-0.98)	0.013	0.98 (0.94-1.03)	0.442	0.94 (0.90-0.99)	0.012	0.99 (0.93-1.05)	0.768

Notes: Model 1: bivariate model of PES-NWI subscale and sepsis outcome variables only
Model 2: adjusted for patient age, sex, 31 comorbidities, & 61 surgical patient DRGs
Model 3: adjusted for Model 2 + hospital characteristics (state, bed size, teaching status, and technology status) and nursing characteristics (proportion med-surg and ICU unit type).
Model 4: Model 3 with all subscales modelled jointly.
All models adjusted for clustering of patients within hospitals.

REFERENCES

AHRQ. (2015). *Patient Safety Indicators #13 (PSI #13) Postoperative Sepsis Rate*. Retrieved from www.qualityindicators.ahrq.gov

Aiken, L. H. (2014). Baccalaureate nurses and hospital outcomes: more evidence. *Med Care, 52*(10), 861-863. doi:10.1097/mlr.0000000000000222

Aiken, L. H., Cimiotti, J. P., Sloane, D. M., Smith, H. L., Flynn, L., & Neff, D. F. (2011). Effects of nurse staffing and nurse education on patient deaths in hospitals with different nurse work environments. *Med Care, 49*(12), 1047-1053. doi:10.1097/MLR.0b013e3182330b6e

Aiken, L. H., Cimiotti, J. P., Sloane, D. M., Smith, H. L., Flynn, L., & Neff, D. F. (2012). Effects of nurse staffing and nurse education on patient deaths in hospitals with different nurse work environments. *J Nurs Adm, 42*(10 Suppl), S10-16. doi:10.1097/01.nna.0000420390.87789.67

Aiken, L. H., Clarke, S. P., Cheung, R. B., Sloane, D. M., & Silber, J. H. (2003). Educational levels of hospital nurses and surgical patient mortality. *Jama, 290*(12), 1617-1623. doi:10.1001/jama.290.12.1617

Aiken, L. H., Clarke, S. P., Cheung, R. B., Sloane, D. M., & Silber, J. H. (2003). Educational levels of hospital nurses and surgical patient mortality. *Jama, 290*(12), 1617-1623.

Aiken, L. H., Clarke, S. P., Sloane, D. M., Lake, E. T., & Cheney, T. (2008). Effects of hospital care environment on patient mortality and nurse outcomes. *J Nurs Adm, 38*(5), 223-229. doi:10.1097/01.NNA.0000312773.42352.d7

Aiken, L. H., Clarke, S. P., Sloane, D. M., Sochalski, J., & Silber, J. H. (2002). Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *Jama, 288*(16), 1987-1993.

Aiken, L. H., Clarke, S. P., Sloane, D. M., Sochalski, J., & Silber, J. H. (2002). Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *Jama, 288*(16), 1987-1993.

Aiken, L. H., Sloane, D. M., Bruyneel, L., Van den Heede, K., Griffiths, P., Busse, R., . . . Lesaffre, E. (2014). Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. *The Lancet, 383*(9931), 1824-1830.

Aiken, L. H., Sloane, D. M., Bruyneel, L., Van den Heede, K., Griffiths, P., Busse, R., . . . Sermeus, W. (2014). Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. *Lancet, 383*(9931), 1824-1830. doi:10.1016/s0140-6736(13)62631-8

Aiken, L. H., Sochalski, J., & Lake, E. T. (1997). Studying outcomes of organizational change in health services. *Med Care, 35*(11), NS6-NS18.

American College of Chest Physicians/Society of Critical Care Medicine Consensus Conference: definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. (1992). *Crit Care Med, 20*(6), 864-874.

Angus, D. C., Linde-Zwirble, W. T., Lidicker, J., Clermont, G., Carcillo, J., & Pinsky, M. R. (2001). Epidemiology of severe sepsis in the United States: analysis of incidence, outcome, and associated costs of care. *Critical care medicine, 29*(7), 1303-1310.

Arefian, H., Heublein, S., Scherag, A., Brunkhorst, F. M., Younis, M. Z., Moerer, O., . . . Hartmann, M. (2017). Hospital-related cost of sepsis: A systematic review. *Journal of Infection, 74*(2), 107-117. doi:http://dx.doi.org/10.1016/j.jinf.2016.11.006

Assembly, S. W. H. (2017). Improving the prevention, diagnosis, and clinical management of sepsis [Press release]

Banta, J. E., Joshi, K. P., Beeson, L., & Nguyen, H. B. (2012). Patient and hospital characteristics associated with inpatient severe sepsis mortality in California, 2005-2010. *Crit Care Med, 40*(11), 2960-2966. doi:10.1097/CCM.0b013e31825bc92f

Barnes, H., Rearden, J., & McHugh, M. D. (2016). Magnet(R) Hospital Recognition Linked to Lower Central Line-Associated Bloodstream Infection Rates. *Res Nurs Health, 39*(2), 96-104. doi:10.1002/nur.21709

Battelle. (2012). *Patient Safety Indicators (PSI) Risk Adjustment Coefficients for the PSI Version 4.4*. Retrieved from http://www.qualityindicators.ahrq.gov

Blegen, M. A., Goode, C. J., Park, S. H., Vaughn, T., & Spetz, J. (2013). Baccalaureate education in nursing and patient outcomes. *Journal of Nursing Administration, 43*(2), 89-94.

Boev, C., & Kiss, E. (2017). Hospital-Acquired Infections: Current Trends and Prevention. *Crit Care Nurs Clin North Am, 29*(1), 51-65. doi:10.1016/j.cnc.2016.09.012

Bone, R. C., Balk, R. A., Cerra, F. B., Dellinger, R. P., Fein, A. M., Knaus, W. A., . . . Sibbald, W. J. (1992). Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. *Chest, 101*(6), 1644-1655.

Bone, R. C., Fisher, J. C., Clemmer, T. P., Slotman, G. J., Metz, C. A., & Balk, R. A. (1989). Sepsis syndrome: a valid clinical entity. Methylprednisolone Severe Sepsis Study Group. *Critical care medicine, 17*(5), 389-393.

Boyle, S. M. (2004). Nursing unit characteristics and patient outcomes. *Nursing Economics, 22*(3), 111.

Brennan, T. A., Hebert, L. E., Laird, N. M., Lawthers, A., Thorpe, K. E., Leape, L. L., . . . et al. (1991). Hospital characteristics associated with adverse events and substandard care. *Jama, 265*(24), 3265-3269.

Carthon, J. M., Kutney-Lee, A., Jarrin, O., Sloane, D., & Aiken, L. H. (2012). Nurse staffing and postsurgical outcomes in black adults. *J Am Geriatr Soc, 60*(6), 1078-1084. doi:10.1111/j.1532-5415.2012.03990.x

CDC/National Center for Health Statistics. (2015). International Classification of Diseases, (ICD-10-CM/PCS) Transition - Background. Retrieved from https://www.cdc.gov/nchs/icd/icd10cm_pcs_background.htm

Cho, E., Sloane, D. M., Kim, E.-Y., Kim, S., Choi, M., Yoo, I. Y., . . . Aiken, L. H. (2015). Effects of nurse staffing, work environments, and education on patient mortality: an observational study. *Int J Nurs Stud, 52*(2), 535-542.

Cho, S. H., Ketefian, S., Barkauskas, V. H., & Smith, D. G. (2003). The effects of nurse staffing on adverse events, morbidity, mortality, and medical costs. *Nurs Res, 52*(2), 71-79.

Chong, J., Dumont, T., Francis-Frank, L., & Balaan, M. (2015). Sepsis and septic shock: a review. *Critical care nursing quarterly, 38*(2), 111-120.

Cohen, J., Vincent, J.-L., Adhikari, N. K., Machado, F. R., Angus, D. C., Calandra, T., . . . Opal, S. (2015). Sepsis: a roadmap for future research. *The Lancet Infectious Diseases, 15*(5), 581-614.

Czura, C. J. (2011). "Merinoff symposium 2010: sepsis"—speaking with one voice. *Molecular Medicine, 17*(1-2), 2.

Dillman, D. A. (1978). *Mail and Telephone Surveys: The Total Design Method*. New York: John Wiley & Sons, Inc.

Donabedian, A. (1966). Evaluating the quality of medical care. *The Milbank memorial fund quarterly, 44*(3), 166-206.

Donabedian, A. (1988). The quality of care: how can it be assessed? *Jama, 260*(12), 1743-1748.

Donaldson, M. S., Corrigan, J. M., & Kohn, L. T. (2000). *To err is human: building a safer health system* (Vol. 6): National Academies Press.

Elixhauser, A., Friedman, B., Stranges, E. (2011). *Septicemia in U.S. Hospitals, 2009* (Statistical Brief #122). Retrieved from https://www.hcup-us.ahrq.gov/reports/statbriefs/sb122.pdf

Elixhauser, A., Steiner, C., Harris, D. R., & Coffey, R. M. (1998). Comorbidity measures for use with administrative data. *Med Care, 36*(1), 8-27.

Esper, A. M., Moss, M., Lewis, C. A., Nisbet, R., Mannino, D. M., & Martin, G. S. (2006). The role of infection and comorbidity: Factors that influence disparities in sepsis. *Critical care medicine, 34*(10), 2576.

Fleischmann, C., Scherag, A., Adhikari, N. K., Hartog, C. S., Tsaganos, T., Schlattmann, P., . . . Reinhart, K. (2016). Assessment of global incidence and mortality of hospital-treated sepsis. Current estimates and limitations. *Am J Respir Crit Care Med, 193*(3), 259-272.

Friese, C. R., Xia, R., Ghaferi, A., Birkmeyer, J. D., & Banerjee, M. (2015). Hospitals In 'Magnet' Program Show Better Patient Outcomes On Mortality Measures Compared To Non-'Magnet' Hospitals. *Health Aff (Millwood), 34*(6), 986-992. doi:10.1377/hlthaff.2014.0793

Gaieski, D. F., Edwards, J. M., Kallan, M. J., & Carr, B. G. (2013). Benchmarking the incidence and mortality of severe sepsis in the United States. *Critical care medicine, 41*(5), 1167-1174.

Gaieski, D. F., Edwards, J. M., Kallan, M. J., Mikkelsen, M. E., Goyal, M., & Carr, B. G. (2014). The relationship between hospital volume and mortality in severe sepsis. *Am J Respir Crit Care Med, 190*(6), 665-674.

Ghaferi, A. A., Birkmeyer, J. D., & Dimick, J. B. (2009). Variation in Hospital Mortality Associated with Inpatient Surgery. *New England Journal of Medicine, 361*(14), 1368-1375. doi:10.1056/NEJMsa0903048

Glance, L. G., Dick, A. W., Osler, T. M., & Mukamel, D. B. (2006). Does Date Stamping ICD-9-CM Codes Increase the Value of Clinical Information in Administrative Data? *Health Serv Res, 41*(1), 231-251.

Glance, L. G., Dick, A. W., Osler, T. M., Mukamel, D. B., Li, Y., & Stone, P. W. (2012). The association between nurse staffing and hospital outcomes in injured patients. *BMC Health Serv Res, 12*, 247. doi:10.1186/1472-6963-12-247

Goode, C. J., Blegen, M. A., Park, S. H., Vaughn, T., & Spetz, J. (2011). Comparison of patient outcomes in Magnet(R) and non-Magnet hospitals. *J Nurs Adm, 41*(12), 517-523. doi:10.1097/NNA.0b013e3182378b7c

Goode, C. J., Pinkerton, S., McCausland, M. P., Southard, P., Graham, R., & Krsek, C. (2001). Documenting chief nursing officers' preference for BSN-prepared nurses. *Journal of Nursing Administration, 31*(2), 55-59.

Guide to Patient Safety Indicators (2003). Retrieved from http://www.qualityindicators.ahrq.gov

Henneman, D., van Leersum, N. J., Ten Berge, M., Snijders, H. S., Fiocco, M., Wiggers, T., . . . Wouters, M. W. (2013). Failure-to-rescue after colorectal cancer surgery and the association with three structural hospital factors. *Ann Surg Oncol, 20*(11), 3370-3376. doi:10.1245/s10434-013-3037-z

IOM. (2011). *The Future of Nursing: Leading Change, Advancing Health*. Retrieved from Washington, DC:

Jane E. Ball, L. B., Linda H. Aiken, Walter Sermeus, Douglas M. Sloane, Anne Marie Rafferty, Rikard Lindqvist, Carol Tishelman, Peter Griffiths. (2017). Post-operative mortality, missed care and nurse staffing in nine countries: a cross-sectional study. *Int J Nurs Stud*. doi:https://doi.org/10.1016/j.ijnurstu.2017.08.004

Kendall-Gallagher, D., Aiken, L. H., Sloane, D. M., & Cimiotti, J. P. (2011). Nurse specialty certification, inpatient mortality, and failure to rescue. *J Nurs Scholarsh, 43*(2), 188-194. doi:10.1111/j.1547-5069.2011.01391.x

Kendall-Gallagher, D., Aiken, L. H., Sloane, D. M., & Cimiotti, J. P. (2011). Nurse specialty certification, inpatient mortality, and failure to rescue. *Journal of nursing scholarship, 43*(2), 188-194.

Kenzaka, T., Okayama, M., Kuroki, S., Fukui, M., Yahata, S., Hayashi, H., . . . Hashimoto, M. (2012). Importance of vital signs to the early diagnosis and severity of sepsis: association between vital signs and sequential organ failure assessment score in patients with sepsis. *Internal Medicine, 51*(8), 871-876.

Kleinpell, R., Aitken, L., & Schorr, C. A. (2013). Implications of the new international sepsis guidelines for nursing care. *American Journal of Critical Care, 22*(3), 212-222.

Kutney-Lee, A., Sloane, D. M., & Aiken, L. H. (2013). An increase in the number of nurses with baccalaureate degrees is linked to lower rates of postsurgery mortality. *Health Affairs, 32*(3), 579-586.

Kutney-Lee, A., Stimpfel, A. W., Sloane, D. M., Cimiotti, J. P., Quinn, L. W., & Aiken, L. H. (2015). Changes in patient and nurse outcomes associated with magnet hospital recognition. *Med Care, 53*(6), 550-557. doi:10.1097/mlr.0000000000000355

Lake, E. T. (2002). Development of the practice environment scale of the Nursing Work Index. *Res Nurs Health, 25*(3), 176-188.

Lasater, K. B., & McHugh, M. D. (2016). Nurse staffing and the work environment linked to readmissions among older adults following elective total hip and knee replacement. *International Journal for Quality in Health Care, 28*(2), 253-258.

Levy, M. M., Fink, M. P., Marshall, J. C., Abraham, E., Angus, D., Cook, D., . . . Ramsay, G. (2003). 2001 sccm/esicm/accp/ats/sis international sepsis definitions conference. *Intensive Care Med, 29*(4), 530-538.

Levy, M. M., Fink, M. P., Marshall, J. C., Abraham, E., Angus, D., Cook, D., . . . Ramsay, G. (2003). 2001 SCCM/ESICM/ACCP/ATS/SIS International Sepsis Definitions Conference. *Crit Care Med, 31*(4), 1250-1256. doi:10.1097/01.ccm.0000050454.01978.3b

Li, B., Evans, D., Faris, P., Dean, S., & Quan, H. (2008). Risk adjustment performance of Charlson and Elixhauser comorbidities in ICD-9 and ICD-10 administrative databases. *BMC Health Serv Res, 8*(1), 12. doi:10.1186/1472-6963-8-12

Liu, H., & Wu, T. (2005). Sample size calculation and power analysis of time-averaged difference. *Journal of Modern Applied Statistical Methods, 4*(2), 9.

Manojlovich, M., & DeCicco, B. (2007). Healthy work environments, nurse-physician communication, and patients' outcomes. *Am J Crit Care, 16*(6), 536-543.

Mark, B. A., Harless, D. W., & Berman, W. F. (2007). Nurse staffing and adverse events in hospitalized children. *Policy Polit Nurs Pract, 8*(2), 83-92. doi:10.1177/1527154407303499

Martin , G. S., Mannino , D. M., Eaton , S., & Moss , M. (2003). The Epidemiology of Sepsis in the United States from 1979 through 2000. *New England Journal of Medicine, 348*(16), 1546-1554. doi:10.1056/NEJMoa022139

Mayr, F. B., Yende, S., & Angus, D. C. (2014). Epidemiology of severe sepsis. *Virulence, 5*(1), 4-11. doi:10.4161/viru.27372

McHugh, M. D., Aiken, L. H., Eckenhoff, M. E., & Burns, L. R. (2016). Achieving Kaiser Permanente quality. *Health Care Manage Rev, 41*(3), 178-188.

McHugh, M. D., Kelly, L. A., Smith, H. L., Wu, E. S., Vanak, J. M., & Aiken, L. H. (2013). Lower mortality in magnet hospitals. *Med Care, 51*(5), 382-388. doi:10.1097/MLR.0b013e3182726cc5

McHugh, M. D., Kelly, L. A., Smith, H. L., Wu, E. S., Vanak, J. M., & Aiken, L. H. (2013). Lower mortality in magnet hospitals. *J Nurs Adm, 43*(10 0), S4.

Mitchell, P. H., Ferketich, S., & Jennings, B. M. (1998). Quality health outcomes model. *Journal of nursing scholarship, 30*(1), 43-46.

Mitchell, P. H., & Lang, N. M. (2004). Framing the problem of measuring and improving healthcare quality: has the Quality Health Outcomes Model been useful? *Med Care, 42*(2), II-4-II-11.

Mokart, D., Leone, M., Sannini, A., Brun, J., Tison, A., Delpero, J., . . . Martin, C. (2005). Predictive perioperative factors for developing severe sepsis after major surgery. *British journal of anaesthesia, 95*(6), 776-781.

National Quality Forum (NQF). (2017). Measures, Reports & Tools. Retrieved from http://www.qualityforum.org/QPS/0206

Needleman, J., Buerhaus, P., Mattke, S., Stewart, M., & Zelevinsky, K. (2002). Nurse-Staffing Levels and the Quality of Care in Hospitals. *New England Journal of Medicine, 346*(22), 1715-1722. doi:10.1056/NEJMsa012247

Needleman, J., Buerhaus, P. I., Mattke, S., Stewart, M., & Zelevinsky, K. (2001). *Nurse staffing and patient outcomes in hospitals*. Retrieved from

Ofoma, U. R., Dahdah, J., Kethireddy, S., Maeng, D., & Walkey, A. J. (2017). Case Volume-Outcomes Associations Among Patients With Severe Sepsis Who Underwent Interhospital Transfer. *Crit Care Med, 45*(4), 615-622. doi:10.1097/ccm.0000000000002254

Ollendorf, D. A., Fendrick, A. M., Massey, K., Williams, G. R., & Oster, G. (2002). Is sepsis accurately coded on hospital bills? *Value in Health, 5*(2), 79-81.

Page, A. (2004). *Keeping patients safe: Transforming the work environment of nurses*: National Academies Press.

PASS 15 Power Analysis and Sample Size Software (2017). NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/pass.

Physicians, A. C. o. C. (1992). Society of Critical Care Medicine Consensus Conference Committee: American College of Chest Physicians/Society of Critical Care Medicine Consensus Conference: Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. *Crit. Care. Med., 20*, 864-874.

Rhee, C., Kadri, S. S., Danner, R. L., Suffredini, A. F., Massaro, A. F., Kitch, B. T., . . . Klompas, M. (2016). Diagnosing sepsis is subjective and highly variable: a survey of intensivists using case vignettes. *Crit Care, 20*, 89. doi:10.1186/s13054-016-1266-9

Rhodes, A., Evans, L. E., Alhazzani, W., Levy, M. M., Antonelli, M., Ferrer, R., . . . Nunnally, M. E. (2017). Surviving sepsis campaign: international guidelines for management of sepsis and septic shock: 2016. *Critical care medicine, 45*(3), 486-552.

Sakr, Y., Elia, C., Mascia, L., Barberis, B., Cardellino, S., Livigni, S., . . . Ranieri, V. M. (2013). The influence of gender on the epidemiology of and outcome from severe sepsis. *Critical Care, 17*(2), R50.

Schmid, A., Hoffman, L., Happ, M. B., Wolf, G. A., & DeVita, M. (2007). Failure to rescue: a literature review. *J Nurs Adm, 37*(4), 188-198. doi:10.1097/01.nna.0000266838.23814.65

Seymour, C. W., Gesten, F., Prescott, H. C., Friedrich, M. E., Iwashyna, T. J., Phillips, G. S., . . . Levy, M. M. (2017). Time to Treatment and Mortality during Mandated Emergency Care for Sepsis. *New England Journal of Medicine, 376*(23), 2235-2244. doi:10.1056/NEJMoa1703058

Shuldham, C., Parkin, C., Firouzi, A., Roughton, M., & Lau-Walker, M. (2009). The relationship between nurse staffing and patient outcomes: a case study. *Int J Nurs Stud, 46*(7), 986-992. doi:10.1016/j.ijnurstu.2008.06.004

Silber, J. H., Gleeson, S. P., & Zhao, H. (1999). The influence of chronic disease on resource utilization in common acute pediatric conditions: financial concerns for children's hospitals. *Archives of pediatrics & adolescent medicine, 153*(2), 169-179.

Silber, J. H., Kennedy, S. K., Even-Shoshan, O., Chen, W., Koziol, L. F., Showan, A. M., & Longnecker, D. E. (2000). Anesthesiologist direction and patient outcomes. *The Journal of the American Society of Anesthesiologists, 93*(1), 152-163.

Silber, J. H., Romano, P. S., Rosen, A. K., Wang, Y., Even-Shoshan, O., & Volpp, K. G. (2007). Failure-to-rescue: comparing definitions to measure quality of care. *Med Care, 45*(10), 918-925.

Silber, J. H., Rosenbaum, P. R., McHugh, M. D., Ludwig, J. M., Smith, H. L., Niknam, B. A., . . . Aiken, L. H. (2016). Comparison of the value of nursing work environments in hospitals across different levels of patient risk. *JAMA Surg, 151*(6), 527-536.

Silber, J. H., Williams, S. V., Krakauer, H., & Schwartz, J. S. (1992). Hospital and patient characteristics associated with death after surgery: a study of adverse occurrence and failure to rescue. *Med Care*, 615-629.

Singer, M., Deutschman, C. S., Seymour, C., & et al. (2016). The third international consensus definitions for sepsis and septic shock (sepsis-3). *Jama, 315*(8), 801-810. doi:10.1001/jama.2016.0287

Smith, H. L. (2009). Double sample to minimize bias due to non-response in a mail survey.

The American Hospital Association (AHA). (2017). Data Collection Methods. Retrieved from http://www.ahadata.com/data-collection-methods/

Torio, C. M., & Andrews, R. M. (2013). National inpatient hospital costs: the most expensive conditions by payer, 2011: statistical brief# 160: Agency for Health Care Policy and Research (US), Rockville (MD).

Torsvik, M., Gustad, L. T., Mehl, A., Bangstad, I. L., Vinje, L. J., Damas, J. K., & Solligard, E. (2016). Early identification of sepsis in hospital inpatients by ward nurses increases 30-day survival. *Crit Care, 20*(1), 244. doi:10.1186/s13054-016-1423-1

Unruh, L. Y., & Zhang, N. J. (2012). Nurse staffing and patient safety in hospitals: new variable and longitudinal approaches. *Nurs Res, 61*(1), 3-12. doi:10.1097/NNR.0b013e3182358968

Vaughan-Sarrazin, M. S., Bayman, L., & Cullen, J. J. (2011). Costs of postoperative sepsis: the business case for quality improvement to reduce postoperative sepsis in veterans affairs hospitals. *Archives of surgery, 146*(8), 944-951.

Vogel, T. R., Dombrovskiy, V. Y., Carson, J. L., Graham, A. M., & Lowry, S. F. (2010). Postoperative sepsis in the United States. *Annals of surgery, 252*(6), 1065.

Wang, H. E., Devereaux, R. S., Yealy, D. M., Safford, M. M., & Howard, G. (2010). National variation in United States sepsis mortality: a descriptive study. *International journal of health geographics, 9*(1), 9.

Weinberg, D. B., Cooney-Miner, D., Perloff, J. N., & Bourgoin, M. (2011). The gap between education preferences and hiring practices. *Nurs Manage, 42*(9), 23-28.

Yakusheva, O., Lindrooth, R., & Weiss, M. (2014). Economic evaluation of the 80% baccalaureate nurse workforce recommendation: a patient-level analysis. *Med Care, 52*(10), 864-869.

Yokoe, D. S., Anderson, D. J., Berenholtz, S. M., Calfee, D. P., Dubberke, E. R., Ellingson, K. D., . . . Klompas, M. (2014). A compendium of strategies to prevent healthcare-associated infections in acute care hospitals: 2014 updates. *American journal of infection control, 42*(8), 820-828.

Zingg, W., Holmes, A., Dettenkofer, M., Goetting, T., Secci, F., Clack, L., . . . Pittet, D. (2015). Hospital organisation, management, and structure for prevention of health-care-associated infection: a systematic review and expert consensus. *The Lancet Infectious Diseases, 15*(2), 212-224.