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Impact of Continuity in Nursing Care on Patient Outcomes in the Pediatric Intensive Care Unit

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Abstract

Background: Nursing care is known to improve patient outcomes during hospitalization, but the mechanisms by which outcomes are improved have not been fully explicated. Continuity in nursing care (CINC) may be an important characteristic of nursing care delivery that impacts patient outcomes. However, evidence linking CINC to patient outcomes is limited. Purpose: The first aim of this study was to examine the relationship between CINC and patient outcomes - length of intensive care unit (ICU) stay, duration of mechanical ventilation, adverse events, and ICU-acquired infections - in a pediatric ICU. The second aim was to examine whether the match of nursing expertise to mortality risk enhances the relationship between CINC and patient outcomes. Methods: This cross-sectional study was a secondary data analysis of prospectively collected data that were merged from multiple databases from one pediatric ICU. The analytical database was a combination of four databases: the Nightingale Metrics database, the Virtual Pediatric Intensive Care Unit Performance System database, the Medical/Surgical Intensive Care Unit-Acquired Infection database, and the Safety Errors Reporting System database. The relationships between CINC and patient outcomes were assessed using a proportional hazard regression model and a logistic regression model. The final sample included 332 pediatric ICU subjects. Results: In multivariable regression analyses, more CINC was associated with a longer ICU stay and a longer duration of mechanical ventilation. CINC was not significantly associated with adverse events and ICU-acquired infections. A match of nursing expertise and mortality risk did not have a significant effect on the relationship between CINC and any of the four patient outcomes. However, the moderating effect of the match variable on the negative association between CINC and nurse-sensitive adverse event was significantly less for the matched group; specifically fewer different experienced nurses created a safer environment, than the mismatched group. Conclusion: This study provides preliminary data evaluating the relationship between CINC and pediatric ICU patient outcomes. Additional studies in other settings are needed to better understand these findings. Future research should focus on refining the measurement of CINC and exploring links between CINC and other outcomes such as patient/family satisfaction and being well-cared-for.

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IMPACT OF CONTINUITY IN NURSING CARE ON PATIENT OUTCOMES IN THE PEDIATRIC INTENSIVE CARE UNIT

DEDICATION

To my parents, Siow See Quan and Ng Jee Pua Sally;

and my husband, Jeffrey Ng and my son, Edward Ng

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ABSTRACT

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Kee Chen Elaine Siow

Martha A. Q. Curley, Dissertation Chair

Background: Nursing care is known to improve patient outcomes during hospitalization, but the mechanisms by which outcomes are improved have not been fully explicated. Continuity in nursing care (CINC) may be an important characteristic of nursing care delivery that impacts patient outcomes. However, evidence linking CINC to patient outcomes is limited. **Purpose:** The first aim of this study was to examine the relationship between CINC and patient outcomes - length of intensive care unit (ICU) stay, duration of mechanical ventilation, adverse events, and ICU-acquired infections - in a pediatric ICU. The second aim was to examine whether the match of nursing expertise to mortality risk enhances the relationship between CINC and patient outcomes. **Methods:** This cross-sectional study was a secondary data analysis of prospectively collected data that were merged from multiple databases from one pediatric ICU. The analytical database was a combination of four databases: the Nightingale Metrics database, the Virtual Pediatric Intensive Care Unit Performance System database, the Medical/Surgical Intensive Care Unit-Acquired Infection database, and the Safety Errors Reporting System database. The relationships between CINC and patient outcomes were assessed using a proportional hazard regression model and a logistic regression model. The final sample included 332 pediatric ICU subjects. **Results:** In multivariable regression analyses, more CINC was associated with a longer ICU stay and a longer duration of mechanical ventilation. CINC was not significantly associated with adverse events and ICU-acquired infections. A match of nursing expertise and mortality risk did not have a significant effect on the relationship between CINC and any of the four patient outcomes. However, the moderating effect of the match variable on the negative association between CINC and nurse-sensitive adverse event was significantly less for the matched group; specifically fewer different experienced nurses created a safer environment, than the mismatched group. **Conclusion:** This study provides preliminary data evaluating the relationship between CINC and pediatric ICU patient outcomes. Additional studies in other settings are needed to better understand these findings. Future research should focus on refining the measurement of CINC and exploring links between CINC and other outcomes such as patient/family satisfaction and being well-cared-for.

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CHAPTER 1: INTRODUCTION

Background

Nurses play a vital role in the healthcare system. The American Nurses Association defines the role of nursing as "the protection, promotion, and optimization of health and abilities, prevention of illness and injury, alleviation of suffering through the diagnosis and treatment of human response, and advocacy in the care of individuals, families, communities, and populations" (American Nurses Association, 2003). According to the United States Bureau of Labor Statistics, registered nurses constitute the largest healthcare occupation, with 2.6 million employed in 2008; this number is expected to grow, with the projected employment being 3.2 million in 2018 (United States Deptment of Labor, 2010). Approximately 60% of registered nurses work in hospitals. Despite the large number of employed registered nurses, there is a significant nursing shortage, which has led to concerns about the adverse impact of this shortage on the delivery of high quality nursing care (Aiken, Buchan, Ball, & Rafferty, 2008; Aiken, Clarke, & Sloane, 2002; Blegen, Goode, & Reed, 1998; Cho, Ketefian, Barkauskas, & Smith, 2003; Griffiths & Wilson-Barnett, 2000; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002; Rothberg, 2005; Sasichay-Akkadechanunt et al., 2003; Tourangeau, Cranley, & Jeffs, 2006). These concerns are especially significant for specialty units such as intensive care units (ICU) where a higher registered nurse to patient ratio is required to care for patients with a higher level of acuity (Buerhaus, Staiger, & Auerbach, 2000).

This study investigates whether continuity in nursing care (CINC) affects the quality of the nursing care delivered to patients in the pediatric ICU. Theoretically, CINC is likely to enhance nursing care delivery by supporting the development of relationships that nurses form with patients and family. The principal reason to expect that CINC will improve patient outcomes is that familiar caseloads and reciprocal relationships between nurses and patients can potentially improve patient outcomes. An engaged relationship between nurses and patients is an essential foundation for caring behaviors. Nursing care can be improved as a result of nurses having a comprehensive understanding of a patient's unique response to illness and needs, greater awareness of patient risk allows for a safer environment, and being better advocates for patients and their families. In the inpatient environment, CINC is achieved by being consistently assigned to the care for the same patient/family. In this study, CINC is defined as the degree to which nursing care is provided by fewer different nurses to patients over the course of their hospitalization experience (Curley & Hickey, 2006).

A secondary aim of this study is to investigate how nurse expertise, when matched to a patient's risk of mortality, moderates the effect of CINC on patient outcomes. This aim is based on the belief that nursing expertise is an important factor in making CINC successful. When expert nurses are matched to patients with complex needs and when they are given the opportunity to know their patients, they may be better able than less expert nurses to communicate and establish trust with the patients and their families, as well as to resolve evolving problems more effectively during their interactions with patients and families.

Continuity in Nursing Care (CINC) is a characteristic of a care delivery process that encourages nurses to know a patient and for the patient to know his or her nurses. Such reciprocal knowledge is important in building a relationship with patients and their families. This relationship may increase the amount of nuanced information the nurse knows about the patient, which may facilitate and guide the nurse in making better clinical judgments that meet the individual needs of the patient and families. Furthermore, when patients and families become active participants in the interaction, the mutuality within the nurse-patient relationship is believed to result in better patient outcomes than those that could have been achieved independently (Curley, 1998). Mutuality is an attribute of the nurse-patient relationship that encompasses the concept of patient/family-centered care and caring behavior (Curley, 1997; McCormack, 2004), which is especially essential in the care of pediatric patients, where patient care is provided in partnership with the parents.

An investigation into the impact of CINC on patient outcomes is important in light of the challenges present in health care today. Two key challenges facing the nursing profession are the need to constrain rising healthcare costs and the inadequate nursing supply in the face of increasing demand, both of which can lead to lower quality of care. Ideally, a well-staffed unit may facilitate the implementation of CINC. Even in cases of inadequate staffing, CINC can potentially improve the quality of care. Implementing CINC could simply involve the assignment of existing nurses within the unit, such that fewer different nurses provide care to each patient. Thus, CINC might be considered a characteristic of a model of nursing care that results in the better utlization of existing resources.

Despite the potential of CINC to improve the quality of patient care, the impact of CINC on patient outcomes in the pediatric ICU has not been extensively examined. The only related study is by Heller and Solomon (2005), who interviewed the bereaved parents of children who died after receiving intensive care at three children's teaching hospitals in the United States. Bereaved parents felt their child was well-cared-for when there was continuity in care. The parents stated that continuity in care helped build relationships and promoted caring, as well as provided a sense of security and confidence. In contrast, the lack of continuity in care led to frustration, hypervigilance, mistrust, and anxiety. To the extent that parents of severely ill children value the importance of CINC in the pediatric ICU, this study examines how CINC, as a characteristic of a model of nursing care delivery, can be linked to patient outcomes, specifically those that are related to quality of care.

Conceptual Underpinnings of the Study

The American Association of Critical Care Nursing Synergy Model for Patient Care guides the theoretical framework of this study (Curley, 1998). This model focuses on the importance of a therapeutic relationship between the nurse and patient. The model purports that, in order to achieve optimal patient outcomes, nursing care should be based on the needs of the patients and families. The key assumption underlying the Synergy Model is that patient characteristics drive nursing competencies. Patient outcomes may be optimized when nurse competencies match and synergize with patient characteristics and needs, which can in turn be facilitated by methods of nursing care delivery such as CINC. Specifically, CINC may allow nurses to develop synergy with the patients and their families.

The Synergy Model is relevant to current nursing practice and describes the importance of the nurse-patient relationship in meeting the needs of patients and their families. It also highlights that nurses' unique contribution to patients, to create safe passage for patients and families. According to Curley (2007), safe passage is facilitated by the unique contribution of nurses in providing therapeutic patient care. Examples of such nursing care includes helping the patient and family move toward self-awareness and understanding, competence, health, and transition through stressful events and/or peaceful death. Creating safe passage in patient care requires that the nurse know the patient (Curley, 1998, 2007). Hence, assigning the same nurses to the patient can be seen as a way for a nurse to know the patient and family better, which will in turn, leads to safe passage through the acute care hospitalization experience.

The key components in the Synergy Model include patient characteristics, nursing competencies, and patient outcomes. In the Synergy Model, patient characteristics evolve over time and span the continuum of health and illness, and nursing competencies are derived from the needs of their patient population. In the context of the Synergy Model, CINC can be seen as enabling nurses to better understand the patient's characteristics and needs, and at the same time develop proficiency in nursing competencies by knowing the typical needs of various patient populations. To the extent that positive synergies develop as a result of CINC, CINC is expected to have a positive impact on patient outcomes. Patients may benefit from models of care that provide both CINC and nursing expertise.

Statement of the Problem

Continuity in nursing care (CINC) is a characteristic of a model of nursing care delivery that can improve the quality of care in hospitals at potentially low cost. The ability to design and test methods of nursing care delivery that can lead to better patient outcomes, especially in the face of the need to constrain rising healthcare costs and the nursing shortage, is of importance to nursing practice. This study investigates the impact of CINC on the quality of care in the pediatric ICU. Apart from its potential practical implications for nursing care, examining CINC addresses an important gap in the literature for the following reasons.

First, CINC is the part of the broader theme of continuity. While the concept of continuity in care has been studied extensively, the focus of these studies was often from a medical perspective. Many studies offer evidence that interpersonal continuity or continuous interaction with fewer physicians, as opposed to many physicians, can lead to better patient outcomes (Brousseau, Meurer, Isenberg, Kuhn, & Gorelick, 2004; Christakis, Feudtner, Pihoker, & Connell, 2001; Christakis, Mell, Wright, Davis, & Connell, 2000; Christakis, Wright, Koepsell, Emerson, & Connell, 1999; Christakis, Wright, Zimmerman, Bassett, & Connell, 2002, 2003; Cree, Bell, Johnson, & Carriere, 2006; Cyr, Martens, Berbiche, Perreault, & Blais, 2006; Flores, Bilker, & Alessandrini, 2008; Gill, Mainous, Diamond, & Lenhard, 2003; Hanninen, Takala, & Keinanen-Kiukaanniemi, 2001; Lin, Huang, Wang, Yang, & Yaung, 2009; Litaker, Ritter, Ober, & Aron, 2005; Parchman, Pugh, Noel, & Larme, 2002; Parkerton, Smith, & Straley, 2004).

Second, a large body of literature describes the relationship between the characteristics of nursing care and the quality of care in hospitals (Aiken, Clarke, & Sloane, 2002; Aiken, Xue, Clarke, & Sloane, 2007; Archibald, Manning, Bell, Banerjee, & Jarvis, 1997; Estabrooks, Midodzi, Cummings, Ricker, & Giovannetti, 2005; Hickey, Gauvreau, Connor, Sporing, & Jenkins, 2010; Marcin et al., 2005; Morrison, Beckmann, Durie, Carless, & Gillies, 2001; Needleman et al., 2002; Ream et al., 2007; Robert et al., 2000; Tibby, Correa-West, Durward, Ferguson, & Murdoch, 2004; Wolfer & Visintainer, 1975). Nursing care characteristics that are commonly studied are nurse staffing, nursing workload, nursing expertise, and nursing experience. This literature generally documents that better nurse staffing, higher nurse expertise, and more years of nursing experience are associated with better patient outcomes.

This prior literature, however, has paid less attention to the relationship between the nurse and the patient. Furthermore, these researchers measured the intensity of nurse staffing levels (e.g., nurse to patient ratios, number of registered nurses full time equivalents, and hours nurses worked per day) but not the CINC (e.g., the proportion of different nurses assigned to each patient). Several studies have indicated that nurses who provide care to the patient over a period of time will get to know the patient better (Jenny & Logan, 1992; Luker, Austin, Caress, & Hallett, 2000; Takemura & Kanda, 2003; Tanner, Benner, Chesla, & Gordon, 1993). To the extent that CINC provides the opportunity for the nurse to know the patient, outcomes should be improved. Only one study has explored the concept of continuity in care in the pediatric ICU using qualitative methods (Heller & Solomon, 2005), and no studies to date have used quantitative methods to investigate the impact of CINC on patient outcomes in the pediatric ICU setting.

Third, there are limited data describing the impact of CINC on the quality of care in the critical care setting (Heller & Solomon, 2005). Only one study examined how CINC affects actual patient outcomes. Continuity in care was not completely measured but generally described by the parents of pediatric patients who died after receiving cancer treatment. Hence, additional research is important so that nurses have a better understanding of how CINC impacts patient outcomes.

Purpose of the Study

The purpose of this study is to examine the extent to which CINC impacts patient outcomes in the pediatric ICU. This study addressed two research questions: i) does CINC impact patient outcomes in the pediatric ICU? and ii) does a match between nursing expertise and a patient's risk of mortality enhance the effect of CINC on patient outcomes in the pediatric ICU? To test the hypotheses, merged data from the Nightingale Metrics database, the Virtual Pediatric Intensive Care Unit Performance System database, the Medical Intensive Care Unit-Acquired Infection database, and a Safety Events Reporting System database were used.

Research Question 1: Does continuity in nursing care impact patient outcomes in the pediatric intensive care unit?

The following hypothesis corresponds to research question 1:

Hypothesis 1: Patients who receive more continuity in nursing care in the pediatric intensive care unit will experience better patient outcomes than patients who receive less continuity in nursing care.

Rationale: Continuity in nursing care (CINC) refers to care that is provided by few different nurses. As a result, nurses are given the opportunity to know the patient better, allowing them to have a better understanding of the patient. The Synergy Model predicts that this method of nursing care may enable nurses to develop a synergistic relationship with their patients. These synergies, in turn, will have a positive impact on patient outcomes. Empirically, there is some evidence in the literature to support that continuity in care has a positive impact on patient outcomes. Many of these studies, however, were conducted in an outpatient setting and/or in medicine. In particular, there is no evidence on how CINC in the pediatric ICU will impact patient outcomes. Hence, the purpose of this study is to advance the science in the area of continuity in care by providing evidence of the relationship between CINC and pediatric ICU patient outcomes. Given the prediction of the Synergy Model and the evidence in the existing literature, the hypothesis is that CINC will have positive impact on pediatric ICU outcomes.

Research Question 2: Does a match between nursing expertise and a patient's risk of mortality enhance the effect of continuity in nursing care on patient outcomes in the pediatric intensive care unit?

The following hypothesis corresponds to research question 2:

Hypothesis 2: The positive impact of continuity in nursing care on patient outcomes will be greater when there is a match between nursing expertise and a patient's risk of mortality.

Rationale: While CINC provides a nurse with opportunities to develop a therapeutic relationship with a patient and thus allows for synergy to be developed, these opportunites have to be effectively harnessed to optimize patient care. Nursing expertise is an important factor in making CINC more successful because nurses with greater expertise have the capacity to provide optimal nursing care to sicker patients. In this paper, the level of nurse expertise is defined by the professional advancement program used by Children's Hospital Boston to promote nurses. When given the opportunity to know patients better, the expert nurse may be better able to communicate and establish trust with patients and their families, as well as to better resolve problems identified effectively during the close interactions between patients and families. On the other hand, if a nurse's expertise does not match with the patient's needs, the nurse may not have a good understanding of the needs of the patient or the best outcome may not occur. Furthermore, even if a therapeutic relationship develops, the nurse might not know how to optimally utilize the knowledge gained from that relationship. Hence, the second hypothesis proposes that a good match between nursing expertise and a patient's needs leads to a positive moderating effect on the impact of CINC on pediatric ICU outcomes.

Assumptions

The first assumption in this study is that, when given the opportunity, nurses will develop therapeutic relationship with the patient and family. CINC is a characteristic of nursing care delivery that provides opportunities for nurses to spend more time with the patient that will, in turn, facilitate knowing their patients and developing therapeutic relationships with them and their families. This relationship will allow nurses to develop knowledge about the patients assigned to their care, which will enable them to provide better nursing care and to positively impact patient outcomes. While it seems likely that CINC will lead to more therapeutic relationships, it is possible that this might not occur if there is a lack of trust in the nurse-patient relationship, differences in personality, difficulties in communication, differences in culture and language, and a prior negative experience with an individual.

The second assumption is that staffing was assumed to be adequate in the pediatric ICU. While CINC provides nurses with the opportunity to come to know their patients over time, inadequate staffing may prevent therapeutic relationships from developing.

The third assumption is that the measure of nursing expertise accurately reflects the level of expertise. This study uses the level of expertise indicated by Children's Hospital Boston Professional Advancement Program. The goal of this program, which is based upon Dr Patricia Benner's (1982) early work on clinical proficiency in nursing practice, is to provide a method for acknowledging the professional growth of an individual nurse that is based on clinical expertise, individual accomplishment, and contribution to patient care and unit activities. There are three levels of professional advancement for registered nurses: Levels I, II, and III. Level I represents a nurse with a competent level of professional practice, a Level II nurse indicates a proficient level of nursing practice that is characterized by having specialized knowledge and skill, and Level III designates an expert level of practice that is characterized by having more advanced skills than a Level II nurse and the ability to direct, support, and influence nursing practice within the organization. The advancement process from Level I to Level II is unit-based, while the advancement process from Level II to Level III is both unit- and department-based. As part of the advancement process, the Synergy Model was included in the evaluation of nurses' core competencies, with a focus on clinical practice and nurse-patient relationships. The eight dimensions for evaluating core nursing competencies include clinical judgment, clinical inquiry, caring practices, response to diversity, advocacy/moral agency, the facilitation of learning, collaboration, and systems-thinking. A limitation of using the measure of nursing expertise based on the Performance Advance Program is that it reflects a promotion as opposed to actual nursing experience. In addition, this designation is optional; a nurse may choose not to be promoted. Specifically, a Level I nurse may have a high level of nursing expertise without wishing to become a Level II nurse.

Definition of Key Terms

This section provides an explanation of key terms that were used in the research questions and hypotheses of this study.

Continuity in Nursing Care (CINC) is defined as the degree to which nursing care is provided by fewer different nurses to the patient during hospitalization (Curley & Hickey, 2006).

Impact is defined as having an incremental effect on outcomes, after controlling for other factors that might affect patient outcomes.

Moderator Variable is described as a variable that affects the direction and/or strength of the relationship between an independent and dependent variable (Baron & Kenny, 1986).

Nursing Expertise is described as the ability to perform expert actions without the awareness that experiential and theoretical nursing knowledge is being used (Benner, 1982; Woolery, 1990). Children's Hospital Boston uses the Professional Advancement Program to describe nurses' level of expertise, based on core nursing competencies.

Patient Outcomes are the results or consequences of interventions received by the patient. The patient outcomes in this study are ICU length of stay, the duration of the time spent on a mechanical ventilator, the occurrence of an adverse event, and the occurrence of an ICU-acquired infection such as a catheter-associated bloodstream infection, ventilator-associated pneumonia, and catheter-associated urinary tract infection.

Pediatric Intensive Care Unit refers to a specialized multidisciplinary unit that provides care for critically ill children, from newborn to 18 years of age, across a spectrum of childhood diseases, except for cardiac disease or severely burned children (Children's Hospital Boston, 2005-2007). The Medical/Surgical Intensive Care Unit (MSICU) is a type of specialized pediatric ICU in Children’s Hospital Boston.

Summary

The primary purpose of this study was to examine the effect of CINC on patient outcomes in the pediatric ICU. The secondary aim was to determine if nursing expertise enhances the effect of CINC on patient outcomes. The following databases were used in the empirical analyses: the Nightingale Metrics database, the Virtual Pediatric Intensive Care Unit Performance System database, Medical/Surgical Intensive Care Unit-Acquired Infection database, and the Safety Events Reporting System database. There is a lack of research in the area of CINC, especially in the inpatient setting. Empirically validating the relationship between CINC and patient outcomes can help nurses develop effective, evidence-based models of nursing care delivery.

CHAPTER 2: REVIEW OF RELATED LITERATURE

This study addresses two research questions. The first question evaluates the impact of CINC on patient outcomes in the pediatric ICU. Based on the Synergy Model and an extensive body of literature, patients who receive more CINC may be more likely to experience better patient outcomes than a patient who does not. The second question addresses whether a match between nursing expertise and a patient's risk of mortality enhances the relationship between CINC and patient outcomes. Based on the argument that nursing expertise may enhance the effectiveness of CINC, the positive impact of CINC on patient outcomes will be greater when nursing expertise is matched to a patient's risk of mortality.

Chapter 2 begins by describing the Synergy Model as the conceptual framework for this study. Next, the literature on the concept of knowing the patient is analyzed, with the aim of providing a review of the theories and research on the concept of knowing the patient. Third, the various conceptual definitions and operational terms of CINC are discussed. Fourth, the body of literature on the impact of continuity in care on inpatient outcomes is critiqued. Fifth, the literature on the concept of nursing expertise and the impact of nurse expertise on patient outcomes is presented. Sixth, patient outcomes that are important in the pediatric ICU setting are identified. The chapter concludes with a critical analysis of the overall literature and a discussion of important gaps.

Synergy Model in Patient Care

The key mechanism by which CINC may positively impact patient outcomes is that CINC may enable a nurse to develop a therapeutic relationship with a patient and his/her family, and as a result, the nurse may be able to provide higher quality nursing care that leads to better patient outcomes. The Synergy Model emphasizes that when the nurse and the patient develop a reciprocal relationship, the nurse may be able to provide better care based on the patient's needs. The fundamental principle of this model is that patient characteristics drive nursing competencies. There are eight patient characteristics that evolve over time and spans across a continuum of health and illness. The eight patient characteristics are stability, complexity, predictability, resiliency, vulnerability, participation in decision making, participation in care, and resource availability. The eight nursing competencies that are derived from the needs of patients are clinical judgment, clinical inquiry, caring practices, diversity of responsiveness, advocacy, facilitation of learning, collaboration, and systems thinking. The model indicates that nurses develop expertise over time within each dimension, based on the typical needs of their patient population. When patient characteristics and nurse competencies match and synergize, optimal outcomes are expected. The three levels of outcomes described in the model are the patient/family level, the unit level, and the systems level.

Theories of Knowing

When nurses are assigned to the same patient, they come to know that patient. CINC is a characteristic of care that may offer nurses the opportunity to better know the patient. Examining the literature on knowing the patient can provide some explanation on the intricacies of nursing care characteristics that might be linked to CINC.

The term “knowing” means to “perceive directly or to have a direct cognition and understanding of something” (Merriam-Webster, 2003). David Hume, a Scottish philosopher known for his writings on empiricism, identified two ways in which knowledge is constructed: the “relation of ideas” and the “matters of fact” (Hume, 1978). The first type of knowledge, the “relation of ideas”, is obtained only from reasoning. The second type of knowledge, the “matters of fact”, is obtained only through experience. According to Bonis (2009), knowing in nursing is grounded in a type of knowledge from a health and illness perspective that is unique to each individual, created through personal experience, shaped by reflection, and manifested by meaning.

Most notably, Carper’s (1978) seminal paper provided a philosophical discussion of four fundamental patterns of knowing in nursing – empirics, esthetics, personal, and ethical knowledge. Each pattern of knowing is described below. Empirics refer to the development of a body of knowledge that is specific to nursing. For instance, such knowledge can come in the form of conceptual or theoretical models that present new perspectives of health and illness from a nursing perspective. Esthetics refers to the art of nursing that is often associated with the general category of manual and/or technical skills involved in nursing practice. For instance, empathy is an art of nursing that is a component of the esthetic pattern of knowing. The more skilled a nurse is in perceiving and empathizing with patients, the more knowledge or understanding that nurse gains about the patient’s current situation. Personal knowledge is the fundamental pattern of knowing in nursing and it is essential to understanding the meaning of the patient's health and illness. This knowledge, however, can be difficult to master and teach. For instance, one of the ways the nurse can develop personal knowledge of the patient is through knowing one's self and through the nurse's interaction and relationship with the patient. CINC may enable the nurse to recognize nuances about the patient's condition and needs. Ethics refers to the moral component of knowing in nursing. Because nursing is a social service that is responsible for conserving life, alleviating suffering, and promoting the health of the patients, such knowledge is important in order for nurses to be sensitive to the difficult personal choices that are made within the complex context of healthcare.

What is Knowing the Patient?

Knowing the patient is an important concept that is embedded in some nursing conceptual models and theories (Carper, 1978; Curley, 2007; Peplau, 1992; Watson, 1988). This concept generally reflects ideas of holistic, humanistic, and patient-centered care. While much is known about knowing the patient both theoretically and empirically, most of this knowledge is subjective. Knowing is often described from the nurse's perspective. Curley (2007) defined knowing the patient as how nurses understand the patient, grasp the meaning of the patient's situation, or determine the need for a particular intervention. Takamura and Kanda (2003) defined knowing the patient as the way in which nurses obtained information and used it to form a perception about the patient. On the other hand, Gramling (2004) conducted a narrative inquiry to understand patients' experiences of nursing within the context of the critical illness experience. Five women and five men, who stayed in the intensive care unit for at least 24 hours, participated in the study. In one of the themes identified, the author found that the patient's ability to know the nurse was just as important to the relationship as the nurse's ability to know the patient. This suggests that CINC is an important element to consider in the care of critically ill patients.

Knowing the patient is an intrinsic characteristic of nursing that often leads to caring practices (Gaut, 1983; Macleod, 1994; Rittman, Paige, Rivera, Sutphin, & Godown, 1997; Tanner et al., 1993; Wilkin & Slevin, 2004) and individualized care (Evans, 1996; Radwin, 1995; Takemura & Kanda, 2003; Tanner et al., 1993; Wilkin & Slevin, 2004). Other authors have identified knowing the patient as one aspect of developing clinical knowledge and clinical judgment (Jenny & Logan, 1992; Tanner, 2006). The benefits of knowing the patient has been associated with patient outcomes such as improving the quality of patient care (Attree, 2001; Bowers, Swan, & Koehler, 1994; Luker et al., 2000), encouraging patients to be active participants in their care (Henderson, 1997; McCormack, 2004), and a lower risk of adverse events (Cioffi, 2000; Minick, 1995). Nursing-related outcomes associated with knowing the patient include improving decision-making (McCormack, 2004; Wilkin & Slevin, 2004), and an increase in job satisfaction (Luker et al., 2000).

Knowing the patient is a complex process that requires nurses to understand the patient as a unique individual and to develop an in-depth knowledge of the patient's typical pattern of responses and needs (Cioffi, 2000; Gaut, 1983; Jackson, 2005; Johnson & Hauser, 2001; Tanner, 2006; Whittemore, 2000). For instance, Tanner et al., (1993) conducted interviews of 130 critical care nurses from eight hospitals to explore how nurses know the patient. Advanced beginner through expert nurses were selected to participate in this study. The nurses indicated that knowing the patient was an important element to skilled clinical judgment that goes beyond formal assessments of physical systems. From the nurses' narratives, knowing a patient involved knowing both the patient's typical responses and the patient as a person. The five aspects of knowing the patient's responses were: outcomes of therapeutic measures, routines and habits, coping resources, physical capacities and endurance, and body topology and characteristics. The nurses who described their experiences of knowing the patient as a person felt that they knew the patient in an involved and attached way. This enabled the nurses to understand issues that were important to the patient, such as the patient's concerns, enthusiasm for life, and importance to friends.

In contrast, Takemura and Kanda (2003) interviewed nurses from medical and surgical inpatient units to study how nurses know the patient as one characteristic of nursing practice in Japan. Nurses who had one or more years of nursing experience participated in the study. The nurses indicated that knowing the patient involved having knowledge of the patient's subjective world (from patient's perspective) and knowing the patient as a holistic person (from the nurses' perspective). The patient's subjective world referred to the nurses' understanding of the patient's perspectives, feelings, thoughts, interpretation, hopes, and expectations about experiences and life. The holistic patient referred to how nurses perceived the patient through their assessments of the patient using professional knowledge and experience. Although both studies found that the extent to which nurses know the patients might differ, both studies indicated that knowing the patient allowed the nurses to implement nursing care that was based on the needs of patients.

Jenny and Logan (1992) interviewed 16 expert nurses to identify their perceptions of weaning practices in the intensive care unit. From the nurses' narratives, they found that knowing the patient included an interpersonal process that involved a number of nursing actions such as perceiving/envisioning, communicating, self-presentation, and showing concern. Perceiving/envisioning referred to the interpretation of observations of patient's behavior. Communicating referred to the use of diverse and subtle skills when conversing with intubated patients. Self-presentation referred to the nurses' conscious efforts to gain the patient's trust. Showing concern referred to using a caring attitude to the patient and family when responding to their concerns. The nurses indicated that knowing the patient is an important aspect of nursing practice and the failure to utilize the knowing process might adversely affect patient outcomes.

Factors that Affect Knowing the Patient

The factors associated with knowing the patient include making a connection, nursing experience, developing a therapeutic relationship with the patient and family, longitudinality, and effective communication. Studies indicated that the knowing process begins with nurses making a connection with the patient that results from being involved in the care and establishing early contact with the patient (Luker et al., 2000; Minick, 1995; Tanner et al., 1993). For instance, Luker et al., (2000) interviewed home care nurses to determine their perspectives on quality care. Several nurses described incidents where initiating early contact and involvement with the patient was important towards building the nurse-patient relationship. In a cited example, one nurse described a situation where early access facilitated the development of the nurse-patient-family relationship. The nurses indicated that providing nursing care to the patient and family early on in a patient's diagnosis of terminal illness allowed them to provide support and build a relationship with the patient and family.

The nurses' past experiences of caring for patients can affect how nurses know their patients. Previous nursing experiences are valuable because they provide with nurses generic knowledge of the typical responses, issues, and expectations of the patient (Jenny & Logan, 1992; Tanner et al., 1993). Jenny and Logan (1992) found that the expert nurses indicated that past experiences allowed them to provide better care and to have more confidence and focus, resulting in a better understanding of the patient, which is vital to a successful weaning process. Similarly, Tanner et al., (1993) found that the more experienced critical care nurses were able to identify the problem based on calculative reasoning and elemental bits of information from a similar prior situation. It has been suggested that the knowledge gained from experience is shared in the language and practices of nursing, allow nurses to know their patients (Benner, 1984). Part of knowing the patient requires nurses to use their clinical judgment, creating the possibility for advocacy that will prevent the occurrences of iatrogenic injury to patient (Curley, 1998).

The therapeutic relationships that exist between the nurse, patient, and family can influence how the nurse knows the patient (Jackson, 2005; Radwin, 1996; Tanner et al., 1993). For instance, Jackson (2005), conducted interviews of newly qualified registered nurses working in a surgical unit to explore their experiences and their description of a good day in nursing. From the nurses' narratives, elements of a good day in nursing included doing something well, having good relationships with patients, having a feeling of achievement, getting their work done, and feeling a sense of teamwork. The author found that the nurses' perception of having a good day involved knowing the patient on a personal level and knowing about their care and condition. The nurses who perceived themselves to having good relationships with their patients indicated that there was mutual sharing of personal information, allowing them to learn about things that were important to the patient. One nurse described how having a therapeutic relationship with the patient enabled her to show empathy and to provide emotional support to the patient. One limitation of this study is that the identified themes of a good day were conducted over two tapes interviews. An ethnographic method of study might allow for a further in-depth exploration of the topic, such as examining how novice nurses know the patient. Tanner et al. (1993) pointed out how the nature of relationships between a nurse and families can play an important role in helping nurses know the patient. Because families have the most contact with the patient throughout the hospitalization, they could provide valuable information to the nurses about the patient's characteristics and/or inform nurses on any signs and symptoms that are different from the patient's usual responses.

Longitudinality has been associated with the extent to which nurses get to know their patients (Jenny & Logan, 1992; Luker et al., 2000; Radwin, 1996; Takemura & Kanda, 2003; Tanner et al., 1993). In this review, longitudinality refers to the patient and nurse developing a patient-focused relationship over a prolonged period of time. For instance, Jenny and Logan (1992) found that the intensive care unit nurses felt that having continued contact with the patient was one important factor that could affect the knowing process. According to the nurses, the time spent in caring for the patient provided nurses with the opportunities to know the patient better and for the patient to know their nurses. Furthermore, when nurses demonstrated their commitment to a patient's concerns and comfort through knowing, the patients trusted the nurses more. The nurses believed that trust enhanced the nurse-patient collaboration and also the knowing process. Similarly, Luker et al., (2000) found that the nurses considered getting to know the patient over a period of time to be an important aspect of community nursing, where the nurses included both the patient and the patient's family in the plan of care. Generally, the nurses indicated that spending time, establishing early contact with the patient and family and limiting the number of nurses caring for to patient to ensure CINC provided a sense of closeness, which facilitated the nurses' knowing the patient. These strategies have enabled the nurses to provide for more than the physical aspects of patient care.

Interactions and communications with the patient can facilitate nurses' ability to know the patient (Attree, 2001; Luker et al., 2000). Using the grounded theory method of study, Attree (2001) interviewed patients discharged from a medical inpatient unit and their relatives to find out their perspectives on quality care. The patients described situations where open communication between the nurses and patients was an important aspect of knowing the patient, highlighting the importance for nurses to spend time talking to patients in order to get to know them. The patients indicated that open communications not only allowed nurses to find out about the patients' needs and problems, but also for the patients to receive information and advice from nurses. Likewise, Curley (1998) suggested that reciprocal knowing (involving the nurse knowing the patient and the patient knowing the nurse) requires the organization to be supportive of a care delivery that provides CINC and the opportunity for the nurse to spend time with the patient and family. Luker et al., (2000) cited a situation where a nurse described how frequent communication between the community nurse, patient, and family were essential to helping the nurse know the patient in order to develop a good relationship that will in turn allow nurses to provide high quality care.

Importance of Knowing the Patient

Most studies highlighted the positive impact of knowing the patient in nursing practice. There are several reasons why it is important for nurses to know their patients. Studies have found that knowing the patient is important in developing generalized and particularistic knowledge of the patient (Jenny & Logan, 1992; Radwin, 1995; Tanner et al., 1993). Tanner et al., (1993) found in the nurses' narratives that knowing the patient allowed them to learn about common issues and important characteristics within that patient population. The nurses indicated that this was achieved through building and synthesizing information over a period of time. For instance, the authors cited an example where the nurses were able to distinguish between babies who were fussy due to cocaine withdrawal and babies who were fussy due to other causes. Jackson (2005) highlighted the importance for novice nurses to know their patients. The author stated that unlike expert nurses, novice nurses do not have vast experience and clinical knowledge. Hence, it is believed that more competent care can be achieved if novice nurses fully understand the patient. Such understanding would allow the nurses to prioritize and get work done more effectively.

Using a grounded theory methodology, Radwin (1995) studied the process of clinical decision making among expert nurses from a cardiology specialty unit. The author found that expert nurses who have extensive knowledge of the patient were able to develop a broader perspective of the patient by combining an understanding of the patient both within and outside the acute care setting and over a period of time. According to the nurses, having a broader perspective of the patient is important in making individualized choices in patient care. The author cited an example where the nurse caring for a patient with unstable angina who did not respond to conventional treatment was able to consider other options based on patient's expectations. Similarly, Jenny and Logan (1992) indicated that knowing the patient provided nurses with a sense of situational control and the authority for making the nursing judgments, decisions, and actions that were required for a successful weaning. In contrast, the nurses felt that those who do not have knowledge of the patient could only base their care on generalized knowledge that was perceived to be insufficient in caring for critically ill patients.

Some studies indicated that knowing the patient is central to the basis for individualizing care (Attree, 2001; Jenny & Logan, 1992; Radwin, 1995; Takemura & Kanda, 2003; Tanner et al., 1993). Tanner et al., (1993) cited an example where a nurse described that knowing a premature infant influenced her nursing care and judgment, leading to individualized patient care. Radwin (1995) found that empathizing, matching a pattern, developing a bigger picture, and balancing preferences with difficulties were four strategies that facilitated nurses in providing individualized nursing care, suggesting that nursing interventions do not exclusively reflect the characteristics of the patient. The nurses indicated that different strategies were used, depending on the duration of time they knew the patient. For instance, the author described an incident where a nurse developed a different perspective of care when taking into account the patient's expectations and the goals of care. The author suggested that this evolved when the nurse was familiar with the patient for a greater period of time. Jenny and Logan (1992) found that when nurses knew the patient, they were able to make judgments about the availability of the patient's personal resources (e.g., patient preferences) necessary to weaning the patient off the ventilator. The nurses felt that including the patient's preferences into their decision to wean enhanced patients' feelings of control, their sense of identity, as well as minimizing stress. Attree (2001) found that patients and their families perceived the patient to be well-cared-for when nurses provided care that was personalized and based on the patient's need. As a result, this led the patients and families to develop a sense of trust and confidence in the nurse.

Nurses' knowing their patients permits the possibility of nurses to be advocates for patients and their families (Jenny & Logan, 1992; Tanner et al., 1993). Jenny and Logan (1992) cited an example where nurses who knew their patients were able to propose alternative methods of weaning approaches or to advocate for additional resources that the patient needed. According to the nurses, trust and professional credibility were established when the nurses knew their patients. Tanner et al., (1993) found that the nurses see themselves as advocates on issues such as being vigilant in ensuring that adequate care is given, about early warning signs that require attention, and on the medical therapies that were given with an understanding of the particular patient's responses. The nurses highlighted the importance of knowing the patient to the care of critically ill patients who were given sedations, analgesia, and paralytics, placing nurses in the role of advocating for the patient and family on vital issues.

Nurses believed that they may positively impact patient outcomes through knowing their patients (Jenny & Logan, 1992; Takemura & Kanda, 2003; Tanner et al., 1993). Jenny and Logan (1992) found that knowing patients' habitual response patterns enabled nurses to detect changes in a patient's condition, to rule out the possibility of problems, and to act on the situation before a significant problem arises. Tanner et al., (1993) suggested that in order to provide safe nursing care, nurses should know their patients sufficiently to see the changing relevance, to recognize early warning signs, and to protect patients from concerns or threats. In addition, Takemura and Kanda (2003) found that nurses who continuously know the patient used this method of nursing care not only as an approach to problem solving in patient care but also as a way of allowing patients to explore and realize the meaning and value of their lives with illness.

Continuity in Nursing Care

The Merriam-Webster Dictionary (2003) defines continuity as an "uninterrupted connection, succession, or union". In the nursing literature, however, there is no clear definition of CINC. CINC is typically regarded as an outcome that is achieved when there is seamless coordination of care and an effective transfer of patient care information from one nurse to another within the unit, the hospital, or across institutions (e.g., nursing homes) (Beaver et al., 2010; Chaboyer et al., 2009; Goode & Rowe, 2001; Kalisch et al., 2008; Manley, Hamill, & Hanlon, 1997; McFetridge, Gillespie, Goode, & Melby, 2007; Payne, Hardey, & Coleman, 2000; Pontin & Lewis, 2008; Waters & Easton, 1999).

The study of CINC dates back to 1948, when Carn and Mole (1949) explored the nursing practices of 30 public health nursing agencies' reported referral systems with 43 hospitals in the U.S. The authors defined CINC as the outcome of a seamless nursing service that extends beyond the hospital and into the community and/or from the community into the hospital. In the context of their study, CINC was also referred to as early home care. CINC is present when there is a nursing referral between hospital nursing services and public health nursing services. Accordingly, this method of care is desired because it allows the patient to be discharged from the hospital earlier if adequate referral systems are in place.

Other references to CINC included the use of i) standardized nomenclatures in nursing, terms for developing nursing diagnoses, interventions, and outcomes, facilitated CINC in integrated healthcare systems (Keenan & Aquilino, 1998), ii) an electronic charting tool or checklists to facilitate the seamless delivery of patient care (Hadjistavropoulos, Garratt, Janzen, Bourgault-Fagnou, & Spice, 2009; Shaw et al., 2010), and iii) a perioperative dialogue with the patient prior to surgery (Lindwall, Von Post, & Bergbom, 2003).

Several studies conceptualized CINC as a characteristic of nursing care delivery, provided by a nurse or a team of nurses assigned to care for the patient (Benjamin, Walsh, & Taub, 2001; Curley & Hickey, 2006; D'Errico & Lewis, 2010; Waldenström, 1998). Curley and Hickey (2006) characterized CINC in the acute care setting as the extent to which the same nurse or a few different nurses were assigned to care for the same patient during the previous seven days of hospitalization. More CINC was established when the patient interacts with fewer different nurses. Similarly, in a home health setting, D’Errico and Lewis (2010) defined CINC as having the same or only a few different home health nurses caring for the patient from admission through discharge. In an obstetrics setting, Waldenstrom (1998) defined CINC as postpartum midwifery care provided by a known midwife who had provided care to the same patients during antenatal care.

Two studies used metrics to calculate a CINC index (Curley & Hickey, 2006; D’Errico & Lewis, 2010). Curley and Hickey (2006) developed the Continuity of Care Index to measure CINC in the acute pediatric setting. The Continuity of Care Index is calculated by dividing the number of different nurses caring for a patient during a hospitalization by the number of nursing shifts in that hospitalization over a seven day period. The Continuity of Care Index ranges from zero to one. A lower Continuity of Care Index indicates more CINC; a higher Continuity of Care Index indicates less CINC. For example, a patient who stayed in the unit for seven days received care from eight different nurses. In this unit, the nurses typically do 12-hour shifts. The Continuity of Care Index would be calculated as $8 \div 14 = 0.57$. In contrast, D’Errico and Lewis (2010) used the Continuity of Care Index by Bice and Boxerman (1977) to measure CINC in terms of registered nurses' visit continuity. The Continuity of Care Index by Bice and Boxerman was derived from Rae and Taylor's index of fragmentation and it measures the extent to which a patient's total numbers of visits during an episode of illness are with a single group of referred providers divided by the dispersion of events represented by the denominator. The Continuity of Care Index ranges from zero to one, and in this case a higher value indicates more continuity in care. In the study by D'Errico and Lewis (2010), an index of 0.5 or higher indicates more CINC; an index of 0.49 and lower signifies less CINC. Although the methods of calculating the indexes differ slightly between studies, D'Errico and Lewis' (2010) method of measuring CINC was conceptually similar to Curley and Hickey (2006). Researchers were able to obtain data on the number of home health visits from existing medical records, making it easier for them to study CINC using secondary data. However, such measures might lack contextual richness. Particularly, it might not measure other elements of continuity in care, such as the quality of the actual interactions taking place between the nurses and the patient.

Other researchers measured CINC by implementing interventions in the clinical setting that reflect either more or less CINC (Benjamin et al., 2001). In a quasi-experimental study, Benjamin et al., (2001) studied two groups of patients. One group of patients was assigned to partnership caseload midwifery care, while another was assigned to conventional midwifery care. The first group received more CINC and the second group received less CINC. The caseload midwifery model of care consisted of three pairs of midwives who provided total care for a defined caseload of patients. This model of care delivery was to ensure that a known midwife would provide post-partum care to the patient. On the other hand, the conventional team midwifery care consisted of a larger team of 25 midwives who provided care to patients. In this model of care, the midwives did not receive a defined caseload of patients, suggesting that the patients might be seen by different midwives.

Determinants of Continuity in Care

Determinants such as patient characteristics, provider characteristics, intervention factors, and organization factors have been shown in the literature to affect continuity in care. In the inpatient setting, continuity in care refers to having the same provider or a team of providers who constantly care for patient throughout the duration of the hospitalization. In the outpatient setting, continuity in care refers to patients who constantly visit the same provider or a few different providers during clinic visits.

Patient Factors that Determine Continuity in Care

Schers, Webster, Van Den Hoogen, Avery, Grol, et al., (2002) conducted a survey of patients' views about continuity in provider care in the primary care setting. They found that most patients indicated it was important to see their own primary care provider mainly for serious medical conditions and emotional problems. The main reasons for the preference of their own primary care provider were the provider's assumed better medical knowledge of the patient and better understanding of the personal and family background. Patient characteristics such as age, sex, and frequency of visits had little impact on the patients' preference for continuity in care. Christakis et al., (2004) investigated the patient, family, provider, and system factors associated with continuity in care using surveys that were distributed to parents in a primary care pediatric clinic. They found that the parents' attitude towards continuity in care, higher family control, increased provider availability, and better provider ratings by parents were associated with more continuity in care, with more continuity in care referring to less dispersion in terms of the different providers seen. They also documented that making more visits to the clinic, having an older child, and more months continuously enrolled at the clinic were significantly associated with less continuity in care.

Provider Characteristics that Determine Continuity in Care

Greater provider availability and better communication during the handover process between nursing staff were associated with more continuity in care (Christakis et al., 2004; McFetridge et al., 2007). In a pediatrics primary care setting, Christakis et al., (2004) found that provider availability in terms of having a provider in the clinic on five full days of the week was associated with an increase in the continuity in patient care, compared to another provider in the clinic a half day per week. The authors suggested that dividing patients between two providers who work complementary schedules rather than having a single identified primary provider may be a more effective and practical means of improving continuity in patient care. Other solutions to reducing multiple handoffs were suggested, such as assigning the same nurses on same shifts (Goldschmidt & Gordin, 2006; Kalisch et al., 2008). For instance, Kalisch et al., (2008) found that when the same nurses were assigned to the same shifts, there was more continuity in nursing care, improved communication between nurses in the team, and a higher satisfaction among patients with the care. This thus improves the unit teamwork.

Intervention Factors that Determine Continuity in Care

Prior studies found that interventions can improve the continuity in care (Niederman, Schwartz, Connell, & Silverman, 2007; Rothbard, Min, Kuno, & Wong, 2004). Niederman et al., (2007) examined patient outcomes that are associated with the implementation of a Healthy Steps for Young Children program into a pediatric primary care practice. The purpose of this program is to improve the quality of preventive health for children through a therapeutic relationship between healthcare providers and parents for addressing the physical, emotional, and intellectual growth and development of children from birth to age three. The benefits of implementing the program included more continuity in care among children who were in the Healthy Steps for Young Children program group compared to those in the non-intervention group. Although they were not found to be statistically significant, the researchers found that there were more developmental, behavioral, and psychosocial diagnoses among children in the Healthy Steps for Young Children program group. Rothbard et al., (2004) examined the long-term effectiveness of implementing the Access to Community Care and Effective Services and Supports project for homeless people with serious mental illness. The authors found that more continuity in care following the patient's hospitalization was achieved during and after the Access to Community Care and Effective Services and Supports intervention. In addition, they found that this project resulted in an increased use of ambulatory services, suggesting the effectiveness of this project in reaching out to a population that was often resistant to standard care.

Organizational Factors that Determine Continuity in Care

Prior studies have considered organizational factors as determinants of continuity in care. In particular, there was more continuity in care when i) a greater proportion of resources was invested in outpatient mental health services (Greenberg & Rosenheck, 2003), ii) nursing turnover rates improved (Minore et al., 2005), iii) nursing team coverage and the nursing skill mix was better (Manley et al., 1997), and iv) changes in nurse staffing and shift work were minimized (Heller & Solomon, 2005). Two studies, however, found that availability of resources in their institutions may not be a determinant of more continuity in care (Anderson, Maloney, Knight, & Jennings, 1996; Greenberg & Rosenheck, 2003). Anderson et al., (1996) conducted interviews of permanently assigned nursing staff at an army medical center and found that the use of supplemental agency nurses negatively affect CINC, even though these nurses provided the institution with the necessary labor. Greenberg and Rosenheck (2003) found that larger healthcare facilities, in terms of the number of full-time employees, was not significantly associated with more continuity in care ($\beta = -0.039$). They stated that it was possible that these larger institutions had more complex organizational settings that might affect the coordination of healthcare services delivery. Academic institutions, on the other hand, were associated with more continuity in care, possibly because these providers were more likely to model continuous care for their trainees.

Continuity of Provider and Patient Outcomes

Continuity of provider is defined as the degree of care provided by fewer different providers to a patient over a period of time (American Academy of Family Physicians, 2010; Curley & Hickey, 2006; D'Errico & Lewis, 2010; Donaldson, Yordy, Lohr, & Vanselow, 1996; Fox, 2003). A large body of literature examines the relationship between continuity of provider and patient outcomes in the outpatient setting (Beattie, Dowda, Turner, Michener, & Nelson, 2005; Benjamin et al., 2001; Brousseau et al., 2004; Christakis et al., 2001; Christakis et al., 2000; Christakis et al., 1999; Christakis et al., 2002, 2003; Cree et al., 2006; Cyr et al., 2006; D'Errico & Lewis, 2010; Flores et al., 2008; Fox, 2003; Gill et al., 2003; Greenberg, Rosenheck, & Fontana, 2003; Greenberg, Rosenheck, & Seibyl, 2002; Hanninen et al., 2001; Lin et al., 2009; Litaker et al., 2005; Miller et al., 2009; Parchman et al., 2002; Parkerton et al., 2004; Shermock, 2009; Waldenström, 1998). The findings generally indicate that continuity of provider is associated with better patient outcomes in the outpatient setting. To the extent that continuity of provider has beneficial effects on outpatient outcomes, it is assumed that such effects might be possible to achieve in the inpatient setting (Krogstad, Hofoss, & Hjortdahl, 2002).

Heller and Solomon (2005) found that greater continuity in care from any healthcare provider was positively associated with the perception of being well-cared-for. They conducted interviews with bereaved parents whose children died after receiving care in the pediatric ICU at three teaching children's hospitals. Parents defined continuity of care as having a healthcare provider (e.g., a nurse, physician, or social worker) who "continuously" worked with the parents from the beginning of their child's diagnosis through death. Parents who perceived the providers as providing continuity in care also perceived their child as having been well-cared-for. The parents indicated that continuity in care helped build relationships, promoted caring, provided a sense of security, and gave them confidence that the quality of care was being optimized. In contrast, the lack of continuity of care led to frustration, hypervigilance, mistrust, and anxiety about the care that their child received.

What is Nursing Expertise?

Nursing expertise is described as the ability to perform expert actions without the awareness that experiential and theoretical nursing knowledge is being used (Benner, 1982; Woolery, 1990). Expertise is believed to influence nurses' clinical judgments and their ability to recognize subtle changes in the patient's condition (Benner, Tanner, & Chesla, 2009; Peden-McAlpine, 2000). The use of nursing expertise is aimed at providing nursing care that is individualized to the needs of the patient that will in turn result in positive patient outcomes (Hardy, Garbett, Titchen, & Manley, 2002). In practice, clinically expert nurses are distinguished from other nurses by their ability to use practical reasoning in combination with an intuitive understanding of the patient's situation when making critical clinical decisions (Benner et al., 2009; Curley, 2007). Expertise influences nurses' clinical judgment and ability to recognize subtle changes in the patient's condition (Benner et al., 2009; Peden-McAlpine, 2000). The early recognition of changes in the patient's condition is an important nursing skill in the care of the critically ill patient. Several authors indicated that the failure to address nursing expertise in the delivery of nursing care may result in a poor quality of patient care, including higher rates of medical errors and negative health outcomes (Hill, 2010; Orsolini-Hain, Malone, Orsolini-Hain, & Malone, 2007).

Nursing expertise is a concept that is largely reflected in Benner's seminal work of *From Novice to Expert: Excellence and Power in Clinical Nursing Practice* (Benner, 1984). Benner (1984) indicated that nursing expertise is developed as nurses gain experience and knowledge in the clinical setting. Adapting from earlier works by Dreyfus and Dreyfus (1980) on skill acquisition, Benner (1982) identified five levels of expertise in the clinical setting: i) novice, ii) advanced beginner, iii) competent, iv) proficient, and v) expert.

Novice nurses are described as having no experience with the situations in which they were expected to perform tasks. An example of a novice nurse is a first year nursing student. Advanced beginner nurses have some experience with real situations in nursing and demonstrate a marginally acceptable performance. An example of an advanced beginner nurse is a recently graduated nursing student. Competent nurses are able to determine which aspects of the situation are important and to see their actions in terms of long-range goals or plans. However, due to inadequate experience they lack the speed and flexibility of the proficient nurse in recognizing the most important aspects of the situation. An example of a competent nurse is a staff nurse who has completed clinical orientation. Proficient nurses based their nursing care on multiple past memories of experiences and developed a sense of intuition in their practice. Using maxims to guide their practice, these nurses are able to perceive situations as a whole and able to understand the situation in terms of long-term goals. These nurses have a more complex knowledge base and use knowledge from past experiences to execute routine skills in a given situation. An example of a proficient nurse is a staff nurse who has worked for several years in the intensive care unit. Expert nurses do not rely on analytic principles to understand the situation. These nurses typically have an extensive background of experience and have developed an intuitive and effortless grasp of multiple complex situations.

Nurse Expertise and Patient Outcomes in the Intensive Care Unit

Studies indicated that nurse expertise has a positive impact on patient outcomes in the general adult acute care hospital units such as medication errors, needle stick injuries, and incidences of patient falls (Blegen, Vaughn, & Goode, 2001; Clarke, Rockett, Sloane, & Aiken, 2002). Blegen et al., (2001) studied the relationships between the quality of nursing care and the level of education and experiences of nurses. They found that after controlling for a variety of factors such as patient acuity, hours of nursing care, and staff mix, hospital units with a higher number of nurses with five or more years of nursing experience were significantly associated with fewer medication errors ($\beta = -0.345$; $p<0.05$) and lower rates of patient falls ($\beta = 0.373$; $p<0.05$). Clarke et al., (2002) examined the effect of nursing experience on nurse needle stick injuries, found that inexperienced nurses, measured as having fewer than five years of nursing experience, were associated with a higher odds of needle stick risk (OR = 1.48; 95% CI = 1.06 – 2.20), suggesting that the nurses' inexperience with risky procedures could have played a role in such occupational injuries.

In contrast, Chang and Mark (2009) studied the antecedents of severe and non-severe medication errors in 146 randomly selected hospitals in the United States. They found that the nurses' expertise was positively associated with non-severe medication errors (Z score = 2.71; $p<0.01$), contradicting a prior belief that more experienced nurses make fewer errors. The authors suggested that this result might be an indication of poor error-reporting behaviors with regard to non-severe medication errors in some hospitals. Aiken et al., (2003) in a multi-center study, found that years of nursing experience was not a significant predictor of patient mortality and failure-to-rescue. In addition, nursing experience as an interaction variable did not significantly influence the relationship between nurses' educational background and nurse staffing on patient outcome. They suggested that this finding provided evidence to disprove beliefs that nurses' experience is more important than their educational background.

The relationship between nursing expertise and patient outcomes in the intensive care unit has not been extensively studied, yet there is evidence to suggest that a lower level of nursing expertise was associated with higher numbers of adverse events in the intensive care unit (Morrison et al., 2001; Tibby et al., 2004). Tibby et al., (2004) conducted a study in the pediatric ICU that used prospective observational methods to examine the association between occurrences of adverse events and clinically-related risk factors such as nursing workload, skill mix, composition of nursing staff, and nursing supervision. To the extent that more senior nurses represent a higher level of nursing expertise, nursing composition measured in terms of nursing seniority and the proportion of rostered permanent staff on duty was not significantly associated with a reduction of adverse events. Interestingly, the authors found that a higher percentage of rostered permanent nursing staff was associated with a lower risk of actual but not near miss adverse events. They suggested that having more rostered permanent nursing staff acts as a defense mechanism that helps prevent the progression of a near miss to an actual adverse event.

In a descriptive study that used data from the Australian Incident Monitoring Study in the Intensive Care Units database, Morrison et al., (2001) examined the effects of nursing staff inexperience on the occurrences of adverse patient experiences in the ICU. The commonly cited incidents related to nursing inexperience included incidents that involved airway and ventilation (21.5%), drugs and therapeutics (31.8%), procedures, lines and equipment (14.9%), patient environment (15.9%), and unit management (15.9%). They suggested that the inexperience of intensive care unit nurses in addition to a shortage of staff and a high acuity in patient workloads increases the likelihood of such errors occurring. A limitation of this study is the level of subjectivity and lack of a clear measurement of nursing inexperience.

These studies provided evidence that nursing expertise is important to consider when evaluating nursing care. Given the possibility that continuity in nursing care could be complemented by or substituted with nurse expertise, more research is needed to examine how continuity in nursing care interacts with nurse expertise to influence patient outcomes.

Patient Outcomes in the Pediatric Intensive Care Unit

In this study, patient outcomes are defined as the result of processes of care that the patient received during hospitalization. Patient outcomes are commonly used in healthcare research to evaluate the quality of patient care and determine the effectiveness of healthcare intervention. Generally, studies have shown that poor patient outcomes in the pediatric ICU, such as increased length of pediatric ICU stay, adverse events, and hospital acquired infections can complicate the patient's hospitalization (Agarwal et al., 2010; Elward, Warren, & Fraser, 2002; Larsen et al., 2007; Marcin et al., 2005; Ream et al., 2007; Woods et al., 2005).

National Standards of Patient Outcome Measures

In 2001, the National Association of Children's Hospitals and Related Institutions, the Child Healthcare Corporation of America and the Medical Management Planning/Benchmarking Effort for Networking Children's Hospitals developed a framework and methodology to establish pediatric core measures known as the Pediatric Data Quality Systems. Using this framework, core measures were developed and subjected to a consensus process. In addition to evaluating the quality of care, these measures are useful to developing performance standards across hospitals.

The Pediatric Data Quality Systems consists of eight pediatric critical care measures that includes the following: i) standardized mortality ratio, ii) severity adjusted length of stay, iii) readmission rate iv) readmissions, v) pain assessment, vi) periodic pain assessments, vii) medication safety practice adoption, and viii) central line infection prevention practice adoption (Loeb, 2005). These measures were identified through a 15-month comprehensive process of multidisciplinary expert advice, a review of the evidence supporting these measures, a development of detailed measure specifications, and a national vetting of the proposed measures. Over 135 hospitals participated in this project and provided feedback on these measures. The significance of the National Quality Forum endorsement allowed for the development of standardized measurements of national reporting across pediatric hospitals for the purposes of pediatric ICU quality improvement and benchmarking.

The Pediatric Data Quality Systems measures are reflected in quality programs such as the Virtual Pediatric Intensive Care Unit Performance System program. The Virtual Pediatric Intensive Care Unit Performance System program is a multi-faceted pediatric ICU quality, research, and management support program that adopts all eight measures into the computer-based web application system. By adopting these measures, the Virtual Pediatric Intensive Care Unit Performance System network hopes to establish a greater evidence base as to the validity and reliability of these measures as well as the resources required to collect these data.

In 2006, the Agency for Healthcare Research and Quality identified eleven potentially preventable complications — known as the Pediatric Quality Indicators — in hospitalized children. The Pediatric Quality Indicators are accidental puncture or laceration, decubitus ulcer, foreign body left behind during procedure, iatrogenic pneumothorax in non-neonates, post-operative hemorrhage or hematoma, post-operative respiratory failure, post-operative sepsis, post-operative wound dehiscence, selected infection caused by medical care, and transfusion reaction. The Pediatric Quality Indicators was based on hospital discharge data from 2003 to 2005 of 76 children's hospitals.

National Standards of Nurse-Sensitive Outcomes

The American Association of Critical-Care Nurses developed the Beacon Award to publicly recognize pediatric critical care institutions that exhibit high quality standards in the nursing care of patients and families (American Association of Critical-Care Nurses, 2008). Applicants for the Beacon Award are required to complete a set of questions and to audit trend data in the pediatric ICU. The questions were generated from evidenced-based research and standards of care recommended by professional organizations such as the Agency of Health Care and Research. The questions include: i) recruitment and retention, ii) education/training and mentoring, iii) evidence-based practice and research, iv) patient outcomes, v) the healing environment, and vi) leadership/organizational ethics. In particular, patient outcomes makes up the largest category of questions; with the intent to collect epidemiologic and trend data in order to evaluate patient outcomes in the pediatric ICU. Measures of ICU patient outcomes include evaluating unit-based: i) catheter-associated bloodstream infection, ii) ventilated-associated pneumonia, iii) catheter-associated urinary tract infection, iv) rate of unplanned extubations, v) pressure ulcers greater than or equal to grade II, and vi) fall risk. These questions provide nurses a standardized framework to measure, monitor, and improve key patient outcomes in their units.

Length of Stay in the Pediatric Intensive Care Unit

Three large multicenter studies documented the average length of a pediatric ICU stay across hospitals in the United States. Overall, the studies reported that the median length of an ICU stay ranged from 2 to 7 days. Agarwal et al., (2010) conducted a cross-sectional retrospective review of randomly selected patient charts from 15 participating pediatric ICUs across the United States to study the prevalence of adverse events in the ICU, between September 2005 and December 2005. In their study population characteristics, the average length of stay in the ICU was 7.1 days (range = 1 – 170). Farias et al., (2004) found that the median length of stay for survivors in the pediatric ICU was 8 days (IQR = 5 – 13); for non-survivors in the ICU, it was 7 days (IQR = 4 – 13).

Ruttimann and Pollack (1996) studied the length of a pediatric ICU stay to the risk of mortality and other factors within the first 24 hours after ICU admission from December 1989 to January 1992. The authors found that the patients geometric mean length of an ICU stay was 1.9 days (range = 1.21 – 2.17) and a median length of stay of 2 days. About 4% of the total patient population stayed in the ICU for 12 days or longer. They considered these patients to be long-stay patients. The authors found that significant patient-related predictors of the ICU length of stay included the Pediatric Risk of Mortality (PRISM) score, diagnostic groups, operative status, inpatient/outpatient status, previous pediatric ICU admission, and first-day use of a mechanical ventilator. In addition, the characteristics associated with increasing the length of a ICU stay were the increased ratio of pediatric ICU to hospital beds ($p < 0.05$), whereas a shorter length of stay was associated with organizational factors such as coordination of care.

Ruttimann and Pollack (1996) found that coordination of care was associated with a shorter length of stay in the Pediatric ICU ($\beta = -0.05$; SE = 0.02; $p = 0.01$). They defined coordinated care as when the medical director was involved in the care of more than 90% of the patients, and/or there was 24-hour, 7-day-a-week physician staffing in the pediatric ICU. Shortell et al., (1994) studied the performance of adult ICU and found that caregiver interactions such as culture, leadership, coordination, communication, and conflict management were associated with a lower risk-adjusted length of stay in the intensive care unit. To the extent that such care characteristics are important elements in the efficient admission and discharge of patients out of the intensive care unit, nursing practices and differences in the nursing organization might be important factors that could impact the duration of a patient's stay in the intensive care unit (Ruttimann & Pollack, 1996).

Duration of Mechanical Ventilation

Two large multicenter cohort studies conducted in the United States described the population of critically ill children who required mechanical ventilation (Farias et al., 2004; Randolph et al., 2002). Farias et al., (2004) conducted a prospective cohort study to describe the daily practices of mechanical ventilation across 36 pediatric ICUs in seven countries. They found that 35% of patients admitted to the ICU required ventilator support for 12 or more hours. The median duration of critically ill children requiring ventilator support of 3 days (IQR = 2 – 6) among survivors and 4 days among non-survivors (IQR = 3 – 7). Randolph et al., (2002) conducted a randomized controlled trial to examine whether weaning protocols were superior to standard care (no defined protocol) for critically ill children requiring mechanical ventilation in ten pediatric ICUs in the United States. They found that 17% of patients admitted to the ICU required ventilator support for more than 24 hours. The authors documented that sedative use in the first 24 hours of ventilator weaning had an influence on the length of time on mechanical ventilation ($p<0.001$) and on extubation failure in children ($p = 0.04$). The authors suggested that improved management of sedative drugs and daily assessment for extubations readiness could potentially reduce the duration on mechanical ventilation.

Nurses in the critical care setting care for patients on mechanical ventilators. Examples of nursing care involve providing oral care, assessing the patient's need for sedation, frequent positioning, and monitoring vital signs. Studies have documented that variability in practices could lead to inadequate or excessive sedation among patients requiring ventilator support (Chevron et al., 1998; Kollef, Ahrens, Schaiff, Prentice, & Sherman, 1998; Ostermann, Keenan, Seiferling, & Sibbald, 2000). As a result, this can lead to patients requiring prolonged mechanical ventilation.

Two randomized controlled trials investigated the impact of nursing-implemented sedation protocol on the duration of mechanical ventilation in the ICU (Brook et al., 1999; Yiliaz et al., 2010). Brook et al., (1999) conducted a randomized controlled trial to investigate the effect of a nursing-implemented sedation protocol on the duration of mechanical ventilation. They found that the use of a nursing-implemented sedation protocol in patients with acute respiratory failure can significantly reduce the duration of time the patient is on mechanical ventilation (chi-square = 7.00, p = 0.01, log rank test; chi-square = 8.54, p = 0.004, Wilcoxon's test; chi-square = 9.18, p = 0.003, -2 log test). In contrast, Yiliaz et al., (2010) compared the effects of a nursing-implemented sedation protocol and a daily interruption of sedation (by physicians). They found that daily interruption of sedative infusions performed by physicians led to a shorter sedation duration, which resulted in patients requiring fewer days of ventilator support. The authors suggested that nurse staffing might be an important factor to consider when implementing such protocols.

Adverse Events in the Pediatric Intensive Care Unit

Adverse event refers to an injury that a patient experienced as a result of poor care management and which was not related to the disease process, leading to complications in the patient's condition and compromising patient safety. Three studies found that adverse events occur frequently in the pediatric ICU and most of these events were preventable (Agarwal et al., 2010; Larsen et al., 2007; Woods et al., 2005). Agarwal et al., (2010) conducted a retrospective study of randomly selected pediatric ICU patient charts from 15 hospitals across the United States in order to study the prevalence of adverse events. Overall, patients in the ICU have adverse event rates of 2.03 per patient-days (28.6 per 100 patient-days). Common types of adverse events included catheter complications (e.g., infiltrated peripheral intravenous catheters), uncontrolled pain, and endotracheal tube malposition. The authors found in risk-adjusted analyses that patients who died had significantly higher rates of preventable adverse events than those who survived ($p = 0.03$). In addition, surgical patients had significantly higher adverse events and preventable adverse event rates than did medical patients. The authors suggested that postoperative patients are at a higher risk of adverse events due to the higher likelihood of having sedation and/or pain related issues than do medical patients.

Larsen et al., (2007) studied the rates of adverse events in a single-institution pediatric ICU, reporting an overall rate of 0.53 per patient day (95% CI = 0.48 – 0.57). They found that preventable adverse events occurred frequently in the ICU but that serious harm preventable events were uncommon. Of all preventable adverse events, 78% were minor harm events, 19% were moderate harm events, and 3% were serious harm events. The authors did not find any deaths associated with preventable adverse events. The common types of preventable adverse events were related to sedation, skin, and medical device complications. Woods et al., (2005) examined 3719 pediatric hospital discharge records from the Colorado and Utah Study Sample for the purpose of studying the incidences and types of adverse events in all pediatric patients. They found an annual adverse event rate of 1% (95% CI = 0.7 – 1.3) and an annual preventable adverse event rate of 0.6% among hospitalized children. Of the preventable adverse events, diagnostic related preventable adverse events (30.4%) were significantly more common. In addition, they found that a child is 1.35 times more likely to experience a preventable diagnostic adverse event compared to an adult patient (OR = 1.352; $p<0.001$).

Studies reported that organizational factors such as a better workload and better nurse staffing were significantly associated with decreased adverse events (Marcin et al., 2005; Ream et al., 2007; Stratton, 2008; Tibby et al., 2004). For instance, Marcin et al., (2005) studied the impact of nurse staffing and unplanned extubations in the pediatric ICU. They found that patients were less likely to experience an unplanned extubation when they were cared for by a nurse who was assigned to one patient compared to a nurse assigned to two patients (OR = 4.24; 95% CI = 1.0 – 19.10; p = 0.04). Interestingly, nursing experience (OR = 0.90; 95% CI = 0.79 – 1.03; p = 0.15) was not significantly associated to a decrease in the risk of unplanned extubations. In order to provide safe patient care, the authors recommended that policymakers and hospital administrators consider a high nurse to patient ratios in the pediatric ICU.

One study reported that physician cross-coverage reduces continuity of care. Petersen, Brennan, O'Neil, Cook, and Lee, (1994) studied the relation between housestaff coverage schedules among physicians and the occurrence of preventable adverse events. Housestaff cross-coverage was considered as having a less continuity in care. They found that an increase in the patients' risk of potentially preventable adverse events was significantly associated with care provided by physicians from another team, particularly when the cross-covering physician was an intern. The authors suggested that having a physician who is familiar with the patient might have detailed knowledge about the patient. Hence, a familiar physician might provide more appropriate care than a cross-covering physician who is less familiar with the patient.

Intensive Care Unit-Acquired Infections

In 2005, the National Healthcare Safety Network was established to develop a national surveillance database that would allow institutions to voluntarily report hospital-acquired infections. The purpose of this database is to allow an estimation of the magnitude of hospital-acquired infections, monitoring of hospital-acquired infections trends, to facilitate the comparison of risk-adjusted data across institutions, and to provide assistance to institutions in developing surveillance and analysis methods that permit the timely recognition of hospital-acquired infections and to develop appropriate interventions.

The National Healthcare Safety Network defined hospital-acquired infections as infections caused by a wide variety of common and uncommon bacteria, fungi, and viruses during the course of care management (Horan, Andrus, & Dudeck, 2008). There are two categories of hospital-acquired infections: device-associated infections and procedure-associated infections. Three types of device-associated infections are commonly studied in the literature: catheter–associated bloodstream infection, ventilator-associated pneumonia, and catheter-associated urinary tract infection. In this review, studies that examined three types of device-associated infections are reviewed.

Several studies found that pediatric ICU patients have lower hospital-acquired infection rates compared to neonates; however, they have higher rates of hospital-acquired infections, compared to non-ICU adult patients (Richards, Edwards, Culver, & Gaynes, 1999; Singh-Naz, Sprague, Patel, & Pollack, 1996; Stoll et al., 1996). Hospital-acquired infections were associated with increased mortality in critically ill children, particularly among neonates (Singh-Naz et al., 1996; Stoll et al., 1996). Three studies found that the use of devices was associated with increased rates of hospital-acquired infections in the pediatric ICU (Richards et al., 1999; Singh-Naz et al., 1996; Singh-Naz, Sprague, Patel, & Pollack, 2000; Yogaraj, Elward, & Fraser, 2002).

In contrast, Elward et al., (2002) found that ventilated-associated pneumonia was significantly associated with processes of care such as reintubation (OR = 2.71; 95% CI = 1.18 – 6.21) and transport out of the ICU (OR = 8.9; 95% CI = 3.82 – 20.74). Similarly, Yogaraj et al., (2002) found that risk factors associated with processes of care such as multiple central venous catheter (adjusted odds ratio = 5.7; 95% CI = 2.9 – 10.9) and arterial catheter (adjusted odds ratio = 5.5; 95% CI = 1.8 – 16.3) insertions in the ICU, invasive procedures performed in the ICU (adjusted odds ratio = 4.0; 95% CI = 2.0 – 7.8), and transport out of the ICU (adjusted odds ratio = 3.4; 95% CI = 1.8 – 6.7) were significantly associated with an increased risk of acquiring bloodstream infections. They found that the patient's underlying medical conditions, the severity of illness on admission, and the length of ICU stay were not associated with bloodstream infection during their stay in the ICU.

In an adult ICU setting, Robert et al., (2000) conducted a nested case-control study to determine the risk factors of catheter-associated bloodstream infections in the adult surgical ICU. They found that a higher pool/agency nurse-to-patient ratio (odds ratio = 3.8) was associated with a higher risk of catheter-associated bloodstream infection. The authors suggested that omitted correlated variables, such as the onset of the severity of infection and differences in the case-mix, could have affected the association between catheter-associated bloodstream infection and nurse-to-patient ratio. It might be possible that pool/agency nurses were unfamiliar with the hospital staff, policies, and practices compared to the permanent nurses working in the intensive care unit, leading to higher rates of infection. In addition, the use of pool/agency nurses may indicate that the intensive care unit was understaffed at that time of study. They suggested that understaffing might reduce the amount of time that could be allocated to the maintenance of invasive catheter lines.

In 2009, the National Healthcare Safety Network published a report of hospital-acquired infections data from 982 institutions between January 2006 and December 2008 (Edwards et al., 2009). Overall, the pooled mean for the catheter-associated bloodstream infection rate in the pediatric ICUs were 3.0 per 1,000 central line days, for ventilator-associated pneumonia, it was 1.8 per 1,000 ventilator days, and for catheter-associated urinary tract infection, 4.2 per 1,000 urinary catheter days. Overall, there was a decrease in the rates of hospital-acquired infections across all device-associated infection in the pediatric ICU. For instance, compared to the 2007 National Healthcare Safety Network report (Edwards et al., 2007), the 2009 report showed a reduction in the catheter-associated bloodstream infection rate in the pediatric ICU from 5.3 to 3.0 catheter-associated bloodstream infections per 1,000 central line days. The authors suggested that the reduction in catheter-associated bloodstream infections might be due to definition changes, an increased contribution of data from smaller hospitals, which have lower risks of hospital-acquired infection, and the success of prevention strategies such as the implementation of pediatric specific bundles of care (e.g., catheter-associated bloodstream infection bundles, ventilator-associated pneumonia bundles, and catheter-associated urinary tract infection bundles).

Summary

The Synergy Model highlights the importance of developing synergy within the nurse-patient relationship. CINC may allow nurses to develop synergy between the nurse and the patient (as well as the patient's family). Simply stated, the implementation of CINC may facilitate the formation of therapeutic relationships, which in turn increased the opportunities for the nurse to know the patient and the family. The literature on knowing the patient supports the notion that knowing the patient is important in the delivery of high quality nursing care. This literature, together with the Synergy Model, suggests that optimal outcomes can result from more CINC.

Studies have shown that the nurses' past experiences of caring for patients can affect the way nurses know their patients. To the extent that the professional advancement process is reflected in nursing expertise, nursing expertise is an important element to include when studying the impact of CINC on patient outcomes. While most of this research is conducted in the general acute adult inpatient units, not much is known about the moderating effect of nursing expertise on the delivery of CINC and patient outcomes in the ICU.

Prior studies have shown that various characteristics of nursing care, e.g., nurse staffing and nurse job satisfaction, affect patient outcomes (Aiken, Clarke, & Sloane, 2002; Aiken, Clarke, Sloane, Sochalski, & Silber, 2002; Needleman et al., 2002). CINC is distinct from the nursing characteristics previously studied. CINC is one component of a model of nursing care delivery that focuses on the opportunity for the development of a therapeutic relationship between the nurse and the patient. Traditionally, CINC is thought as providing nurses with the capacity to deliver nursing care that is practiced through the relationships they form with patients and family, which will in turn impact patient outcomes. Relative to the number of studies on the impact of nurse characteristics on patient outcomes, there are few studies on the impact of CINC on patient outcomes.

CINC fits into the broader theme of continuity in care. The literature on continuity in care typically focuses on the care provided by physicians and other allied healthcare providers such as pharmacists. Many studies have highlighted that continuity in care can lead to better patient outcomes because of the possibly of developing stronger therapeutic relationships between the healthcare providers and the patient. Overall, the evidence on the impact of continuity in care on patient outcomes remains mixed. Some of the explanations from those that either found no effect or opposite effects include: i) problems with the measures of continuity in care (Cyr et al., 2006), ii) the timing of the measurement of the outcomes (D'Errico & Lewis, 2010), and iii) reverse causality – the negative patient outcomes that might cause the patients to discontinue their care; this would lead to a negative association between continuity in care and patient outcome (Greenberg et al., 2003; Greenberg et al., 2002). The explanations are important because they highlight the importance of using an appropriate measurement of CINC and outcomes, as well as considering potential biases introduced by reverse causality and omitted correlated variable biases.

The review indicates that most of the research on continuity in care has been done in the outpatient setting. More research in understanding how continuity in care impacts outcomes in the inpatient setting would be helpful for two reasons. First, the inferences made from findings in an outpatient setting might not be generalizable to an inpatient setting because the nature of continuity in care is different in the two settings. For instance, continuity in care in the outpatient setting tends to focus on the extent to which patients choose to receive care from the same provider. In the inpatient setting, however, continuity in care tends to be about the extent to which therapeutic relationships can be developed over the duration of a single hospitalization. This typically depends on how hospital staff are assigned to patients. Second, outpatient and inpatient outcomes are very different. Outcomes that are typically examined in the outpatient setting include emergency department visits, management of chronic diseases, and the utilization of preventive care services. Outcomes that are typically examined in the inpatient setting include the length of the hospital stay, the risk of complications, and the frequency of adverse events. Most of the studies focused on continuity in care by physicians (Haggerty et al., 2003; O'Malley, 2004). Various measures of continuity in care, such as the Continuity of Care index by Bice and Boxerman, were constructed using readily available physician-related data. So far, only three studies examined the associations between CINC and patient outcomes (Benjamin et al., 2001; D'Errico & Lewis, 2010; Waldenström, 1998).

This review of potential gaps in the literature shows that there is limited research on the impact of CINC on inpatient outcomes. This study adds to the literature by providing data of the impact of CINC on patient outcomes in the pediatric ICU. Among the many inpatient settings, pediatric ICU is one where nursing care is extremely important in influencing patient outcomes. Critically ill children in particular can benefit from vigilant care by nurses who have specialized knowledge and experience. A further review of all the studies that have examined continuity in care in the pediatric outpatient setting finds that these studies typically considered continuity in care as having continuous visits with the same or with a few physicians. Some outcomes that were measured in studies were from the parents' perspective, such as parent satisfaction with care and being well-cared-for. The evidence generally indicated that continuity in care leads to better outcomes such as being well-cared for, satisfaction with care, and the utilization of preventive care services. Only one study examined pediatric outcomes in the inpatient setting (Heller & Solomon, 2005). In this study, continuity in care contributed to parent perception that their child was being well-cared-for. To the extent that pediatric patients can benefit from continuity in care in the outpatient setting, it is possible that continuity in care might have an impact on inpatient care.

While the focus of this study is on the impact of CINC on patient outcomes, the review documents several studies that have examined the determinants of continuity in care. Determinants such as patient characteristics, provider characteristics, intervention factors, and organization factors have been shown to affect continuity in care. Studies have suggested that better CINC could reduce the need for multiple handoffs. In addition, handoffs in nursing reports could help the oncoming shift nurse to benefit from what was learned about the patient (Curley, 1998). There are concerns that multiple handoffs could reduce the quality of care due to errors that occur as a result of miscommunication.

Four patient outcomes on which CINC is expected to have a significant influence were examined. The outcomes are pediatric ICU length of stay, the duration of mechanical ventilation, and the occurrences of adverse events of pediatric ICU-acquired infections. These outcomes have been recommended by nationally recognized organizations such as the National Association of Children's Hospitals and Related Institutions and the American Association of Critical-Care Nurses as standard outcome measures that providers should adopt in their practices. These outcomes have also been examined in prior studies in the pediatric ICU setting: i) length of stay (Ruttimann & Pollack, 1996), ii) mechanical ventilation (Brook et al., 1999; Twite et al., 2004; Yiliaz et al., 2010), iii) occurrences of adverse events (Marcin et al., 2005; Ream et al., 2007; Stratton, 2008; Tibby et al., 2004), and iv) occurrences of ICU-acquired infections (Singh-Naz et al., 1996; Richards et al., 1999; Singh-Naz et al., 2000; Elward et al., 2002; Yogaraj et al., 2002).

Overall, this study is informed by the Synergy Model and the related literature on knowing the patient to test the impact of CINC on patient outcomes. Furthermore, extending the study of CINC on patient outcomes in the inpatient pediatric ICU setting, this paper fills important gaps in the literature. Clinically, the findings of this study provide useful information to nurse managers who are involved in resource allocation in the unit and the assignment of nurses.

CHAPTER 3: RESEARCH DESIGN AND METHODS

This study addressed two research questions. The first question evaluates the impact of CINC on patient outcomes in the pediatric ICU. The Synergy Model and an extensive body of literature suggest that more CINC might be associated with better patient outcomes. The second question addresses whether a match between nursing expertise and patient's risk of mortality enhances the effect of CINC on patient outcomes. Based on the argument that nursing expertise may enhance the effectiveness of CINC, the positive impact of CINC on patient outcomes will be greater when nursing expertise is matched to patient's risk of mortality.

Study Design

This quantitative study was a secondary data analysis of existing data merged from four databases: the Nightingale Metrics database, the Virtual Pediatric Intensive Care Unit Performance System database, the Medical/Surgical Intensive Care Unit-Acquired Infection database, and the Safety Event Reporting System database. Data from March 2004 to December 2010 were used in this study. Data from the databases were collected by nurses and/or coordinators managing the databases for the purposes of quality improvement and/or national registries. The methods of data collection included the use of direct observations, checklists, and patient information from medical records.

Study Setting and Study Population

Children's Hospital Boston is a 396-bed comprehensive center for pediatric health care. It is one of the largest pediatric medical centers in the United States and offers a wide range of healthcare services for children from birth through 21 years of age. Children's Hospital Boston is one of the first children's hospitals in the United States to be a certified Magnet hospital for nursing excellence. The Magnet award is the highest honor of recognition awarded to the hospital by the American Nurses Credentialing Center.

Annually, over 2,200 critically ill children with a wide spectrum of pediatric diseases, except children with cardiac disease or severe burns, are cared for in the MSICU at Children's Hospital Boston. The MSICU is a specialized pediatric ICU that is a unique state-of-the-art 29-bed unit in the hospital where patients ranging in age from neonates to adults receive intensive care. The critical care services include specialties such as medicine, general surgery, transplantation, neurosurgery, craniofacial reconstruction, orthopedics, otolaryngology and trauma. In addition, the MSICU is one of the largest Extracorporeal Membrane Oxygenation centers in the United States, with approximately 60 patients being supported annually. The MSICU was awarded the American Association of Critical-Care Nurses Beacon Award for critical care excellence in Fall 2009/2010.

According to the Beacon Award report, the MSICU clinical staff includes a Nurse Director, a Clinical Nurse Coordinator, approximately 135 staff nurses, two Clinical Nurse Specialists, a Nurse Scientist, 15 Clinical Assistants, 20 Attending Physicians, 15 Critical Care Fellows, four Nurse Practitioners, ten Respiratory Therapists, two Social Workers, a Clinical Psychologist, and a Child Life Specialist. Support staff includes a Patient Service Administrator, approximately 15 Administrative Assistants, a Patient

Care Coordinator, and members of the Division of Critical Care Services management and administrative staff. Registered nurses make up the largest proportion of the healthcare staff. All registered nurses receive subspecialty training in pediatric critical care nursing. Approximately 97% of the registered nurses are either bachelors- or masters-prepared. Of the nurses qualified to take the pediatric CCRN® examination from the American Association of Critical-Care Nurses, 49% hold the credential. Approximately 61% have been employed on the unit for greater than five years. Of those, 66% have been part of the unit for ten years or more and 31% have been on the unit for 20 years or more.

Nurses in the MSICU work 12-hour shifts. Full-time nurses work at least 30 hours per week. There are a total of 97 full-time nurses. Of these nurses, 75 work three shifts per week. The remaining 22 full time nurses work two to three shifts per week in rotating three week blocks. There are a total of 22 part-time nurses who work one to two shifts per week in rotating three week blocks.

Upon admission, the charge nurse and the admitting nurse work together to determine an appropriate nursing care team, after considering the individual and cultural needs of the patient and family. For instance, decisions are made regarding nurse-patient assignments that include matching the patient's need with the registered nurses' nursing expertise the nurses' schedule building continuity in care. In terms of patient care assignments, the nurse to patient ratio is not more than 1:2. Depending on the level of patient acuity, one nurse may be assigned to one patient. Patients who stay in the MSICU for five days or more are assigned one attending physician for the remainder of their stay.

The attending physician participates in all family meetings and is updated regularly on the patient's progress and condition when off service.

The expertise of each nurse is differentiated by criteria from Children's Hospital Boston Professional Advancement Program. These criteria, based upon the Synergy Model, are incorporated into the process for the professional advancement program. For example, nurses who wish to advance to Levels II and III should meet the criteria for each dimension of the Synergy Model: clinical judgment, caring practices, and advocacy/moral agency. There are three levels of professional advancement for registered nurses: Levels I, II, and III – Level I represents a competent level of professional practice; Level II signifies a proficient level of nursing practice; and Level III signifies an expert level of practice.

Nursing practice is assessed annually through self-evaluation, peer review, and performance evaluations by the leadership staff. The unit-based Nurse Managers make the decision to promote a nurse from a Level I to Level II. The advancement process begins when the staff nurse submits a formal application and portfolio to support the candidate's promotion. This advancement process is typically based upon the annual performance evaluation and peer reviews. The application process for professional advancement is similar for a nurse who wishes to advance from Level II to Level III. In this instance, the nurse manager of the unit and a hospital-based board of review are involved in the decision making process. The vice president of patient care services appoints a professional advancement chair/facilitator and eight Level III nurses to serve as members of the board of review. The members of the board review the candidate's materials. In addition, they conduct an open session with the candidate and the nurse manager to discuss in detail the candidate's level of practice and accomplishment. This Professional Advancement Program was used by Children's Hospital Boston at the time the data were collected for this study.

Data Sources

This study was a secondary analysis of four existing databases that were merged to create the CINC-outcomes analytical dataset. The four databases are the Nightingale Metrics database, the Virtual Pediatric Intensive Care Unit Performance System database, the Medical Surgical Intensive Care Unit-Acquired Infection database, and the Safety Errors Reporting System database.

Nightingale Metrics Database

The Nightingale Metrics program is a quality monitoring program that identifies, implements, and monitors best nursing practices. The Nightingale Metrics database consists of cross-sectional nursing care related data from the MSICU. The Nightingale Metrics program began in 2004, when Martha A. Q. Curley, RN, PhD, Patricia A. Hickey, RN, PhD, and a team of nurses from Children's Hospital Boston led the collaborative development of the Nightingale Metrics program to help improve the quality of pediatric nursing care across the Cardiovascular and Critical Care program at Children's Hospital Boston (Curley & Hickey, 2006). The purpose of the Nightingale Metrics program is to help pediatric nurses develop effective measures to evaluate their nursing care practices, based on what they perceive as important to their patients and families. Based on the information collected, nurses are able to make informed data-based improvements in their practice.

The Nightingale data were collected every three months from March 2004 to May 2008, then every four months after August 2008. The frequency of data collection was reduced from every three months to every four months to conserve resources and to allow nursing staff an opportunity to improve their practices before continued data collection. Currently, the data are still being collected.

To ensure data reliability, a Level II/III staff nurse (Nightingale leader) who is trained in the data collection process and a research assistant (who is not a nurse) are responsible for data collection. Additionally, the research assistant is responsible for data entry and report generation. Having a single research assistant collect and enter data improves the reliability of the database. All copies of the case reports are stored in a locked cabinet in the research assistant's office. The Nurse Scientist oversees the overall project and conducts data checks of each report for inconsistencies and errors.

Data are collected on all patients who are in the unit at the time of data collection. A random day is selected for the data collection, which could occur at any date/time within the data collection month. The staff nurses are not informed when the data collection will occur. The research assistant and staff nurse obtain relevant patient information from electronic medical records such as the Power chart and/or Eclipsys. Such data include the patient's medical record number, documentation of pain scores pre and post intervention, and the completion of an admission assessment within 24 hours of

ICU admission. The research assistant and staff nurse also perform direct observation on data not typically documented in the medical record. For example, when collecting data on the urinary tract infection bundle, the research assistant and staff nurse are required to directly assess the patient to determine whether the tubing is taped to the thigh and the urine collection bag is placed below the level of the bladder – these data are typically not documented in the medical record.

Data from March 2004 through December 2010 were used in this study. Each patient was identified by their medical record number. The Nightingale Metrics database consists of the Continuity of Care Index (measure of CINC), nurse expertise data (proportion of Level II/III nurses), nursing care indicators such as pressure ulcer bundles, bloodstream infection bundles, ventilator-associated pneumonia bundles, and other nursing care variables such as pain documentation, nutrition plan documentation, sedation score documentation, and time to critical intervention data. Most of the data are categorical variables such as "yes", "no", or "not applicable". Examples of continuous variables in the dataset includes the Continuity of Care Index, the proportion of level II/III nurses caring for a patient, the proportion of travelers, and the proportion of nurses with less than a year of nursing experience.

In the Nightingale Metrics program, the process improvement strategy consists of a "rapid-cycle" change method that enables staff nurses to identify best practices, set internal benchmarks and audit their practice against those benchmarks. This method requires the staff nurses to review their practice and identify important aspects of care within the patient population that reflect measurable standards of care, known as "nursing care indicators". The Nightingale lead nurses, nurse manager, research assistant, and Nurse Scientist meet every three to four months to review data and discuss important issues about the data prior to data collection. New indicators are pilot-tested to determine their feasibility and validity. Process improvements followed by monthly audits are conducted if the results show a need for immediate improvement. Items are retired to yearly spot checks if the results reach a benchmark of 100% for three consecutive audits.

Virtual Pediatric Intensive Care Unit Performance System Database

The Virtual Pediatric Intensive Care Unit Performance System is an integrated line of services that include data collection, comparative reports, and data analyses with the aim of improving the quality of care for critically ill children through the networking of children's hospitals and facilities worldwide. The Virtual Pediatric Intensive Care Unit Performance System database was formed by the National Association of Children's Hospitals and Related Institutions, Children's Hospital Los Angeles and Children's Hospital of Wisconsin. This database was developed to standardize data sharing and benchmarking among pediatric intensive care units. The Virtual Pediatric Intensive Care Unit Performance System organization supports each institution by maintaining the database, developing and implementing quality control standards to ensure data integrity, and providing comparative program reports. Although this database is primarily used for standardizing data sharing and benchmarking among ICUs, it also serves as a database to examine important clinical questions in the ICU.

The Virtual Pediatric Intensive Care Unit data collection in the MSICU began in 2004. Three key persons are involved in the management of the database – the MSICU physician leader, a MSICU nurse leader, and Quality Improvement technicians from the Program for Patient Safety and Quality. All data are collected and entered by the Nurse Leader, who is a retired Level-III MSICU staff nurse. Prior to data collection, the Nurse leader underwent definitions and technical training. Subsequently, the Nurse and Physician Leaders work closely to oversee the Virtual Pediatric Intensive Care Unit database. The Nurse Leader is responsible for obtaining data from patients' medical records, identifying trends in the data, closing chart system alerts, and generating monthly and yearly reports to the Virtual Pediatric Intensive Care Unit Performance System organization. Electronic system alerts are in place to ensure that missing and/or incomplete patient data are verified and completed in order for the data to be submitted.

Prior to the release of data for analysis, extensive quality control checks are performed by the Virtual Pediatric Intensive Care Unit Performance System staff at the National Outcomes Center in Wisconsin. The staff performs initial, then quarterly, inter-rater reliability tests on the database. Each site coordinator is responsible for maintaining copies and submitting the inter-rater reliability forms to the Virtual Pediatric Intensive Care Unit Performance System staff. The patient information that is submitted to the Virtual Pediatric Intensive Care Unit Performance System staff contains de-identified data. Following the inter-rater reliability review, the Nurse Leader may make the necessary corrections, documenting the results of this process, and re-submit the cleaned data to the Virtual Pediatric Intensive Care Unit Performance System organization.

All patients admitted to the MSICU and those who meet the inclusion criteria regardless of age are included in the data collection. A case identification number is automatically assigned to each patient upon admission to the MSICU. The case identification number is a unique patient identifier that can be viewed by both the Virtual Pediatric Intensive Care Unit Performance System staff and authorized users at each site. Patients with multiple ICU admissions have a different case identification number assigned on each admission.

The MSICU Virtual Pediatric Intensive Care Unit Performance System data consists of patient information from 2004 to present. In this study, data from March 2004 to December 2010 were extracted from the Virtual Pediatric Intensive Care Unit Performance System database, for cases with medical record numbers matched to those found in the Nightingale database.

The Virtual Pediatric Intensive Care Unit Performance System database consists of clinical data from admission to ICU through discharge. As part of the requirements of this program, it is mandatory to collect information on patient admission, diagnoses, and risk of mortality score (PIM2 and PRISM3), interventions and procedures, and discharge disposition. The patient admission data consists of the patient’s identifier information (e.g., medical record number, account number, and name), patient demographic data (e.g., race, gender, and date of birth), and ICU admission data (e.g., hospital admission date, date and time of ICU admission, and patient origin prior to ICU admission). The patient’s primary diagnosis refers to the principal reason for admission to the ICU, identified by the physician at the time of discharge from the ICU. The International

Classification of Diseases, Ninth Revision is used to code and classify morbidity data. There may be instances when the admitting diagnosis and the cause of death may not be the patient's primary diagnosis. For example, some patients who are admitted to the ICU post-operatively might have a primary diagnosis that is different from the diagnosis that necessitated the surgery. To ensure accuracy in data collection, the MSICU nurse leader collaborates with the physician leader to verify this information at the time of patient discharge. For example, the primary diagnosis is verified by comparing the intensivist's discharge summary, which includes the patient's primary diagnosis.

Beginning in January 2004, all patients enrolled in the Virtual Pediatric Intensive Care Unit database were required to have a risk of mortality score. The patient's risk of mortality score are calculated using the PIM2 and PRISM3 scoring systems. The PIM2 values are calculated within the period from the time of first contact (i.e. the first "face-to-face" contact between the patient and physician) to one hour after arrival to the MSICU. The PIM2 scores were available from March 2004 to December 2010. On the other hand, all PRISM3 values are calculated within the first 12 hours of admission to the ICU. A minimum of two hours' stay in the ICU (excluding a continuous state of resuscitation on admission) is required to compute a PRISM3 score. The data collection of PRISM3 began in August 2005.

The interventions and procedures data include information on the operative procedures, diagnostic therapeutic and palliative interventions performed during the patient's stay in the ICU. It also includes records of prior surgical procedures that the child underwent prior to MSICU admission. Examples of interventions/procedures include arterial catheter insertion, endotracheal intubation, and the use of high frequency oscillator ventilation.

The discharge data include information related to the patient's length of stay and status upon discharge from the ICU. The patient's discharge information is required to close a case and includes the date and time of ICU discharge, the outcome (e.g., mortality), and disposition (e.g., discharge to general floor or other hospital).

Intensive Care Unit Infection Control Practices and Surveillance Data

The ICU infection control practices and surveillance data, also known as the MSICU-Acquired Infection database, consists of prospectively collected data of all patients who developed an infection during their stay in the MSICU and up to 48 hours after discharge from the MSICU. A patient who developed an infection less than 48 hours after transfer/admission into the MSICU is not considered as ICU-acquired infection. Three types of infection data are closely monitored and collected in the MSICU: Catheter-Associated Bloodstream Infection, Ventilator-Associated Pneumonia, and Catheter-Associated Urinary Tract Infection. The surveillance definitions of the three main types of ICU-acquired infections defined by the Centers for Disease Control and the Prevention/National Healthcare Safety Network are described in Appendix A. The purpose of the MSICU-Acquired Infection database is to improve the quality of patient care and outcomes through the monitoring of infection trends and internal and external benchmarking. The continuous surveillance of infection in the ICU allows for the timely recognition and management of systematic issues related to iatrogenic infection.

In August 2006, the MSICU-based infection control coordinator position was created and filled by an active Level III staff nurse who is experienced in pediatric critical care and the nursing practices in the MSICU. One MSICU-based infection control coordinator collected all the data used in this study. The infection control coordinator works closely with the infection control department, infection control critical care attending physician and epidemiologist in the surveillance and prevention of infection in the MSICU. They conduct monthly meetings to review all infection data.

The MSICU-Acquired Infection database contains infection data from 2006 to the present. Each patient is identified by a medical record number. Patient information includes age, diagnosis, and type of service. The infection data include information such as the date of a culture, the type of device used, the indication for using a device, where the device was placed, when the device was placed, when the device was removed, the type of organism causing the infection, and compliance with related bundle elements and practices. Chart reviews from the patient’s medical records are used to obtain patient-related information such as demographics, culture date, and diagnosis.

External data checks conducted by the Program for Patient Safety and Quality staff ensure the accuracy of the audits. The audits are performed by the infection control coordinator and members of the unit-based infection control committee, a multidisciplinary group of unit based nurses, physicians, and respiratory therapists.

The night nurses in the ICU conduct daily collection of the device utilization data. To identify patients with an infection, the night nurses use the midnight census to determine the patient days-device utilization rate, such as the presence and type of central line, invasive ventilation, and indwelling urinary catheter. In this study, MSICU-acquired infection referred to a positive diagnosis of infection that occurred during the period of the patient's stay in the ICU and within 48 hours of the discharge from the ICU. The diagnosis of ICU-acquired infection must meet the criteria defined by the National Healthcare Safety Network, the hospital acquired infection surveillance arm of the Centers for Disease Control and Prevention (see Appendix A). All these ICU-related issues are adjudicated by the infection control coordinator, critical care attending physician, and epidemiologist team during their monthly meetings.

Safety Event Reporting System Database

The Safety Event Reporting System database is a set of patient data describing any adverse events that occurred during a patient's hospitalization. This project began in 2005, when senior hospital administrators at Children's Hospital Boston initiated a hospital-wide computer-based data collection and management system known as the Safety Event Reporting System program. The purpose of developing this program was to improve patient care quality and safety across the entire system through the tracking and monitoring of data. In this program, all hospital staff are encouraged to report errors such as a near miss, a procedure related problem, or a patient event through the electronic Safety Event Reporting System. Staff from the Program for Patient Safety and Quality manages the Safety Event Reporting System program; notify hospital staff and hospital administrators of any adverse events that occur in the hospital. Each event that is submitted is comprehensively reviewed. In particular, serious events are reviewed at the departmental level, divisional level, and/or at other multidisciplinary forums.

In the Safety Event Reporting System database, patients are identified by their medical record number and last name. A file identification number is assigned to each adverse event and the date of the adverse event is documented. Table 3-1 presents the definition and examples of adverse events categories in the Safety Event Reporting System database. Adverse events often related to nursing care are asterisked.

Table 3-1
Definition and examples of adverse event categories

Incident Classification	Definition	Examples
Lab/specimen/test	Events relating to the errors in the process of obtaining laboratory specimen/test that was used to obtain diagnostic laboratory results to assist clinicians in the diagnosis or management of patient's condition.	Mislabeling of the blood specimen with another patient's name.
Medication/fluid*	Events relating to errors in the administration of medication or fluid.	Wrong concentration of IV heparin was found hanging from patient's IV line.
Diagnosis/assessment/treatment	Severe events resulting from the lack of definitive patient diagnosis, assessment, and treatment, resulting in the worsening of patient's condition.	Inpatient death as a result of sudden change in condition. For instance, patient was admitted to ICU with diagnosis of pneumonia. Patient's condition worsens over the period of few hours and was found to have ARDS with hemodynamic instability. Resuscitative efforts failed.
Vascular access device*	Events relating to the use of vascular access devices such as central lines, intravenous catheters.	Extravasation of fluid into patient's interstitial or subcutaneous tissue, resulting in edema.

Skin/Tissue*	A symptom or complication resulting from injuries or breakdown of skin or tissue.	Pressure sore noted on patient's sacrum while turning patient.
Airway management*	Events relating to errors in management of airway in patient care.	Unplanned extubation of endotracheal tube by patient.
Surgery/procedure	Complications that occurred resulting from surgery or procedures.	Missing gauze was realized after surgery was completed. Patient was returned to surgery and the gauze was found in the patient.
Lines tubes*	Incidents occurring in patient with lines and/or tubes such as bladder catheter, nasogastric tubes, and chest tube drainage.	Disconnected bladder catheter from the drainage bag.
Care service coordination*	Events associated with work flow processes and coordination of care among providers.	Delay or lack of response of physician to change in patient's condition.
Identification/documentation*	Events relating to the identification or documentation of patient care.	Wrong dose of medication was indicated on the computer system for several days.
Blood products*	Events relating to errors the administration of blood/blood products.	Blood left in room temperature for over 6 hours was discarded.
Safety*	Incidents relating to patient safety	Patient sustained a needle stick injury from a syringe and needle that was found on patient's bed.

Adverse drug reaction	Harmful or unpleasant reaction resulting from the use of medications.	Rash occurred after drug was administered to patient.
Surgical site infections	Infections that occurred after surgery in the part of the body where surgery took place.	Unexpected return to the operating room due to a persistent wound exudate.
Infection control*	Complications resulting from infections that occurred during hospitalization.	Patient was discharged home soon after surgery and required another readmission due to septicemia.
Fall*	Fall accident/incident that occurred during hospitalization.	Patient fell while trying to get out of bed.

Note. * denotes nurse-sensitive adverse events

Each adverse event is given a final severity and preventability assessment score. The severity and preventability assessment scores are described later in this section. The specific adverse event type provides additional information on what kind of incident is involved; one example is a patient who had a lab/specimen test adverse event involving mislabeling/unlabeled specimens. A brief factual description of the adverse event provides a concise summary of the event, such as who was notified of the adverse event, the actions that were taken to resolve the issue, and follow-up evaluations. Data with medical record numbers that matched to those in the Nightingale Metrics database were used in this study.

A limitation of this and similar adverse event reporting programs is that the reporting is voluntary. There is ongoing, regular training for the hospital staff to ensure compliance on reporting requirements and all safety initiatives and goals. The Program for Patient Safety and Quality staff include four risk coordinators who are nurses and one quality improvement consultant. Their responsibilities include the oversight and regulatory reporting responsibilities of the Safety Event Reporting System database, such as identifying safety issue trends using statistical analyses to determine important areas that require attention and to present the data to committees within the hospital. In addition, they continually monitor and measure compliance with important organizations such as the Centers for Medicare and Medicaid Services, the Joint Commission, and other regulations, requirements, and initiatives.

At the unit level, a Safety Event Reporting System manager, typically a nurse in a leadership position is appointed to monitor any adverse events that occur within each unit. Every Safety Event Reporting System manager receives training in the definition, documentation, and management of adverse events. In any adverse event report, the Program for Patient Safety and Quality staff and Safety Event Reporting System managers review the data relevant to their areas of responsibility, ensuring that there is proper follow-up to the event, and ultimately signing off on the event. Both the Program for Patient Safety and Quality staff and the Safety Event Reporting System managers and MSICU staff work closely in the adjudication and validity of the data, coordinating efforts for the resolution of any issues raised, and generating corrective action plans.

The hospital employee involved in the incident enters information into the computer system such as the date of the event, a brief narrative description of the event, the incident classification, the type of specific event, a severity assessment score, and a preventability assessment score. A unique file identification number is assigned to each reported incident. An internal investigation is conducted by the Safety Event Reporting System manager in order to verify the accuracy of event and to close the case. In addition, the Safety Event Reporting System manager works closely with the staff from the Program for Patient Safety and Quality, to ensure that the information is verified and reported accurately. Generally, in less serious incidents with severity scores of less than three, the Safety Event Reporting System manager assigns a final severity assessment score and a final preventability score. In situations when the final severity score assigned was in question, the quality improvement consultant offers guidance and discusses the case with the Safety Event Reporting System manager to agree on a final score. Less serious incidents typically do not require follow-up from the quality improvement consultant and/or Safety Event Reporting System manager. In more serious incidents with severity scores of three or more, however, the risk coordinators and the Safety Event Reporting System manager work together to agree on a final severity score and preventability score and they conduct additional follow-ups to monitor and remediate the situation as necessary.

A set of severity level definitions are used to determine the degree of an event's severity. There are six levels of severity – Level zero refers to a near miss or potential harm event (used in 2004 to 2005); Level one refers to a no harm or near miss event; Level two refers to a minor event; Level three refers to a moderate event; Level four refers to a major event; and Level five refers to a catastrophic event. The list of definitions of the levels of severity scores is shown in table 3-2.

Table 3-2
Definition of levels of severity in the Safety Event Reporting System database

Levels	Definitions
0	Near miss or potential harm event
1	No harm or near miss event
2	Minor event
3	Moderate event
4	Major event
5	Catastrophic event

Preventability scores refer to the extent to which the event could have been avoided. There are three levels of preventability scores – a preventable event, a possibly preventable event, and a not preventable event. The levels of preventability scores are presented in table 3-3. Preventable events refer to events that should not occur if the standard of care or institutional practices and policies had been followed. For example, the medication error occurred because the nurse did not double-check with another nurse prior to administering the intravenous drug per hospital procedure. Possibly preventable events refer to events that may be preventable if the standard of care or institutional practices and policies had been followed; as an example, the patient signed the consent for a femoral line insertion but sustained an unintentional suprapubic bladder tap. Not preventable events refer to those that occurred that were unavoidable, despite following the standard of care or institutional practices and policies. For example, the patient died despite receiving the appropriate care and there was a general consensus among the healthcare team that there was no opportunity to improve the patient outcome.

Table 3-3
Definition of levels of preventability in the Safety Event Reporting System database

Levels	Definitions
Preventable	Events that should not occur if the standard of care or institutional practices and policies are followed
Possibly Preventable	Events that might be preventable if standard of care or institutional practices and policies are adhered to
Not Preventable	Events that occurred could not be avoided, despite following the standard of care or institutional practices and policies

The levels of severity and preventability are determined by the person reporting the incident and the nurse manager of that unit. Once the incident is reported internally, the Program for Patient Safety and Quality staff receives information about the event.

The quality improvement consultant is in charge of evaluating minor incidents with severity levels of one and two. The four risk coordinators are in charge of evaluating moderate to catastrophic incidents with severity levels of three to five.

Measurements

Continuity of Care Index

The Continuity of Care Index was developed by Curley and Hickey (2006) to measure CINC for the Critical Care and Cardiovascular program at Children's Hospital Boston. Curley and Hickey's Continuity of Care Index is calculated by the ratio of the total number of different nurses assigned to one patient to the total number of nursing shifts up to seven days. This index ranges from zero (if the same nurse cared for a single patient every shift) to one (if different nurses cared for a single patient every shift). That is, *lower* values of the index indicate *more* CINC.

The Continuity of Care Index is found in the Nightingale Metrics database. On the day of data collection, the research assistant obtains a list of the nurses who took care of a patient over the past seven days. The list is obtained from the daily nursing assessment forms that are completed for each patient every shift. The research assistant then compares this information with the administrative clerk's records to ensure that the nurses listed corresponded to the nurses actually working on the indicated days. By using data on the total number of different nurses caring for the patient and the total number of nursing shifts up to seven days experienced by the patient, the research assistant computes a Continuity of Care Index for each patient in SPSS.

To facilitate exposition, all analyses in the study were conducted using the reverse score of Curley and Hickey's Continuity of Care Index. Particularly, to allow higher values to indicate more CINC, a slightly modified index, Continuity of Care Index (CCI), was computed as:

$$\text{Curley \& Hickey's CCI} = \frac{\text{Total number of different nurses}}{\text{Total number of shifts}}$$

$$\text{CCI} = 1 - \text{Curley \& Hickey's CCI}$$

$$= 1 - \frac{\text{Total number of different nurses}}{\text{Total number of shifts}}$$

To illustrate the computation of CCI, assume a patient who received care from 12 different nurses over a total of 14 nursing shifts. Thus, CCI would be calculated as: 1 - (12 ÷ 14) = 0.14. Note that in this case, *higher* values of CCI indicate *more* CINC.

Pediatric Index of Mortality

The Pediatric Index of Mortality, version 2, (PIM2) provides a quantitative measure of the patient's mortality risk (Slater, Shann, & Pearson, 2003). The PIM2 is based on data collection that began in 1997 in pediatric ICUs in Australia and New Zealand. Based on the Physiologic Stability Index, PIM2 assumes that physiologic instability of a patient's condition reflects a higher risk of mortality. The PIM2 was developed by forward and backward logistic regression. Variables were selected based on the inclusion and exclusion of variables on discrimination and goodness of fit.

Discrimination and calibration are methods commonly used to determine the validity of PIM2 score. Discrimination refers to the accuracy of the scoring system in predicting higher probabilities of death of patients who died (Iezzoni, 1994), assessed by the area under the Receiver Operating Characteristic curve (Hanley & McNeil, 1982), which measures the overall ability of the scoring system to predict mortality across a range of risks. Calibration refers to how well the average-predicted values are close to the average-observed outcomes (Iezzoni, 1994). Lemeshow and Hosmer (1982) proposed a statistical method known as the goodness-of-fit Hosmer-Lemeshow χ^2 statistic to determine whether average and predicted rates of mortality were similar or different within the population subgroups.

The PIM2 consists of ten variables that are collected from the first contact with the patient to one hour after arrival in the ICU. A higher probability score reflects a higher risk of death. Compared to version one, PIM2 uses three more variables, is better calibrated, and adjusts for use in a more heterogeneous population of patients in the ICU. Because PIM2 is based on objective measurements of physiological variables, clinicians use this score to make comparisons among children with varying degrees of mortality risk. PIM2 is calculated using the following equation, where:

PIM2 logit = (-4.8841) + (values*beta) + (0.01395* (absolute (SBP – 120))) + (0.1040*(absolute base excess)) + (0.2888*100*FiO_2/PaO_2)).

The PIM2 logit results were converted to the predicted probability of death using the following equation, the predicted death rate = e^{logit}/ (1 + e^{logit}). The key advantage of using PIM2 is the use of current admission data to estimate the patient's mortality risk that is not biased by the quality of treatment after admission. In this study, the PIM2 probability of mortality scores was used in the analyses.

Slater et al. (2003) conducted a prospective cohort study of ten ICUs in Australia and New Zealand to develop and validate the second generation of the PIM score. The authors indicated that PIM2 resulted in the addition of new ICU admission variables (admitted for recovery from surgery or a procedure, admitted following cardiac bypass, and low risk diagnosis), revisions to the criteria for cardiac arrest and high risk diagnosis, and the inclusion of liver failure that resulted in a model that was more accurate and better discriminatory performance. Overall, they reported that PIM2 had good discrimination and was accurately calibrated.

Slater et al. (2003) reported on the discrimination performances between PIM and PIM2. They found that PIM2 discriminated well between death and survival among patients in the pediatric ICU (Area under curve = 0.90; 95% CI = 0.89 – 0.91) compared to PIM (Area under curve = 0.88; 95% CI = 0.87 – 0.89). They reported that PIM2 had excellent calibration (Goodness-of-fit $\chi^2 = 11.56$, df (8), p = 0.17). However, PIM had poor calibration in respiratory illness and in non-cardiac post-operative patients (observed: expected deaths, 160: 212.8 and 48: 82 respectively). Using PIM2, the authors found that calibration across all diagnostic groups was improved compared to PIM. In particular, the performance in respiratory illness and non-cardiac post-operative patients was improved in the revised model (observed: expected deaths, 160: 4302 and 48: 3951.7 respectively)

Pediatric Risk of Mortality

The Pediatric Risk of Mortality version 3 (PRISM3) was developed by Pollack, Patel, & Ruttimann (1996) to provide a quantitative measurement of the patient's mortality risk in children 18 years and younger. PRISM3 was derived using data collected in pediatric ICUs in the U.S. from 1993 to 1994. Similarly, PRISM3 was based on the Physiologic Stability Index. This metric is used to measure the patient's risk of mortality at two time points: 12 hours after admission to the ICU and 24 hours after admission to the ICU. Data collection within 12 hours of ICU admission is recommended for quality assessments (Pollack et al., 1996). Researchers have suggested that data collected 12 hours after ICU admission allows for the observation of treatment effects. Data collection 24 hours after ICU admission is recommended when accuracy in individual patient mortality risk assessments is needed. The PRISM3 has a score that ranges from 0 to 76, with a higher score reflecting a higher risk of death. Pollack et al., (1996) indicated that the use of large diverse database in the development of the PRISM3 score makes this version more reflective of recent care of pediatric ICUs in the United States.

To develop and validate PRISM3, Pollack et al., (1996) conducted a prospective cohort study of 32 pediatric ICUs in the United States. The authors indicated that the discrimination performance of PRISM3 significantly increased by 9% compared to the previous PRISM score (Area under curve = 0.831 (PRISM); Area under curve = 0.906 (PRISM3); $p<0.005$). They reported that PRISM3 had excellent calibration. As expected, PRISM3 (Chi-Square = 4.992, df (5), $p = 0.4168$) performed better compared to the previous version of PRISM (Chi-Square = 3.993, df (5), p = 0.5504). Additionally, two goodness-of-fit evaluations were conducted on the total sample to assess the model calibration across different patient groups. As expected, PRISM3 had good calibration across different age groups (PRISM: Chi-Square = 6, df (4.576), p = 0.5992; PRISM3: Chi-Square = 6, df (3.118), p = 0.7939) and across different diagnostic groups (PRISM: Chi-Square = 4, df (6.541), p = 0.1622; PRISM3: Chi-Square = 4, df (3.944), p = 0.4137).

Data Management

This section details the management of data such as the creation of variables, the development of the CINC-Outcomes analytical database, and data checks. The patients' medical record numbers were obtained from the Nightingale Metrics database. Every patient admitted to Children's Hospital Boston is assigned a medical record number that is a unique identifier consisting of up to ten numbers. The Nightingale database consists of patient-level data from March 2004 to December 2010. The patients' medical record number served as the common identifier to link relevant data across all databases.

Creating Variables

The patient's number of days in the MSICU, ventilator days, and number of device days were constructed from the Virtual Pediatric Intensive Care Unit Performance System database. The duration of stay in the ICU was calculated by taking the difference between the ICU discharge date and the ICU admission date. The number of ventilator days was computed using the difference between the date mechanical ventilation was discontinued for more than 24 hours and the date that mechanical ventilation was initiated. The number of device days was calculated by obtaining the difference between the date of the device removal and the date the device was inserted. The number of device days was computed for patients who were supported on mechanical ventilation, and/or had central venous catheters and/or urinary catheters in place.

All adverse events that occurred during the patient's stay in the MSICU were selected. Variables such as the number of adverse events, the characteristics of the adverse events (e.g., medication/fluid error, vascular access device error, or fall), the severity assessment score, and the preventability assessment score were also added into the CINC database. The occurrence of adverse event was indicated as follows: a value of "0' refers to no adverse event and a value of "1" refers to the occurrence of at least one adverse event. In addition, death in the MSICU was included as an adverse event. This data were obtained from the Virtual Pediatric Intensive Care Unit Performance System database. Nurse-sensitive adverse events were created based on events that might occur as a result of nursing care (Morrison et al., 2001). The following characteristics were considered to be nurse-sensitive adverse events: medication/fluid, vascular access device, skin/tissue, airway management, line/tube, care/services coordination, identification/documentation/consent, blood/blood product, safety, infection control, and fall. In addition, the lack of pain documentation was included as a nurse-sensitive event. This data was obtained from the Nightingale database.

In the Safety Event Reporting System database, a severity score is assigned to each adverse event. For example, a patient with three adverse events would be assigned a total of three severity assessment scores, one score for each adverse event. In the original dataset, the severity of the adverse event is measured using a severity assessment score that ranges from zero to five. In the merged dataset, the severity scores were categorized into “low severity” and “high severity”. “Low severity” was a frequency count of all level zero, level one, or level two severity assessment scores; “High severity” was a frequency count of all level three, level four, or level five severity assessment scores.

The preventability assessment scores indicate if the adverse event was avoidable or not. In the merged database, the preventability scores were categorized as “preventable”, “possibly preventable”, and “not preventable” adverse events. “Preventable” referred to the total number of adverse events that were avoidable; “possibly preventable” referred to the total number of adverse events that were potentially avoidable; and “not preventable” referred to the total number of adverse events that were unavoidable. The lack of pain documentation was considered as an adverse event. These data were obtained from the Nightingale Metrics dataset.

All infections that occurred during the patient’s stay in the MSICU and up to 48 hours after MSICU discharge were selected. The occurrences of MSICU-acquired infection were indicated in each category (i.e. catheter-associated bloodstream infection, ventilator-associated pneumonia, and catheter-associated urinary tract infection). A value of “0” referred to no MSICU-acquired infection and a value of “1” referred to presence of at least one MSICU-acquired infection.

Construction of CINC-Outcomes Analytical Database

The CINC-outcomes analytical database was created from extracting and merging selective data from four databases: the Nightingale Metrics database, the Virtual Pediatric Intensive Care Unit Performance System database, the Medical/Surgical Intensive Care Unit-Acquired Infection database, and the Safety Error Reporting System database. The medical record number was the common identifier that linked all data together. Data from four databases were merged based on the medical record number from the Nightingale Database. Only data that were used to answer the research question were included in the analytical dataset. Prior to data analysis, a de-identified database was created. All patient identifiers such as the medical record number, the Virtual Pediatric Intensive Care Unit Performance System case identification number, and the patient's last name were removed from the analytical database.

The analytical database consisted of the following independent variables and indicated in parentheses were how the variables were determined: CINC (Curley and Hickey's Continuity of Care Index), nursing expertise (Level II/III nurses), and probability of mortality (PIM2 and PRISM3). The analytical database consisted of the following dependent variables: MSICU length of stay (days), duration on mechanical ventilation (days), adverse event, and MSICU-acquired infection. Table 3-4 outlines a data dictionary of key variables in the analytical database.

Table 3-4
Key variables in analytical dataset

Variable	Description	Response categories	Data origin
<u>*Dependent Variables:*</u>			
MSICU length of stay	Duration of patient's stay in the MSICU	Continuous variable from 0 to *n*, reported in days	Virtual PICU System
Duration on mechanical ventilation	Total number of days on mechanical ventilator support in the MSICU	Continuous variable from 0 to *n*, reported in days	Virtual PICU System
Adverse event	Occurrence of adverse event	0 = No 1 = Yes	Safety Event Reporting System
MSICU-acquired infection	Occurrence of infection in the MSICU, such as CA-BSI, VAP, and CA-UTI	0 = No 1 = Yes	MSICU-Acquired Infection
<u>*Independent variables:*</u>			
Curley and Hickey's Continuity of Care Index	Measure of Continuity in Nursing Care up to 7 days prior, from time of data collection	Continuous variable, ranging from 0 to 1	Nightingale Metrics
Match of expertise to mortality risk	At least one Level II/III RN assigned to patient with high mortality risk is considered a match	0 = Mismatch 1 = Match	Nightingale Metrics
<u>*Control Variables:*</u>			
Age	Age at time of MSICU admission	Continuous variable from 0 to 21, reported in years	Virtual PICU System
Gender		0 = Male 1 = Female	Virtual PICU System

Predicted mortality	PIM2 measured within 1 hour of MSICU admission; PRISM3 measured within 12 hours of MSICU admission	Continuous variable from 0 to 100	Virtual PICU System
MSICU admission status	Type of ICU admission	0 = Scheduled 1 = Unscheduled	Virtual PICU System
MSICU patient type	Type of patient	0 = Medical 1 = Surgical	Virtual PICU System
MSICU Diagnosis	Diagnosis at time of MSICU admission	1 = Respiratory 2 = Neurologic 3 = Oncologic 4 = Genetic 5 = Others	Virtual PICU System
Level II/III RN	Proportion of Level II/III RNs assigned to patient up to 7 days prior, from time of data collection	Continuous variable from 0 to 100.	Nightingale Metrics

Note. RN = registered nurse. CA-BSI = catheter-associated bloodstream infection. VAP = ventilator-associated pneumonia. CA-UTI = catheter-associated urinary tract infection. PICU = pediatric intensive care unit

A criterion was established to avoid statistical biases that might arise when multiple observations of the same patient are used in empirical analyses. To address this concern, repetitive observations of the same admission and discharge dates on two or more Nightingale data collection periods were removed and the latest period of data collection period was included in the analysis. To illustrate, assume that a patient stayed in the MSICU from April 2004 to February 2005. Assume further that data were collected in April 2004, May 2004, August 2004, November 2004, and February 2005. In this case, only the patient's data that was collected in February 2005 were used in the final database. The two assumptions underlying the use of the latest data was to: i) provide a rough representation of the overall severity of the patient's illness and ii) account for patients who required planned or unplanned readmissions into the ICU.

Data Checks

Data checks were conducted on the analytical database against the original four databases to confirm the accuracy of the merged data. If necessary, hard-copies of the data were used to verify the information. Random database checks were conducted by comparing the merged data in the analytical database to the original databases. The purpose of conducting random checks was to ensure that the data were merged properly while creating the analytical database. Selecting random samples eliminated bias in the selection process and ensured that all cases in the database had an equal chance of being selected for data checks. Ten percent of the total number of observations (about 43 observations) from the analytical database was randomly selected to perform data checks against the original data and paper reports for accuracy. Random samples were selected using a random number generator program from the website http://www.random.org.

To identify duplicate data entries and errors, descriptive statistics such as frequency tables with counts, ranges, minimum and maximum values were conducted on the merged dataset. Subsequently, the merged data were carefully examined for ambiguous observations; for example, data consisting of missing, incomplete, or different medical record numbers but the same last name from the Virtual Pediatric Intensive Care Unit Performance System data warranted further investigation.

Variables

This section describes the independent and dependent variables of this study. The statistical methods to test the hypotheses are specified. The section also presents the Cox proportional hazards regression model and a binary logistic regression model for risk-adjusted analyses. All analyses were conducted using the IBM SPSS version 19.

Continuity in Nursing Care

Continuity in Nursing Care (CINC) was evaluated in the statistical model as both a continuous and categorical variable. The main analyses were conducted using the modified version of Curley and Hickey's Continuity of Care Index, known as the CCI, as a continuous variable. Additionally, sensitivity analyses were conducted based on the distribution of CCI scores in terms of quartiles.

Nursing Expertise Matched to Patient's Mortality Risk

A match was assumed when a nurse with high expertise was assigned to a patient with high mortality risk. A match was determined as having at least one Level II/III nurse who cared for the patient during the data collection period in the ICU. High mortality risk was determined by the fourth quartile of the distribution of the PIM2 probability of mortality scores.

Control Variables

Multivariable analyses were risk-adjusted on the basis of patients' age, gender, PIM2, ICU admitting diagnosis, type of MSICU admission (scheduled/unscheduled), type of MSICU patient (medical/surgical), , and MSICU length of stay (for adverse event and ICU-acquired infection only). The purpose of risk-adjustment was to ensure that the results of the analyses were comparable across patients with different case-mix and mortality risks. The control variables were selected based on findings from prior literature (Ruttimann & Pollack, 1997; Agarwal et al., 2010; Richards et al., 1999).

Length of Stay

The Virtual Pediatric Intensive Care Unit Performance System database contains the date of the MSICU admission and discharge for each patient. The length of stay referred to the total duration of stay in the MSICU. The length of stay was calculated by obtaining the difference between the date of MSICU admission and the date of MSICU discharge.

Duration of Mechanical Ventilation

The duration of mechanical ventilator support referred to the total number of days the patient was on a ventilator in the MSICU. The number of days the patient was on a mechanical ventilator was calculated by obtaining the difference in dates between the initial use and the removal of mechanical ventilator support for more than 24 hours.

Adverse Events

In this study, adverse events referred to situations that occurred during the patient's stay in the MSICU that were related to the management of patient's illness (e.g., unintended diagnosis and omissions of care) that, rather than the patient's severity of illness, resulted in complications. Such complications included indications of an unfavorable symptom, sign, syndrome, and disease that either occurred or appeared to worsen (National Institute of Health, 2011). In the Safety Event Reporting System database, adverse events were organized into the following categories: laboratory specimen/test error, medication/fluid error, diagnostic/assessment/treatment error, vascular access device error, skin/tissue error, airway management, surgery/procedure error, line/tube error, care/services coordination error, identification/documentation/consent error, blood/blood product error, safety error, adverse drug reaction, surgical infection error, infection control error, and fall. In addition, death in the MSICU and lack of pain documentation was regarded as an adverse event. A dummy variable was created to indicate the occurrence of an adverse event. For instance, adverse event was coded as "1" if the patient experienced at least one adverse event during his/her stay in the ICU and "0" if the patient did not experience any adverse event.

Intensive Care Unit-Acquired Infections

Three types of ICU-acquired infections were analyzed: Catheter-Associated Bloodstream Infection, and Ventilator-Associated Pneumonia, Catheter-Associated Urinary Tract Infection. After identifying the patients who experienced infections in the ICU, a dummy variable was created with "1" referring to the occurrence of at least one ICU-acquired infection and "0" referring to no occurrence of infection. The incidences of Catheter-Associated Bloodstream Infection were assessed in patients with central line catheters; Ventilated-Associated Pneumonia in patients with endotracheal tubes; and Catheter-Associated Urinary Tract Infection in patients with bladder catheters.

Inclusion and Exclusion Criteria

All patient data from March 2004 to December 2010 were included in the analysis, unless the following exclusion criteria were present:

(i) Cases with incomplete patient demographic data (e.g., age, gender, PIM2 score, and length of stay) were absent. Cases were excluded because data were incomplete and could not be recreated.

(ii) Patients who were 21 years or older at the time of ICU admission. Cases were excluded because they are not typically considered pediatric patients.

(iii) Subjects with the same admission and discharge dates on two or more consecutive Nightingale data collection periods. Cases were excluded because these data were not independent observations.

(iv) Cases with less than five nursing shifts. Cases were excluded because CINC could not be established in these abbreviated time period.

(v) Patient deaths in the MSICU. Nonsurvivors were excluded from length of pediatric ICU stay and duration of mechanical ventilation analyses because these outcomes are not relevant in these patients.

All the 292 survivors were used in the analyses of length of day. There were 198 survivors supported on mechanical ventilation used in the calculation of ventilator days.

Sensitivity analyses were conducted with Pediatric Risk of Mortality version 3 (PRISM3) as an alternative to Pediatric Index of Mortality version 2 (PIM2) to control for risk of mortality. The sample size was smaller in this cohort as these data were only available from June 2005 to December 2010.

Power Analysis

A power analysis was conducted to study the relationship of CCI as a continuous variable to MSICU length of stay based on a univariate proportional hazards regression model using STATA version 12 software (StataCorp LP, College Station, TX). The dependent variable is MSICU length of stay (in days) and the independent variable is CCI, having a standard deviation of 0.14. Using a sample of 292 cases and a two-sided 0.05 significance level provides 80% power to detect a hazard ratio of 3.23 and 90% power to detect a hazard ratio of 3.88 corresponding to a one unit change in CCI. Thus, for a 1/14 = 0.07 unit change in CCI (equivalent to a change of one nurse per week), there is 80% power to detect a hazard ratio of exp(0.07 x log(3.23)) = 1.09 (corresponding to a 8% change in MSICU length of stay) and 90% power to detect a hazard ratio of 1.10 (corresponding to a 9% change in MSICU length of stay).

Data Analysis

The methods of conducting the analyses are detailed below. The Predictive Analytics Software version 18 was used to conduct all statistical analyses. Extreme outliers related to the duration of any event could have a distorting effect on the results of empirical analyses. The outliers were detected by studying the distribution of the variables. To determine outliers in the dataset, measures of central tendency such as mean, median, skewness, and kurtosis values were analyzed. In addition, histograms scatter plots, and Q-Q plots were generated to check for outliers. Residual plots and scatter plots were constructed to assess the appropriateness of using a linear model in the analyses. In cases of non-linearity and non-normality, appropriate transformations were applied or non-parametric procedures were performed.

Univariable descriptive characteristics covering patient demographics, patient outcomes, and nursing care were provided for the sample. Results were presented as mean, median, standard deviations, and interquartile ranges for continuous data, and proportions and frequencies for categorical data. Additional unadjusted comparisons among groups were conducted using: i) a t-test and F-test for interval or ratio data, ii) a Mann-Whitney U test, a Pearson chi-square test, and a Kruskal-Wallis test for ordinal and nominal data.

Correlation analyses were conducted to ensure that multicollinearity was not present among the independent variables. Depending on the nature of the variables, different types of analyses were conducted. For instance, the Pearson correlation coefficient was used for normally distributed variables. When there was at least one variable in the correlation that was not normally distributed, then, the Spearman correlation coefficient was used. The Phi correlation coefficient was conducted on two dichotomous variables and the point biserial correlation coefficient was conducted on one dichotomous variable and one continuous variable.

Kaplan Meier analyses were conducted to describe the distribution of data. Specifically, the purpose was to estimate the impact of CCI in terms of quartiles, on the unadjusted length of stay and the duration of ventilator support among survivors. Quartiles of CCI were used to minimize the effect of outliers when analyzing the data. Survival plots were generated to present a plot of the cumulative percent of patients on a linear scale to determine the probability of an event occurring (i.e. days in MSICU or ventilator days), which provided a graphical description of trends. The log-rank test (χ^2) was used to determine if there were significant differences in the occurrences of an event at any time point, when two or more Kaplan-Meier curves were generated.

In the multivariable analysis, the proportional hazard regression model and logistic regression model were used. The proportional hazard regression model served to test the hypothesis for the dependent variables, MSICU length of stay and duration of mechanical ventilation. The key property of this model was that it was not affected by the shape of the underlying survival distribution. For instance, MSICU length of stay has a markedly positive skew distribution. This model assumes that the underlying hazard rate is a function of the independent variables. Another property of this model was that it allowed for monotonic transformations to achieve normality in the model. Based on findings from prior literature, the following independent variables were considered in the regressions: age, gender, mortality risk, diagnosis on admission to MSICU, type of admission, and type of patient. No censoring was present in the proportional hazards regression models.

A logistic regression was used to test the hypothesis for dichotomous dependent variables for occurrences of adverse events and MSICU-acquired infections. The following independent variables were considered in the regressions: age, gender, mortality risk, diagnosis on admission to MSICU, type of admission, type of patient, and length of stay. In this study, statistical significance was specified at less than 0.05. Based on the earlier multivariate models, sensitivity analyses were conducted to determine the impact of different levels of CCI (quartiles) on the length of stay and ventilator days. Additional analyses were conducted to explore if CINC has an impact on patient outcomes in particular groups.

Research question 1: Does CINC impact patient outcomes in the pediatric ICU?

Hypothesis 1: Patients who received more CINC in the pediatric ICU will experience better patient outcomes than patients who receive less CINC.

Depending on the patient outcome, different models are used. In particular, a proportional hazard model was used to examine the effect of CINC on ICU length of stay and duration of ventilator support. A logistic regression model was used for adverse events and ICU-acquired infections.

The proportional hazard model is written as:

$$h(t|\, X_i) = h_0(t)\exp(\beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n), \text{ where } (i=1,2,\ldots.n) \tag{1}$$

where $h(t|...)$ is the resultant hazard related to the event of interest; specifically, the event is ICU discharge when examining the length of the ICU stay; it is the termination of ventilator support when examining the duration of ventilator support. $h_0(t)$ is the baseline hazard where all covariates equal zero; $\beta_{1,} \beta_{2,} \ldots \beta_n$ represent the influence of the designated covariates on event occurrence; X_1 is a vector of CCI; $X_{2,} \ldots X_n$ is a vector of control variables.

The logistic regression model is written as:

$$\ln(p/1 - p) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \qquad (2)$$

where $ln(p/\ 1 - p)$ is the log odds of the outcome of interest (adverse event and MSICU-acquired infection); β_0 is the constant term; $\beta_{1,} \beta_{2,} \ldots \beta_n$ represent the influence of the covariates on outcome occurrence; X_1 is a vector of CCI; and $X_{2,} \ldots X_n$ is a vector of control variables.

Research Question 2: Does a match between nursing expertise and a patient's risk of mortality enhance the effect of CINC on patient outcomes in the pediatric ICU?

Hypothesis 2: The positive impact of CINC on patient will be greater when there is a match between nursing expertise and patient's risk of mortality.

The proportional hazard model is written as:

$$h(t|\ X_i) = h_0(t) \exp(\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 \cdot X_2 + \beta_4 X_4 + \ldots + \beta_n X_n), \text{ where } (\ i=1,2,\ldots.n) \qquad (3)$$

where $h(t|\ldots)$ is the resultant hazard related to the event of interest; specifically, the event is ICU discharge when examining the length of the ICU stay; it is the termination of ventilator support when examining the duration of ventilator support. $h_0(t)$ is the baseline hazard where all covariates equal zero; $\beta_{1,} \beta_{2,} \ldots \beta_n$ represent the influence of the designated covariates on event occurrence; X_1 is a vector of CCI; X_2 is a vector of match; $X_1 \cdot X_2$ is a vector of the interaction term of CCI and match; $X_4, \ldots X_n$ is a vector of control variables.

The logistic regression model is written as:

$$\ln(p/1 - p) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 \cdot X_2 + \beta_4 X_4 + \ldots + \beta_n X_n \tag{4}$$

Where $\ln(p/ 1 - p)$ is the log odds of the outcome of interest (adverse event and MSICU-acquired infection); β_0 is the constant term; $\beta_1, \beta_2, \ldots \beta_n$ represent the influence of the covariates on outcome occurrence; X_1 is a vector of CCI; X_2 is a vector of match; $X_1 \cdot X_2$ is a vector of the interaction term of CCI and match; $X_4, \ldots X_n$ is a vector of control variables.

Human Subject Considerations

The focal point of human subject consideration was to protect patient confidentiality. To limit the risks of the loss of confidential data, all files were strictly maintained in a password-protected secure shared drive that could only be accessed by the dissertation chair and the primary investigator. No saved data were allowed on computer hard-drives, Universal Serial Bus storage drives, and/or floppy disks. At the end of data cleaning and the merging of databases, all patient identifiers were removed. After that point, a unique database identification number that could not be traced to any individual was assigned to each case. All data cleaning, data verification, and data analyses were closely monitored by the dissertation chair. This study was approved under expedited review by the Institutional Review Board of the University of Pennsylvania and Children's Hospital Boston.

Summary

This study used four databases (the Nightingale Metrics database, the Virtual Pediatric Intensive Care Unit Performance System database, the Medical Surgical Intensive Care Unit-Acquired Infection database, and the Safety Errors Reporting System database) from Children's Hospital Boston to examine the association between CINC and patient outcomes. In this study, patient outcomes referred to the length of stay in the MSICU, the duration of mechanical ventilator support, the occurrence of adverse event, and the occurrence of MSICU-acquired infection. Methods of data collection for the databases included cross-sectional and prospective data collection. Using a set alpha of 0.05, the power analysis conducted on 332 observations resulted in a power of close to100% to detect significant differences in the primary dependent variable of this study. A risk-adjusted Cox proportional hazards regression model and risk-adjusted logistic regression models were used to test the hypotheses. The significance value for this study was set at 0.05.

CHAPTER 4: RESULTS

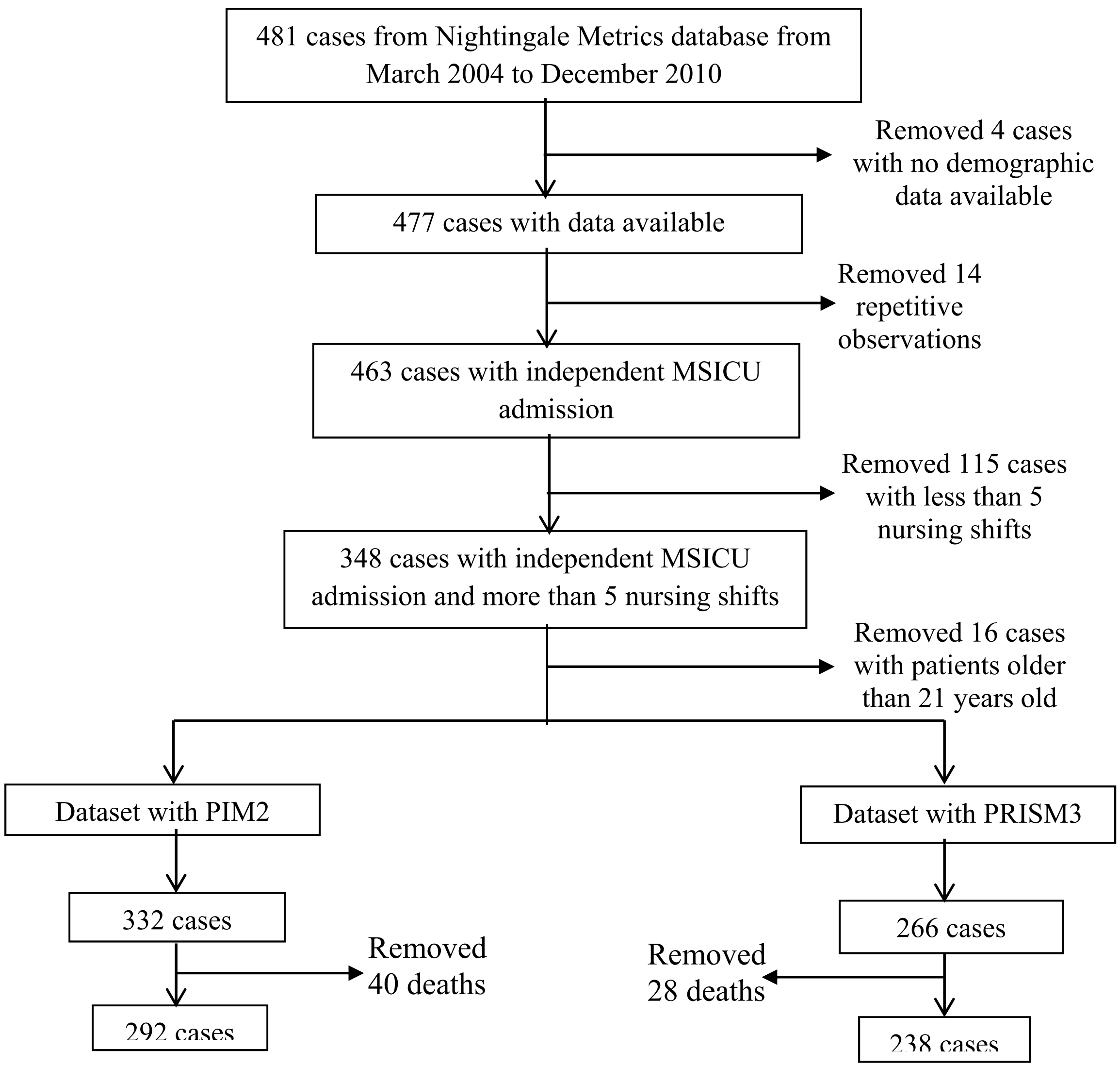
This study was a secondary analysis of merged data from four databases from the MSICU of Children's Hospital Boston. The primary aim of the study was to examine the impact of CINC on patient outcomes; specifically, ICU length of stay, days of mechanical ventilation, adverse events, and ICU-acquired infections. The two hypotheses were i) patients who receive more CINC in the pediatric ICU will experience better patient outcomes than patients who received less CINC and ii) a match of nursing expertise to patient acuity would strengthen the relationship between CINC and patient outcomes.

This chapter is organized as follows. First, the demographics, outcomes, and nursing characteristics of the sample are presented. Next, the differences in the characteristics among survivors and nonsurvivors are presented. The results of correlation analysis, collinearity diagnostics, and Kaplan-Meier curves are then discussed. The results of multivariable regressions examining the association between CINC and patient outcomes and the moderating effect of match are reported.

Description of Sample

A total 481 MSICU cases from the Nightingale Metrics database were merged with the other three databases to create the CINC-outcomes analytical database. After removing four cases with no demographic data from the analytical database, 477 cases remained. To ensure that the sample had independent ICU observations, when a patient had the same admission and discharge dates on two or more Nightingale data collection periods the most recent case was retained. This resulted in a loss of 14 cases from nine subjects who were had relatively long hospitalizations. Next, 115 cases with less than five nursing shifts were removed. In addition, 16 cases with patients older than 21 years old were removed. The final sample of 332 cases consisted of 292 from subjects who survived the ICU stay and 40 deaths. Figure 4-1 presents a flowchart that depicts how the sample was constructed.

Figure 4-1
Flow Chart of Case Selection



Overall Sample Characteristics

An overview of the characteristics of 332 subjects is provided in table 4-1. The median age of these subjects was 2.89 years (IQR = 0.73 – 11.58). Forty-two percent (139/332) of the subjects were females. The proportion of deaths in the sample was higher than predicted by both PIM2 and PRISM3. Of the 332 patients admitted to the MSICU, 40 (12%) subjects did not survive to ICU discharge. In contrast, the median PIM2 risk of mortality at the time of admission, was 2.99 (IQR = 0.86 – 5.53); reflecting a 3% risk of mortality. For the subsample of 266 patients with PRISM3 data (N = 266), the median PRISM3 risk of mortality was 1.75% (IQR = 0.51, 10.22). Among these subjects, 28 (11%) died in the ICU.

The majority of the sample was medical cases (220/332, 66%) and had unscheduled MSICU admissions (230/332, 69%). Patient diagnoses on MSICU admission included disorders such as respiratory dysfunction (138/332, 42%), neurologic dysfunction (43/332, 13%), oncologic disorders (29/332, 9%), genetic disorders (29/332, 9%), and others (93/332, 28%).

Table 4-1
Patient Demographic Information

	N = 332
Age on MSICU admission, median (IQR) in years	2.89 (0.73, 11.58)
Female, *n* (%)	139 (42%)
PIM2 risk of mortality, median (IQR)	2.99 (0.86, 5.53)
PRISM3 risk of mortality, median (IQR)	1.75 (0.51, 10.22)[#]
Medical cases, *n* (%)	220 (66%)
MSICU diagnosis categories, *n* (%)	
Respiratory	138 (42%)
Neurologic	43 (13%)
Oncologic	29 (9%)
Genetic	29 (9%)
Others	93 (28%)
MSICU readmission	25 (8%)
Unscheduled MSICU admission, *n* (%)	230 (69%)
Deaths, *n* (%)	40 (12%)

Note. [#]Additional analyses conducted on subsample of 266 cases with PRISM3 scores.

A summary of patient outcomes and related information is found in table 4-2. The median length of MSICU stay among survivors was 21 days (IQR = 8.25 – 35). Almost 70% (199/292) of survivors were supported on mechanical ventilation in the MSICU. In general, patients were placed on ventilator support for a median duration of 15.50 days (IQR = 6.75 – 31). Of these patients, 89% were ventilated within 24 hours admission into the MSICU. Among the survivors who received ventilator support within 24 hours of MSICU admission, 64% (188/292) of them were medical patients and 36% (104/292) were surgical patients.

Of the total sample, 191 (58%) survivors and nonsurvivors experienced at least one adverse event in the MSICU; specifically, adverse event rate of 1.66 per 100 patient days. The majority of adverse events were reported as preventable in nature (147/191, 77%); 31% (60/191) experienced a severe adverse event. Almost, 50% of the sample experienced a nurse-sensitive adverse event.

There were a total of 49 adjudicated ICU-acquired infections. During the study period, 38 (38/332, 11%) patients experienced at least one ICU-acquired infection.

Table 4-2
Patient Outcomes

Characteristics of Survivors (N = 292)	Statistic
MSICU length of stay, median (IQR) in days	21 (8.25, 35)
Ventilator days, median (IQR) in days (198/292)	15.50 (6.75, 31)
Ventilated within 24 hours, *n* (%)	176/198 (89%)
Characteristics of Survivors and Nonsurvivors (N = 332)	**Statistic**
At least one adverse event, *n* (%)[1]	191/332 (58%)
At least one preventable events	147/191 (77%)
At least one severe events (severity score 3 to 5)	60/191 (31%)
At least one nurse-sensitive events	167/332 (50%)
At least one MSICU-acquired infection, *n* (%)	38/332 (11%)

Note. [1]Rate of 1.66 adverse events per 100 patient days. Adverse event rate calculated by total number of adverse event/total number of days in ICU X 100.

Table 4-3 provides additional information on the various categories of adverse events. There were a total of 584 adverse events reported for the 332 patients. The majority of adverse events were errors related to laboratory specimen/test (244/584, 42%). Sensitivity analyses were conducted on nurse-sensitive adverse events.

Table 4-3
Categories of Adverse Events

Categories, *n* (%)	(N = 584)
Lab specimen/test	244 (42%)
Medication/fluid*	142 (24%)
Lack of pain documentation*	53 (16%)
Diagnostic/assessment/treatment	42 (7%)
Vascular access device*	43 (7%)
Skin/tissue*	29 (5%)
Airway management*	19 (3%)
Surgery/procedure	17 (3%)
Line/tube*	19 (3%)
Care/services coordination*	9 (2%)
Identification/documentation/consent*	8 (1%)
Blood/blood product*	5 (0.9%)
Safety*	2 (0.3%)
Adverse drug reaction	2 (0.3%)
Surgical site infection	1 (0.2%)
Infection control*	1 (0.2%)
Fall*	1 (0.2%)

Note. *denotes nurse-sensitive adverse events.

Table 4-4 provides additional information on the various types of ICU-acquired infections. There were a total of 144 subjects with central venous catheters. Of these cases, 24 of them experienced a catheter-associated blood stream infection (17%). Of the 232 subjects who were intubated and supported on mechanical ventilation, 6 experienced ventilator associated pneumonia (3%). There were 196 subjects who had a bladder catheter inserted. Of these cases, 14 experienced catheter-associated urinary tract infection (7%).

Table 4-4
MSICU-Acquired Infection

Potential Source of Infection	N	Cases with MSICU-Acquired Infection	Event Per 1,000 Device Days[1]
Central venous catheter (CA-BSI)	144	24 (17%)	8.78
Invasive mechanical ventilator (VAP)	232	6 (3%)	1.55
Bladder catheter (CA-UTI)	196	14 (7%)	5.40

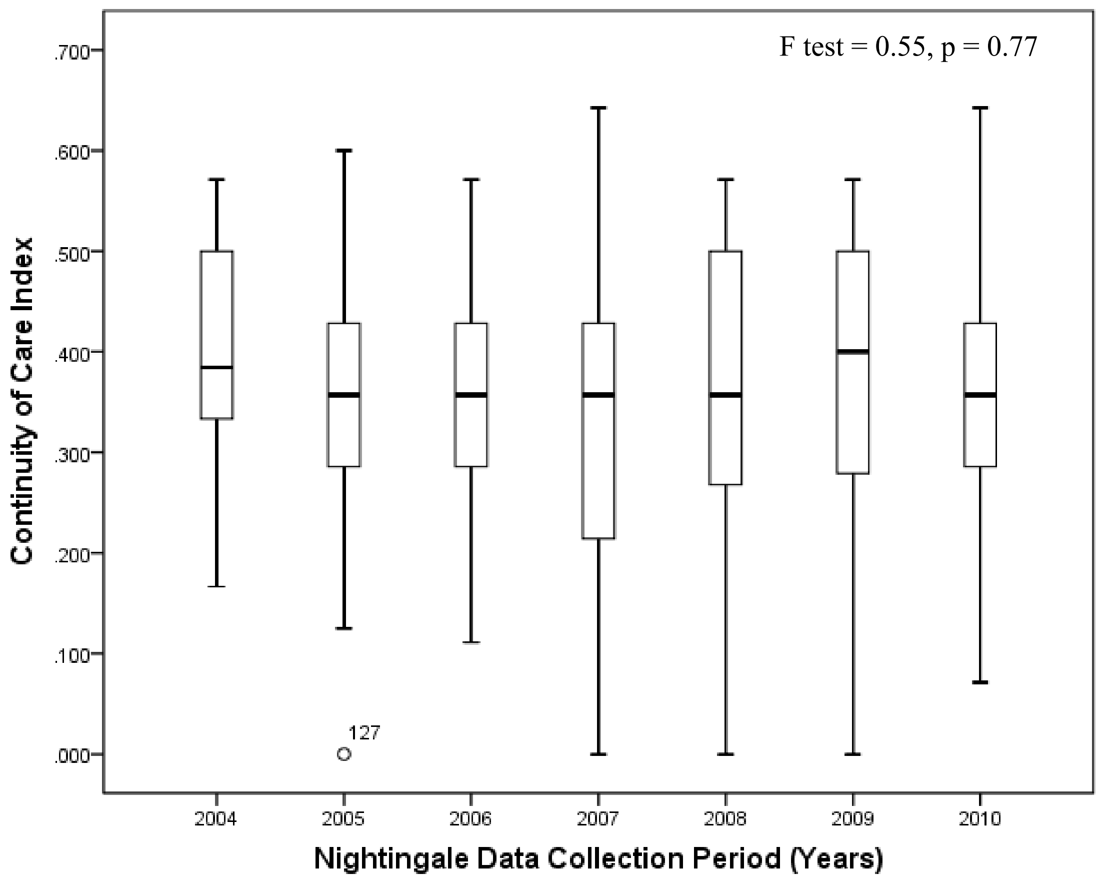
Note. CA-BSI = catheter-associated bloodstream infection. VAP = ventilator-associated pneumonia. CA-UTI = catheter-associated urinary tract infection. [1]Event per 1,000 device days calculated by total number of event/total device days X 1,000.

A summary of nurse characteristics is shown in table 4-5. As discussed in Chapter 3, CCI data were collected up to seven days preceding the day of Nightingale data collection. The average CCI was 0.36 (SD = 0.14). Theoretically, values of CCI can range from zero (less CINC) to one (more CINC). The lowest CCI score was zero (11/332, 3%) and the highest CCI score was 0.64 (2/332, 1%). The CCI scores were not significantly different across the Nightingale data collection periods (see figure 4-2). The average number of nursing shifts in the previous seven days was 12 (SD = 3.27). On average, seven (SD = 2.09) different nurses were assigned to each patient. In a typical week of 14 shifts, nine (SD = 1.90) different nurses were assigned to each case. Of the nurses assigned to each case, 23% of them were Level II/III nurses (SD = 17.55).

Table 4-5
Nurse Characteristics

Characteristics	N = 332
CCI, (mean ± SD)	0.36 ± 0.14
Number of nursing shifts in 7 days, (mean ± SD)	12 ± 3.27
Number of different nurses, (mean ± SD)	7 ± 2.09
Number of different nurses per 14 shifts, (mean ± SD)	9 ± 1.90
Percent Level II/III nurses, (mean ± SD)	23 ± 17.55

Figure 4-2
CCI Scores across Nightingale Data Collection Period



Comparison of Survivors and Nonsurvivors

To provide a better understanding of the nature of the sample, this section provides comparisons of the differences between survivors and nonsurvivors in terms of i) patient characteristics at the time of MSICU admission, ii) patient outcomes, iii) differences in device use, and iv) nurse characteristics.

Table 4-6 presents a comparison of the differences in patient demographics at time of MSICU admission between the survivors and nonsurvivors. While the median age of survivors and nonsurvivors at the time of ICU admission was 3.01 years and 1.92 years, respectively, this difference was not statistically significant. There were no differences in the proportion of females in both survivor and nonsurvivor groups. Survivors had lower median PIM2 and PRISM3 scores than nonsurvivors ($p < 0.001$). There was no significant difference between survivors versus nonsurvivors in terms of the types of ICU admitting diagnosis. Respiratory illness such as pulmonary insufficiency, acute lung injury, and pneumonia were common causes of admission into the MSICU. Overall, 68% to 78% of the sample had unscheduled MSICU admissions. The proportion of unscheduled admissions was not significantly different between survivors and nonsurvivors ($p = 0.23$). There was a higher proportion of medical patients among nonsurvivors, compared to survivors ($p = 0.05$).

Table 4-6
Demographics at Time of MSICU Admission by Survivors and Nonsurvivors

	Survivors (N = 292)	Nonsurvivors (N = 40)	p-value
Age in years, median (IQR)[1]	3.01 (0.79, 11.52)	1.92 (0.47, 12.11)	0.45
Female, *n* (%)[2]	120 (41%)	19 (478%)	0.44
PIM2 ROM, median (IQR)[1]	2.87 (0.82, 4.60)	4.66 (1.78, 15.06)	**<0.001**
PRISM3 ROM, median (IQR)[1]	1.58 (0.50, 7.69)	19.67 (3.46, 49.56)	**<0.001**
Medical cases, *n* (%)[2]	188 (64%)	32 (80%)	**0.05**
MSICU diagnosis categories, *n* (%)[2]			0.25
Respiratory	121 (41%)	17 (43%)	
Neurologic	42 (14%)	1 (3%)	
Oncologic	24 (8%)	5 (13%)	
Genetic	24 (8%)	5 (13%)	
Others	81 (28%)	12 (30%)	
Unscheduled ICU admission, *n* (%)[2]	199 (68%)	31 (78%)	0.23

Note. Abbreviation: ROM = risk of mortality. [1]p-values comparing continuous variables were based on Wilcoxon-rank-sum test. [2]P-values comparing categorical variables were based on chi-square test.

Table 4-7 presents the comparison of the patient outcomes between survivors and nonsurvivors. Compared to survivors, nonsurvivors had longer median length of ICU stay ($p = 0.002$). A higher proportion of nonsurvivors were intubated ($p = 0.03$), had significantly more days of ventilator support ($p = 0.001$), and more likely to experience a severe (not mortality related) adverse event ($p < 0.001$). In addition, 10% of survivors and 20% of non survivors experienced at least one ICU-acquired infection. The difference, however, was not statistically significant.

Table 4-7
Patient Outcomes by Survivors and Nonsurvivors

Characteristics	Survivors (N = 292)	Nonsurvivors (N = 40)	p-value
Length of stay, median (IQR) in days[1]	21 (8.30, 35)	36.50 (13.50, 64.30)	**0.002**
Ventilator days, median (IQR) in days[1]	15.50 (6.75, 31)	26.50 (10.75, 49.50)	**0.001**
Ventilated within 24 hours, (*n*, %)[2]	176 (89%)	30 (88%)	0.91
Intubated, *n* (%)[2]	199 (68%)	34 (85%)	**0.03**
At least one adverse event, *n* (%)[2]	151 (52%)	40 (100%)	**<0.001**
Preventable event	124 (43%)	23 (58%)	0.07
Severe event (severity score 3 to 5)	34 (12%)	26 (65%)	**<0.001**
At least one ICU-acquired infection, *n* (%)[2]	30 (10%)	8 (20%)	0.07
Catheter-associated bloodstream infection	17 (14%)	7 (27%)	0.09
Ventilated associated pneumonia	6 (3%)	0 (0%)	0.31
Catheter-associated urinary tract infection	11 (6%)	3 (12%)	0.31

Note. [1]p-values comparing continuous variables were based on Wilcoxon rank-sum tests. [2]p-values comparing categorical variables were based on chi-square test.

Table 4-8 presents a comparison of the median days of device use in the MSICU between survivors and nonsurvivors. Nonsurvivors had more median days of endotracheal intubation (p = 0.002) and more invasive catheter/lines days than survivors (p = 0.01).

Table 4-8
Duration of Device Use by Survivors and Nonsurvivors

		Survivors		Nonsurvivors	
Devices	N	median (IQR)	N	median (IQR)	p-value[1]
Invasive catheter/lines	207	26 (11, 60)	33	51 (28, 88.50)	**0.01**
Central venous catheter	119	13 (8, 24)	25	18 (10, 37.50)	0.08
Arterial line	158	10 (5, 21)	30	18 (8, 35.80)	0.06
PICC line	104	22 (13, 39.50)	13	24 (8.50, 39)	0.61
Hickman catheter	28	15 (6, 36)	10	13 (1, 56.3)	0.51
Port-A-Cath	16	16.5 (6.25, 26)	6	12.5 (9.50, 40.50)	0.71
Endotracheal tube	173	12 (6, 23)	31	26 (11, 44)	**0.002**
Cuffed tracheostomy	55	34 (18, 57)	6	27.50 (11.50, 105.75)	0.95
Bladder catheter	171	9 (3, 16)	25	10 (3, 21)	0.74

Note. [#]Invasive catheter/lines refer to sum of central venous catheter, arterial line, PICC line, Hickman catheter, and Port-A-Cath days. Abbreviations: PICC = peripherally inserted central catheter. [1]All p-values comparing continuous variables were based on Wilcoxon rank-sum test.

Table 4-9 provides the nurses characteristics of the study population by survivors and nonsurvivors. The mean CCI among survivor and nonsurvivor groups was similar. The number of nursing shifts, number of different nurses assigned to cases, and percent of traveler nurses did not differ between survivors and nonsurvivors. Compared to nonsurvivors, survivors were more likely to receive care from a higher percent of nurses with less than one year nursing experience (p = 0.02). Nonsurvivors, on the other hand, were more likely to receive care from a higher percent of Level II/III nurses ($p = 0.02$). There were statistically significant differences in the match of nurse expertise to mortality risk among survivors and nonsurvivors ($p=0.02$).

Table 4-9
Nurse Characteristics by Survivors and Nonsurvivors

Characteristics	Survivors (N = 292)	Nonsurvivors (N = 40)	p-value
CCI, (mean ± SD)[2]	0.36 ± 0.14	0.38 ± 0.13	0.40
Quartile 1, *n* (%)	68 (23.3%)	9 (22.5%)	
CCI < 0.286: 10 nurses per 14 shifts			
Quartile 2, *n* (%)	43 (32%)	8 (20%)	
0.286 ≤ CCI < 0.357: 9 to 10 nurses per 14 shifts			
Quartile 3, *n* (%)	64 (22%)	12 (30%)	
0.357 ≤ CCI < 0.429: 8 to 9 nurses per 14 shifts			
Quartile 4, *n* (%)	66 (23%)	11(28%)	
CCI > 0.429: less than 8 nurses per 14 shifts			
Number of nursing shifts in 7 days, (mean ± SD)[2]	11.75 ± 3.29	12.08 ± 3.14	0.56
Number of different nurses, (mean ± SD)[2]	7.36 ± 2.12	7.35 ± 1.90	0.98
Different nurses per 14 shifts (mean ± SD)[2]	9 ± 1.91	8.75 ± 1.79	0.40
Percent of Level II/III nurses, (mean ± SD)[2]	22.06 ± 17.57	29.16 ± 16.25	**0.02**
Percent of less than 1 year experience, median (IQR)[1]	0 (0, 11.11)	0 (0)	**0.02**
Percent of travelers, median (IQR)[1]	0 (0, 12.50)	0 (0, 6.82)	0.20
Match of nursing expertise to mortality risk, *n* (%)[3]	29 (10%)	9 (23%)	**0.02**

Note. [1]p-values comparing continuous variables were based on Wilcoxon rank-sum test for differences in medians. [2]p-values comparing continuous variables were based on Student's T-test for differences in means. [3]p-values comparing categorical variables were based on chi-square test for differences in proportions.

Table 4-10 is an Analysis of Variance of the differences of Level II/III nurses across CCI quartiles among survivors and nonsurvivors. The mean percent of Level II/III nurses differed across CCI quartiles among survivors (p = 0.004).

Table 4-10
Level II/III Nurses in CCI Quartiles Among Survivors and Nonsurvivors

CCI	Survivors (N = 292)	Nonsurvivors (N = 40)
Quartile 1 (CCI < 0.286)	16.33 ± 15.32	34.42 ± 22.08
Quartile 2 (0.286 ≤ CCI < 0.357)	23.68 ± 17.93	26.65 ± 11.18
Quartile 3 (0.357 ≤ CCI < 0.429)	26.87 ± 18.1	28.42 ± 16.93
Quartile 4 (CCI > 0.429)	21 ± 17.32	27.49 ± 14.26
F-test	4.51	0.41
p-value	**0.004**	0.75

In summary, the sample consisted of 292 survivors and 40 nonsurvivors. There was no significant difference in age, gender, ICU admitting diagnosis, unscheduled admission, ventilated within 24 hours of ICU admission, and CCI scores between survivors and nonsurvivors. However, survivors stayed in the ICU for significantly shorter periods of time and had a lower acuity score on ICU admission. Nonsurvivors, on the other hand, had a longer length of ICU stay, more days on invasive ventilator support, more invasive line days, and were more likely to be assigned a higher percentage of Level II/III nurses.

Correlation Analyses

Table 4-11 presents the correlation matrix among the independent and dependent variables; the objective is to provide some preliminary indications of the relationships among the variables. Higher CCI scores (more CINC) were significantly correlated with higher PIM2, longer ICU length of stay, and higher proportion of Level II/III nurses. In addition, higher CCI scores were more likely to be associated with a non-mortality adverse event. Medical cases were more likely to have higher risk of mortality and unscheduled ICU admissions. In addition, unscheduled admissions were unlikely to be ventilated within 24 hours of ICU admission.

Variables significantly correlated with longer length of ICU stay include higher CCI scores, higher PIM2 scores, younger age, female subjects, and higher percentage of Level II/III nurses. Variables significantly correlated with longer duration of mechanical ventilation include higher CCI scores, higher PIM2 scores, female subjects, and longer ICU length of stay.

The occurrence of an adverse event was associated with higher CCI scores, higher PIM2, female subjects, higher percent of Level II/III nurse, longer ICU stay, and longer ventilator days. The occurrence of an ICU-acquired infection was associated with higher PIM2 scores, younger age, scheduled admissions, longer ICU stay, longer ventilator days, and a higher likelihood of an adverse event.

Table 4-11
Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11
1 CCI	1										
2 PIM2	0.14*	1									
3 Age	-0.01	-0.11	1								
4 Female	-0.04	0.04	0.01	1							
5 Unscheduled	-0.01	0.32***	0.11	-0.06	1						
6 Surgical	-0.01	-0.26***	0.05	0.03	-0.58***	1					
7 Level II/III	0.12*	0.10	-0.09	0.01	0.05	-0.08	1				
8 LOS	0.16**	0.18**	-0.13*	0.14*	-0.003	-0.09	0.22***	1			
9 Vent days	0.14*	0.18**	-0.03	0.14*	-0.01	0.03	0.11	0.36***	1		
10 AE	0.15**	0.26***	-0.01	0.12*	-0.004	0.01	0.17**	0.5***	0.44***	1	
11 Infection	0.10	0.20***	-0.15**	-0.06	-0.11*	0.08	0.001	0.29***	0.30***	0.19***	1

Note. All correlation coefficients obtained using dataset of survivors (N = 292), except for adverse event and MSICU-acquired infection (N = 332). Abbreviations: LOS = length of stay. Vent = ventilator. AE = adverse events.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Multicollinearity

Even though none of the correlations in table 13 were at 0.8 or above, mulicollinearity could still be present. Multicollinearity occurs when there are two or more predictors in a multiple regression model are highly correlated. It causes the coefficient estimates to change erratically when there are small changes in the model or the data. In this study, the variance inflation factor (VIF), which measures how much the variance of an estimated regression coefficient is increased because of multicollinearity, was computed for CCI. As a rule of thumb, a VIF value of 1 suggests weak collinearity and a VIF value of greater than 5 or 10 would suggest strong collinearity.

Table 4-12 presents the VIF values of the independent variables (i.e., the other independent variables) used in each of the four regressions of patient outcomes (ICU length of stay, duration of ventilator support, occurrences of adverse events, and ICU-acquired infections) on CINC. In each of the columns, the VIFs for CCI and the control variables ranged from 1.01 to 1.77. Overall, the VIF values indicate that there would be unlikely to be multicollinearity in the regression analyses later. Hence, none of the variables were excluded from the regressions due to concerns about mulitcollinearity.

Table 4-12
Multicollinearity Diagnostic Test

	Variance Inflation Factor Values			
Independent Variables	Length of Stay	Ventilator Days	Adverse Event	Infection
CCI	1.03	1.03	1.04	1.04
PIM2 predicted mortality	1.07	1.13	1.09	1.09
Age in years	1.03	1.06	1.05	1.05
Gender	1.02	1.01	1.04	1.04
MSICU admitting diagnosis	1.07	1.09	1.07	1.07
MSICU admission status	1.55	1.77	1.60	1.60
Medical/surgical patient	1.57	1.74	1.56	1.56
MSICU Length of stay	N/A	N/A	1.15	1.15

Note. N/A = not applicable.

Kaplan-Meier Analyses

Kaplan Meier analyses were conducted to determine the likelihood of patients staying in the MSICU on being supported on mechanical ventilation conditional on CINC. For these analyses that are not risk-adjusted, subjects were grouped into quartiles based on CCI values.

Figure 4-3 is the Kaplan-Meier curve for the proportion of patients in the MSICU over time by CCI in quartiles. There were significant differences in the ICU length of stay among CCI quartiles ($\chi^2 = 29.68$, $p < 0.001$). In addition, the Kruskal-Wallis test was conducted to determine the extent of differences in the median length of stay. The median length of stay was the longest in patients with the third quartile of CCI (median = 27.5 days; IQR = 11.5, 43.5) than patients with the first quartile of CCI (median = 8.5 days, IQR = 4, 22), second quartile of CCI (median = 26 days; IQR = 13, 43), and fourth quartile of CCI (median = 23.5 days, IQR = 12.75, 41.5) (Kruskal-Wallis $\chi^2 = 34.73$; $p<0.001$).

Figure 4-3
Kaplan-Meier Curve for Proportion of Patients in the MSICU by CCI Quartiles

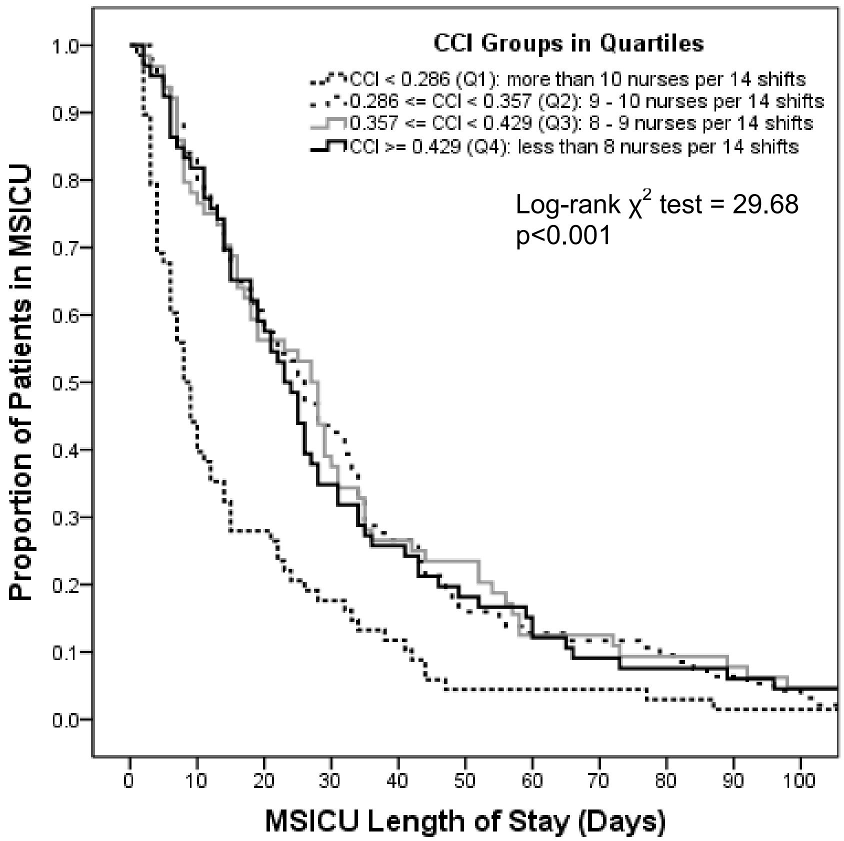
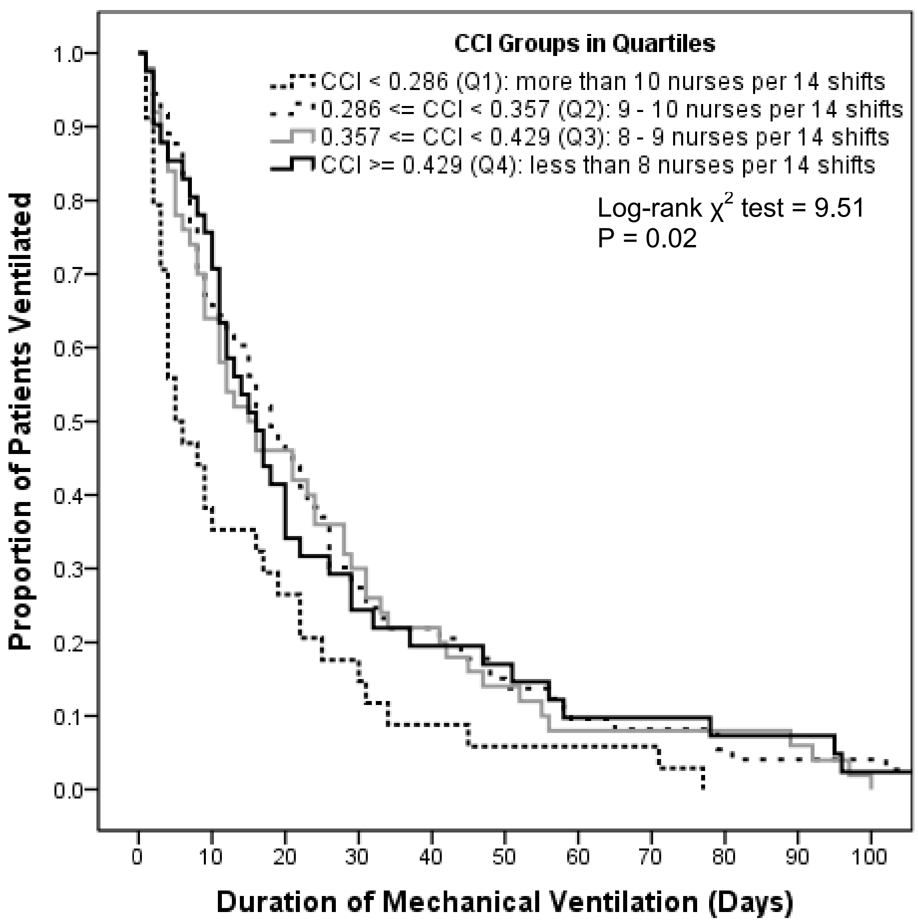


Figure 4-4 is the Kaplan-Meier curve of duration of mechanical ventilation across the four CCI groups. The Kaplan-Meier curves of ventilator days were significantly different among the CCI groups ($p < 0.02$). This result indicated that cases with more CINC (CCI ≥ 0.286 this equates to less than 10 nurses per 14 shifts) were associated with more days of mechanical ventilation than those with less CINC (CCI < 0.286 this equates to more than 10 nurses per 14 shifts). In addition, the Kruskall-Wallis test indicated that the median days of mechanical ventilation was more in patients with the second quartile of CCI (median = 18 days, IQR = 8, 32), than patients in the first quartile of CCI (median = 5.5 days; IQR = 3, 22), third quartile of CCI (median = 15.5 days, IQR = 6.75, 33.25), and fourth quartile of CCI (median = 16 days, IQR = 9.5, 30.5) (Kruskall-Wallis χ^2 = 10.64; p = 0.01).

Figure 4-4
Kaplan-Meier Curve for Proportion of Patients Ventilated Over Time by CCI Quartiles



Regressions of Patient Outcomes on Continuity in Nursing Care

<u>*Hypothesis 1:*</u> *Patients who receive more CINC in the pediatric ICU will experience better patient outcomes than patients who received less CINC.*

Multivariable proportional hazard regression and logistic regression was used to examine the relationship between the patient outcomes i) CINC and length of stay among survivors and ii) adverse event and ICU-acquired infection among survivors and nonsurvivors, respectively. All regression analyses included the following control variables: to control for confounding effects: predicted mortality (PIM2), age, gender, ICU admitting diagnosis, type of ICU admission (scheduled/unscheduled ICU admission), type of patient (medical/surgical case), and ICU length of stay. For patient outcomes, adverse event and ICU-acquired infection, the control variable "length of stay" was included.

Table 4-13 presents the results of proportional hazards regression analyses of MSICU patient outcomes – length of stay and ventilator days – on CINC. As discussed earlier, the samples used in analyses are from the 292 survivors. It is important to note that a hazard ratio that is less than one implies a risk of longer length of stay and longer ventilator days compared to the baseline hazard.

The results for length of stay are first presented. CINC was associated with an increased risk of longer duration of stay in the ICU (HR = 0.12, 95% CI = 0.05 – 0.31). The control variables that were statistically significant ($p<0.05$) were: PIM2, gender, and medical status. Other control variables that were marginally significant ($p<0.10$) were oncologic diagnosis and unscheduled ICU admission. A higher predicted mortality, female patients, and medical patients were associated with a longer duration of stay in the ICU. The log-likelihood χ^2 test indicated that the model was a good fit ($\chi^2 = 54.15$, $p < 0.01$).

Next, the results examining the association between duration of ventilator support and CINC are presented. The sample used in this analysis consisted of 198 survivors who were mechanically ventilated. The results indicated that a higher CCI was associated with significantly more risk of a longer duration on mechanical ventilation (HR = 0.21, 95% CI = 0.06 – 0.71). Among the control variables, only PIM2 was a significant predictor of ventilator days. A higher predicted mortality (PIM2) was associated with significantly more ventilator days (HR = 0.97, 95% CI = 0.95 – 1.00). Other marginally significant predictor of ventilator days was medical case (HR = 0.69, 95% CI = 0.47 – 1.02). The log-likelihood χ^2 test indicated that the model was a good fit ($\chi^2 = 21.88$, $p = 0.02$).

Table 4-13

Proportional Hazard Regression Models of MSICU Patient Outcomes and CINC

	Length of Stay (N = 292)			Ventilator Days (N = 198)		
Parameter	HR	95% CI	p-value	HR	95% CI	p-value
CCI	0.12	[0.05, 0.31]	**<0.001**	0.21	[0.06, 0.71]	**0.01**
PIM2	0.98	[0.96, 0.99]	**0.01**	0.97	[0.95, 1.00]	**0.03**
Age	1.01	[0.99, 1.03]	0.61	0.99	[0.97, 1.01]	0.43
Female (male : ref)	0.74	[0.58, 0.95]	**0.02**	0.86	[0.64, 1.16]	0.32
Diagnosis: respiratory (others: ref)	0.92	[0.69, 1.24]	0.59	0.80	[0.55, 1.16]	0.23
Diagnosis: neurologic	1.03	[0.70, 1.52]	0.90	1.00	[0.60, 1.66]	0.99
Diagnosis: oncologic	1.53	[0.96, 2.44]	0.07	1.58	[0.85, 2.96]	0.15
Diagnosis: genetic	0.67	[0.40, 1.12]	0.13	0.74	[0.42, 1.31]	0.30
Unscheduled admission (scheduled: ref)	1.34	[0.98, 1.83]	0.07	1.35	[0.90, 2.03]	0.15
Medical case (surgical: ref)	0.72	[0.54, 0.96]	**0.03**	0.69	[0.47, 1.02]	0.06

Note. Hazard ratio less than 1 implies a longer length of stay and longer ventilator days compared to baseline. Sensitivity analyses were conducted using negative binomial regression specification. The results remained similar. Abbreviations: HR = Hazard ratio. CI = confidence interval. ref = reference group.

Table 4-14 presents the results of logistic regressions of the association between MSICU patient outcomes – occurrences of adverse events and ICU-acquired infections – and CINC. These regressions were conducted on the full sample of 332 survivors and nonsurvivors.

The results for occurrence of adverse event are first presented. There was no significant association between the occurrences of adverse events and CINC (OR = 2.40, 95% CI = 0.38, 15.18). The only control variables with statistically significant coefficients were length of stay and neurologic diagnosis. A longer length of stay (OR = 1.04, 95% CI = 1.02, 1.05) was associated with a 4% increase in the odds of adverse events. On the other hand, a neurologic diagnosis on admission to the ICU (OR = 0.45, 95% CI = 0.21, 1.00) was associated with a 55% decrease in the odds of adverse events. The likelihood ratio chi-square statistic demonstrated a good model fit ($\chi^2 = 67.96$, $p<0.001$). The Nagelkerke R^2 value of 0.25 showed that the overall model explained 25% of the variation in the explanatory variable (i.e. adverse event).

Next, the results for ICU-acquired infection are presented. There was a positive association between the occurrence of ICU-acquired infection and CINC and this association was marginally significant (OR = 11.92, 95% CI = 0.69 – 206.86). Among the control variables, predicted mortality (PIM2) (OR = 1.05, 95% CI = 1.02 – 1.09) was significantly associated with the occurrence of ICU-acquired infection; this association indicates that patients with higher mortality risk were more likely to experience a ICU-acquired infection. Other control variable that was marginally significant was ICU length of stay. The overall likelihood ratio chi-square test indicated that the model was a good fit (χ^2 = 35.13, $p < 0.001$). The Nagelkerke R^2 value of 0.2 showed that the overall model explained 20% of the variation in the explanatory variable, ICU-acquired infection.

Table 4-14
Logistic Regression Models of MSICU Patient Outcomes and CINC

	Adverse Event (N = 332)			Infection (N = 332)		
Parameter	OR	95% CI	p-value	OR	95% CI	p-value
CCI	2.40	[0.38, 15.18]	0.35	11.92	[0.69, 206.86]	0.09
PIM2	1.03	[1.00, 1.07]	0.06	1.05	[1.02, 1.09]	**0.001**
Age	1.03	[1.00, 1.08]	0.09	0.97	[0.91, 1.04]	0.40
Female (male : ref)	1.43	[0.87, 2.36]	0.16	0.51	[0.22, 1.14]	0.10
Diagnosis: respiratory (others: ref)	0.68	[0.37, 1.24]	0.20	1.08	[0.41, 2.82]	0.88
Diagnosis: neurologic	0.45	[0.21, 1.00]	**0.05**	2.54	[0.82, 7.85]	0.11
Diagnosis: oncologic	0.72	[0.28, 1.81]	0.48	0.29	[0.03, 2.54]	0.26
Diagnosis: genetic	0.82	[0.28, 2.44]	0.73	1.73	[0.50, 6.00]	0.39
Unscheduled admission (scheduled: ref)	1.34	[0.67, 2.67]	0.41	0.60	[0.24, 1.53]	0.29
Medical case (surgical: ref)	0.72	[0.37, 1.40]	0.33	0.56	[0.23, 1.35]	0.20
Length of MSICU stay	1.04	[1.02, 1.05]	**<0.001**	1.01	[1.00, 1.01]	0.10
Constant	0.33		**0.03**	0.07		**0.001**

Note. Odds Ratio value refers to every 1 unit increase in CCI. Abbreviations: OR = Odds ratio. CI = confidence interval. ref = reference group.

Hypothesis 2: The positive impact of continuity in nursing care on patient outcomes will be greater when there is a match between nursing expertise and a patient's risk of mortality.

To test the above hypothesis, an interaction term was introduced into the earlier regression models. In particular, match, a dummy variable equaling one if patients with high mortality risk (PIM2) were assigned to nurses with high expertise, was added as a main effect and an interaction effect with CINC. Since the hypothesis is about the moderating effect of match, the independent variable of interest in the regressions was the interaction term between CINC and match. In other words, the coefficient on the interaction term indicates whether there is a difference in the relationship between patient outcomes and CINC between patients with a match of nurse expertise to mortality risk and those without.

Table 4-15 presents the results of multivariable proportional hazard regression models examining the moderating effect of match on the association between CINC and two patient outcomes – length of stay and ventilator days. The results for length of stay are first presented. The statistically insignificant coefficient on the interaction term between CCI and match suggest that there was no significant difference in the association between CINC and length of stay between the matched and non-matched groups (HR = 9.26, 95% CI = 0.06 – 1340.30). The control variables with statistically significant coefficients were: PIM2, female, unscheduled ICU admissions, and percent of Level II/III nurses. Other control variable that was marginally significant was medical cases. A higher predicted mortality (PIM2) and higher nurse expertise (Level II/III nurses) was significantly associated with a longer duration of stay in the ICU.

Next, the results for ventilator days are presented. The statistically insignificant coefficient on the interaction term between CCI and match suggest that there was no significant difference in the association between CINC and duration of ventilator use between the matched and non-matched groups (HR = 29.64, 95% CI = 0.11 – 8421.69). Of the control variables, only higher predicted mortality was significantly associated with a longer duration of mechanical ventilation. Medical cases were marginally significant with a longer duration of mechanical ventilation.

Table 4-16 presents the results of multivariable logistic regression models examining the moderating effect of match on the association between CINC and two patient outcomes - occurrences of adverse events and MSICU-acquired infections. The results for the occurrences of adverse events are first presented. The statistically insignificant coefficient on the interaction term between CCI and match suggest that there was no significant difference in the association between CINC and the occurrence of adverse event between the matched and non-matched groups (OR = 0.01, 95% CI = 0 – 21.66). The control variables that were statistically significant were neurologic diagnosis and ICU length of stay. A neurologic diagnosis on admission into the ICU was significantly associated with a lower likelihood of experiencing an adverse event. However, a longer length of ICU stay was significantly associated with a higher likelihood of experiencing an adverse event.

Next, the results for ICU-acquired infection are presented. The statistically insignificant coefficient on the interaction term between CCI and match suggest that there was no significant difference in the association between CINC and ICU-acquired infection between the matched and non-matched groups (OR = 0.05, 96% CI = 0 – 141.81). Among the control variables, only higher PIM2 was associated with a higher likelihood of experiencing an ICU-acquired infection. Other control variables that were marginally significant were CCI and ICU length of stay.

Table 4-15

Proportional Hazards Regression Models of Moderating Effect of Match on Relationship Between CINC and MSICU Patient Outcomes

	Length of Stay (N = 292)			Ventilator Days (N = 198)		
Parameter	HR	95% CI	p-value	HR	95% CI	p-value
CCI	0.13	[0.05, 0.35]	**<0.001**	0.17	[0.05, 0.62]	**0.01**
CCI x Match	9.26	[0.06, 1340.30]	0.38	29.64	[0.11, 8421.69]	0.24
PIM2	0.97	[0.95, 0.99]	**0.003**	0.97	[0.95, 1.00]	**0.05**
Age	1.01	[0.99, 1.02]	0.57	0.99	[0.97, 1.02]	0.55
Female (male : ref)	0.76	[0.60, 0.97]	**0.03**	0.89	[0.66, 1.20]	0.45
Diagnosis: respiratory (others: ref)	0.89	[0.66, 1.20]	0.43	0.82	[0.56, 1.19]	0.30
Diagnosis: neurologic	1.08	[0.73, 1.60]	0.69	1.03	[0.61, 1.74]	0.90
Diagnosis: oncologic	1.49	[0.93, 2.38]	0.10	1.63	[0.86, 3.06]	0.13
Diagnosis: genetic	0.70	[0.42, 1.18]	0.18	0.74	[0.41, 1.33]	0.31
Unscheduled admission (scheduled: ref)	1.39	[1.01, 1.91]	**0.04**	1.36	[0.90, 2.06]	0.15
Medical case (surgical: ref)	0.76	[0.57, 1.02]	0.07	0.69	[0.47, 1.02]	0.06
Percent Level II/III nurses	0.99	[0.98, 1.00]	**0.001**	1.00	[0.99, 1.01]	0.98
Match (mismatch: ref)	0.59	[0.08, 4.41]	0.60	0.28	[0.03, 2.89]	0.28

Note. Hazard Ratio less than 1 implies a longer length of stay and longer ventilator days compared to baseline. Hazards Ratio value refers to every 1 unit increase in CCI. Sensitivity analyses were conducted using negative binomial regression specification. The results remained similar. Abbreviations: HR = Hazard ratio. CI = confidence interval. ref = reference group.

Table 4-16
Logistic Regression Models of Moderating Effect of Match on CINC and MSICU Patient Outcomes

	Adverse Event (N = 332)			Infection (N = 332)		
Parameter	OR	95% CI	p-value	OR	95% CI	p-value
CCI	3.07	[0.43, 21.57]	0.26	19.29	[0.81, 458.57]	0.07
CCI x Match	0.01	[0.00, 21.66]	0.22	0.05	[0.00, 141.81]	0.46
PIM2	1.02	[0.98, 1.05]	0.34	1.04	[1.01, 1.08]	**0.01**
Age	1.04	[1.00, 1.08]	0.07	0.97	[0.91, 1.04]	0.41
Female (male : ref)	1.44	[0.87, 2.38]	0.16	0.50	[0.22, 1.15]	0.10
Diagnosis: respiratory (others: ref)	0.66	[0.36, 1.22]	0.18	1.06	[0.40, 2.77]	0.91
Diagnosis: neurologic	0.40	[0.18, 0.89]	**0.03**	2.47	[0.79, 7.74]	0.12
Diagnosis: oncologic	0.70	[0.27, 1.79]	0.45	0.30	[0.03, 2.61]	0.27
Diagnosis: genetic	0.77	[0.25, 2.37]	0.65	1.78	[0.51, 6.25]	0.37
Unscheduled admission (scheduled: ref)	1.36	[0.67, 2.78]	0.40	0.63	[0.25, 1.59]	0.33
Medical case (surgical: ref)	0.69	[0.35, 1.36]	0.28	0.57	[0.24, 1.40]	0.22
MSICU length of stay	1.01	[1.02, 1.05]	<**0.001**	1.01	[1.00, 1.01]	**0.06**
Percent Level II/III nurses	15.66	[0.99, 1.03]	0.29	0.99	[0.96, 1.01]	0.35
Match (mismatch: ref)	0.27	[0.47, 519.71]	0.12	5.64	[0.19, 169.97]	0.32
Constant	3.07		**0.01**	0.07		**0.002**

Note. Odds Ratio value refers to every 1 unit increase in CCI. Abbreviations: OR= Odds ratio. CI = confidence interval. ref = reference group.

Sensitivity Analyses

Sensitivity analyses were conducted to determine the impact of outcomes resulting from changes in the independent variables of the regression models. Based on the primary multivariate regression models, three types of sensitivity analyses were conducted. First, because of the potential nonlinearities in the association between CINC and patient outcomes, additional analyses were conducted with CCI quartiles that were constructed by ranking CCI into four groups. Second, further analyses of length of stay and duration of mechanical ventilation were conducted by using PRISM3 as an alternative to PIM2 to control for patient's mortality risk. The sample used in this analysis consisted of 238 survivors. Third, other patient outcomes such as nurse-sensitive adverse events were examined. Fourth, an across group analyses were conducted to determine if there were any significant associations between CCI and patient outcomes in different group characteristics (e.g. gender, type of patient, and admission status).

Appendix B presents the results of multivariable proportional hazard regression analyses of CCI in quartiles on patient outcomes – length of stay and ventilator days. The control variables that were included in both models were similar to those in the earlier regression models. Patients in CCI quartile 2, 3, and 4(more CINC) had longer length of stay and more ventilator days, compared to patients in CCI quartile 1(less CINC). However, there was no clear trend across the four quartiles.

Appendix C presents the multivariable logistic regression analyses of CCI in quartiles on patient outcomes – occurrence of adverse event and occurrence of ICU-acquired infection. Using the same controls in the earlier regression models, the CCI quartiles were not significantly associated with the occurrence of adverse event. On the other hand, patients in CCI quartile 3 had a higher likelihood of experiencing an ICU-acquired infection compared to patients in CCI quartile 1 (OR = 3.74, 95% CI = 1.07, 13.01).

Appendix D presents a multivariable proportional hazard regression analysis of CINC on patient outcomes (length of stay and ventilator days), controlling for PRISM 3 predicted mortality. The results remained similar to the main analyses even after replacing PIM2 with PRISM3 – more CINC was associated with a longer length of stay in the MSICU and more ventilator days.

Appendix E presents the multivariable logistic regression analyses of nurse-sensitive adverse event on CINC. This table repeats the earlier analyses related to adverse events (tables 4-14 and 4-16). In this case, nurse-sensitive adverse events were considered in the analyses. More CINC was not associated with the occurrence of nurse-sensitive events in the MSICU. However, when the match of nurse expertise to predicted mortality was included as the interaction term, the negative relationship between CINC and the match group was significantly associated with a lesser likelihood of experiencing a nurse-sensitive adverse event compared to the mismatch group (OR = 0.001, 95% CI = 0 – 0.91). Appendix F provides the results of multivariable logistic regression analyses of CCI in terms of quartiles on nurse-sensitive adverse event. The analyses did not yield significant results.

Summary

Overall, the results of the first hypothesis indicated that more CINC was associated with an increased risk of longer ICU length of stay and longer duration of mechanical ventilation. The findings were similar in additional analyses where CINC was examined in terms of quartiles. In further analyses where PRISM3 was used in place of PIM2 to control for mortality risk, the regression results were similar to the main analyses.

In terms of the second hypothesis, there was no moderating effect of a match between nurse expertise and predicted mortality on the relationship between CINC and patient outcomes (length of stay, ventilator days, adverse event, and ICU-acquired infection). Sensitivity analyses were conducted where CCI in groups of quartiles were used in the regression models. The likelihood of experiencing an ICU-acquired infection was higher in CCI quartile 3 than CCI quartile 1. The impact of CINC was further examined on nurse-sensitive adverse events. The results indicated that the odds of CCI in reducing the likelihood of nurse-sensitive adverse events were significantly more for the matched group than the mismatched group.

CHAPTER 5: DISCUSSION

The purpose of this study was to examine the impact of continuity in nursing care (CINC) on patient outcomes in a pediatric ICU. The Synergy Model, which served as the conceptual framework for the current study, states that patient outcomes are optimized when nurses provide care that is based on patient needs (Curley, 1998). CINC might be an important characteristic of a model of care delivery that has the potential to improve patient outcomes because CINC facilitates the development of better knowledge of the patient and a higher quality nurse-patient relationship. Much of the literature was derived from studies conducted primarily in the outpatient setting. In addition, the complexity of defining and measuring CINC has led to varied definitions (Curley & Hickey, 2006; D'Errico & Lewis, 2010; Sparbel & Anderson, 2000). Despite the apparent importance of this concept in patient care, there is no evidence of an association between CINC and improved patient outcomes in the acute care environment.

This study had two research aims. The first was to determine whether there was a positive association between CINC and patient outcomes. A positive association was hypothesized because CINC was expected to result in nurses being more knowledgeable about their patients. The second aim was to determine if a match of nurse expertise and patient acuity had an enhancing effect on the association between CINC and patient outcomes. The hypothesis was that a match between nurse expertise and a patient's predicted mortality would have synergistic effects with CINC, which would lead to a more positive association between CINC and patient outcomes.

This chapter is organized as follows. First, a summary of the main findings are discussed. Second, the strengths and limitations of the study are discussed. Finally, the implications for clinical practice and recommendations for future research are presented.

Summary and Discussion of Findings

This study found that more CINC was associated with worse patient outcomes. Specifically, the results indicated that more CINC was associated with an increased risk of longer length of stay in the MSICU and of longer duration of mechanical ventilation. There were no significant associations between CINC and the occurrence of adverse events and ICU-acquired infection. Similar results were documented in additional analyses where CCI (a measure of CINC) was examined in terms of quartiles instead of as a continuous variable. Hence, the findings were the opposite of the hypothesis that more CINC would lead to better patient outcomes. The findings conflict with what was expected and with those of D'Errico and Lewis (2010) and Benjamin et al., (2001) who found that more CINC was associated with a lower likelihood of complications, and a shorter hospital stay

There are several possible explanations for these findings. More CINC might be associated with worse patient outcomes. Positive associations between CINC and patient outcomes were predicted based on the arguments that more CINC would lead to better knowledge about the patient and to stronger patient-nurse relationships. There are competing arguments that could lead one to expect negative associations. As CINC involves the assignment of fewer different nurses to a single patient, more CINC might lead to higher nurse burnout, which might, in turn, reduce the quality of patient care. Studies have shown that ICU nurses are highly susceptible to burnout and this in turn, could negatively affect patient care (Goode & Rowe, 2001; Gurses, Carayon, & Wall, 2009; Keijsers, Schaufeli, Le Blanc, Zwerts, & Miranda, 1995). In addition to nurse burnout, more continuity in care over a period of time was associated with a reduced sharing of expertise and experience (Gallagher, Geling, & Comite, 2001), which might lead to worse patient outcomes. Finally, an advantage of having different nurses care for the same patient is that it might lead to different perspectives on clinical problems that could improve patient outcomes (Alazri, Neal, & Heywood, 2006; Ali et al., 2011; Infante et al., 2004).

Endogenity could be a problem with the use of secondary data. The data were not specifically collected for this study. In particular, CINC was an endogenous construct in the research setting essentially because the nurses were not randomly assigned to the patient. The assignment of nurses was, to a large extent, decided by the charge nurses based upon their perception of patient needs, nurse competencies and schedule. In addition, expected patient outcomes might have influenced the nurse assignment, especially if the charge nurses believe that CINC was relatively more important for patients with worse outcomes. The use of actual, instead of expected, patient outcomes in the analyses does not mitigate the concern that the documented associations could have arisen because expected patient outcomes can influence nurse assignment. Actual outcomes can proxy for expected outcomes as long as one assumes that the charge nurses are somewhat accurate in their expectations of patient outcomes; in other words, there is likely to be a high correlation between expected patient outcomes and actual patient outcomes.

The consideration of expected patient outcomes in nurse assignment is especially likely to happen at Children's Hospital Boston because the Synergy Model has been adopted in nursing practice. As discussed, this model is centered upon matching of patient needs to nurse competencies to optimize patient outcomes. More CINC might be associated with worse patient outcomes because charge nurses assign more continuous care to more complex patients (e.g., patients with a higher mortality risk and expected worse outcomes). For example, one inference from the positive correlation between CINC and predicted mortality documented in this study is that charge nurses assigned fewer different nurses to sicker patients – they intentionally try to build continuity in care. To the extent that charge nurses also took into account other dimensions of complexity (e.g., expected length of stay, diagnosis) when assigning nurses, the finding that higher CINC was associated with worse patient outcomes may have occurred because the charge nurses were able to assign more continuous nursing care to more complex patients who needed such care. Stated differently, the experienced charge nurse was able to identify something that cannot be defined using traditional risk of mortality measures such as the PIM2 or PRISM3.

In addition to reverse causality, there might also be concerns about biased coefficients due to measurement errors. CCI might not fully capture the concept of CINC because of underlying limitations. CCI was calculated using data on nursing shifts up to a maximum of seven days preceding the date of random data collection. As a result, it only offered a snapshot of CINC for a period of time that might not be reflective of the actual total CINC for the duration of the stay in the MSICU. Further, patients could vary in the need for CINC over their trajectory of illness.

Another limitation is that the optimal CCI is unknown. Hence, it is not possible to determine whether the reported CCI is above or below optimal. Theoretically, for a patient who experiences 7 days (14 shifts), the minimum and maximum CCI is 0 and 0.65, respectively. The former occurs when 14 different nurses take care of a patient over 14 shifts, whereas the latter occurs when 5 full-time nurses care for the patient over 14 shifts. At Children's Hospital Boston, 82% of the nursing staff are full-time nurses who work three shifts per week.

Another limitation of the CCI measure is that it simply captures the distribution of different nurses taking care of a patient. It does not directly capture important attributes of CINC. First, CCI does not measure the actual interactions that take place between the nurse and patient or the quality of the patient-nurse relationship. In particular, CCI does not measure the reciprocal relationship between the patient and the nurse. As described in the Synergy Model, a reciprocal relationship is an important element of developing a therapeutic nurse patient relationship (Curley & Hickey, 2006). Second, CCI does not directly capture the nursing knowledge and patient/family-nurse relationship, as well as the evolution of these characteristics and relationships. Jackson (2005) found through the nurses' narratives that more competent care could be achieved if novice nurses fully understood their patient both at a personal level as well knowing about their care and condition. Studies have shown that the development of a close patient-nurse relationship is likely to occur when the nurse established early contact (Luker et al., 2000; Minick, 1995; Tanner et al., 1993; Heller & Solomon, 2005) and continuously maintained that contact over a long period of time (Luker et al., 2000; Jenny & Logan, 1992).

Finally, having more different nurses care for a patient does not necessarily mean less continuous care if there is consistency of information, good communication, and good handoffs among the different nurses (Hadjistavropoulos et al., 2009; Kalisch et al., 2008; McFetridge et al., 2007; Shaw et al., 2010). In other words, with effective coordination, continuous care that results in greater knowledge of patients and the development of therapeutic relationships can still occur without the need for the same nurse or fewer different nurses taking care of the patient.

The second hypothesis was based on the premise that CINC would be associated with better patient outcomes if there was a match between nurse expertise and mortality risk; in other words, a match enhances the relationship between CINC and patient outcomes. Prior studies generally found that higher nurse expertise was found to be associated with fewer adverse events, such as medication errors, needlestick injuries, and patient falls (Blegen et al., 2001; Clarke et al., 2002; Chang & Mark, 2009; Tibby et al., 2004). This study assumed that patients with higher predicted mortality required more competent nurses, and defined a match to be as an assignment of nurses with higher expertise to patients with a higher predicted mortality.

The results of the main tests indicated no evidence that a match between nurse expertise and predicted mortality moderated the association between CINC and patient outcomes. There are several possible explanations for the lack of significant findings. First, only a small proportion (about 10% of the sample) had a match of nursing expertise to predicted mortality, which could have resulted in a lack of statistical power. Second, a match of nurses with higher expertise to patients with a higher predicted mortality might not accurately reflect all the factors that charge nurses use in practice when matching nurses with patients. For example, other characteristics such as stability, complexity, vulnerability predictably, resiliency, might also have been taken into account in matching nurses to patients (Curley, 1998). More prospective research is needed in order to develop a better understanding of how the matching between nurse characteristics and patient needs is done.

Finally, the lack of significant evidence could also be due to the limitation of the match variable as a proxy of a match between nurse expertise and predicted mortality. There is no consensus on a definitive measure of nurse expertise (Blegen et al., 2001; McHugh & Lake, 2010; Tibby et al., 2004). Further it is unclear how much expertise is needed or optimal in a nursing team. There are some concerns about the ability of PIM2 to predict mortality. The prior literature has documented many limitations and concerns about PIM2 as indicators of mortality risk. Thurkal, Lodha, Irshad, and Arora (2006) found that PIM2 had the tendency to under-predict death in their population, suggesting that population differences such as case-mix between the original populations where the scoring system was developed, could have driven the differences in the performance. Studies have also indicated that PIM2 discriminates poorly between survivors and nonsurvivors with respiratory and cardiac diseases (Qureshi, Ali, & Ahmad, 2007; Tibby et al., 2002). In this study, descriptive statistics comparing PIM2 with actual deaths indicated that PIM2 significantly understated the mortality risk; the median predicted proportion of deaths was 3%, whereas the actual proportion of deaths was 12%. PIM2 scores were used in this study due to incomplete PRISM3 data in the Virtual Pediatric Intensive Care Unit Systems dataset. Clinical studies conducted in the United States typically use PRISM3 because these models were developed using data from the United

States (Briassoulis, Filippou, Hatzi, Papassotiriou, & Hatzis, 2005; Curley et al., 2005; Lacroix et al., 2007; Pollack et al., 1996; Randolph et al., 2002; Rouette et al., 2010; Schultz et al., 2001; Upadhyay, Singhi, Murlidharan, Kaur, & Majumdar, 2005; Vlasselaers et al., 2009). While there are studies that have compared the use of PIM2 and PRISM3 in other countries (Brady et al., 2006; Slater, Shann, Group, Slater, & Shann, 2004), no paper has done a similar comparison in the United States.

The patient outcomes chosen in this study were ICU length of stay, duration of ventilator support, occurrence of adverse events, and ICU-acquired infection. While these are important outcomes that indicate the patient's physical well-being, they might not be the most sensitive metrics of CINC. For example, at Children's Hospital Boston, respiratory therapists determine when to wean patients off mechanical ventilation. Ventilator days may be a better outcome for other units where nurses are involved in the weaning process. For example, there are many units in the United Kingdom in which the nurses play an important role in weaning decisions. There is prior evidence that nurses consider knowledge of the patient is important in the weaning process (Jenny & Logan, 1996). Hence, in addition to the above outcomes, one might want to study patient outcomes such as patients' perception of the ability of the nurses to advocate for them (Curley, 1998; Jenny & Logan, 1992; Tanner et al., 1993), trust and confidence (Attree, 2001), satisfaction of patient/family and being-well-cared-for (Heller & Solomon, 2005). In pediatric nursing, a more sensitive metric for CINC may be parent satisfaction. One might also want to study nurse outcomes such as burnouts, satisfaction, and retention (Jackson, 2005) to develop a more comprehensive understanding of how nurses could be affected by the implementation of CINC.

Various sensitivity analyses were conducted. Almost all the results were similar to those in the main analyses. An exception was the sensitivity analysis that focused on the occurrence of nurse-sensitive adverse events instead of all adverse events. The results of this analysis indicated that when there is a match between nurse expertise and predicted mortality, CCI was associated with lower odds of nurse sensitive adverse event compared to the mismatched group. An implication of this finding was that fewer different experienced nurses created a safer environment. In addition, the inclusion of all adverse events could have added noise to the measure, which, in turn, is likely to reduce statistical power.

Limitations

An important limitation of this study is the use of secondary databases that were not created specifically to study the relationship between CINC and patient outcomes. These databases were constructed for the purposes of quality improvement and/or benchmarking. As a result, there are likely to be significant endogeneity concerns, some of which were discussed in the previous section. The ability to construct variables, including control variables, was limited to the variables that could be constructed using the data already collected in the databases. For instance, while it would be good to control for previous MSICU admission and sedation use in the first 24 hours of ventilator weaning because prior literature has documented that they affect patient outcomes (Odetola, Moler, Deschert, VanDerElzen, & Chenoweth, 2003; Randolph et al., 2002; Ruttimann & Pollack, 1996), the data were not available in the databases.

A further limitation of this study is the generalizability of the findings. First, this study was conducted in a single MSICU. Further, since the Synergy Model was used in this unit, it could lead to associations that might not be relevant to settings where the Synergy model is not used. In this study, the median length of ICU stay of the cohort group was 21 days, which was higher compared to other studies (two to seven days) which included all pediatric ICU patients (Agarwal et al., 2010, Farias et al., 2004, Ruttimann & Pollack, 1996). Similarly, the median duration of mechanical ventilation for survivors and nonsurvivors was 15.5 and 26.5 days, respectively; these contrast with the three and four days documented in all ICU patients in Farias et al., (2004). The rate of adverse events in the MSICU was 1.66 per 100 patient-days, which was lower than that reported by Agarwal et al., (2010) even though the length of stay was longer. The rates of catheter-associated bloodstream infection, ventilator-associated pneumonia, and catheter-associated urinary tract infection, were 8.78 per 1,000 central line days, 1.55 per 1,000 ventilator days, and 5.40 per 1,000 bladder catheter days, respectively. As a comparison, the 2009 National Healthcare Safety Network report of pediatric ICU-acquired infections indicated rates of 3.0 per 1,000 central line days, 1.8 per 1,000 ventilator days, and 4.2 per 1,000 bladder catheter days, respectively (Edwards et al., 2009). The higher rates of catheter-associated bloodstream infection and catheter-associated urinary tract infections in this cohort group are expected because patients with shorter lengths stays were excluded.

Despite the above limitations, the data from the four databases consisted of comprehensive historical information that spanned a period of six years, which would have taken a long time to collect prospectively. The merging of the databases allowed for the unique opportunity to study this topic in a timely manner.

Implications of Findings and Future Research

There was mixed evidence about the association between CINC and patient outcomes. Of the four patient outcomes considered in this study, only two were significantly associated with CINC. In particular, more CINC was associated with an increased risk of longer stay in the MSICU and of longer duration of mechanical ventilation, suggesting that CINC might have negative effects on patient outcomes. One implication of these findings is that CINC should be reduced to improve patient outcomes. However, the conclusion that more CINC leads to negative patient outcomes is likely to be premature in the absence of additional research in this area. Future studies should address the limitations of this study. For example, using an alternative clinical setting that has not been subjected to the influence of the Synergy Model might reduce concerns about reverse causality because, in such a setting, there is likely to be more random assignment of nurses. In addition, further investigation on whether and how charge nurses take expected patient outcomes into account when assigning continuous care is needed.

No clear implications can be drawn from the findings about how a match between nurse expertise and predicted mortality enhances the association between CINC and patient outcomes because of the lack of statistically significant results. Improvements in the construction of the match variable might result in the ability to document significant results. Hence, more research into how charge nurses actually match nurses to patients would be helpful. For instance, future analysis could include conducting focus groups to determine how charge nurses conduct nurse assignments.

To identify the influence of CINC on patient outcomes, prospective designs are needed. Ideally, a randomized control trial design in which patients are randomly assigned to high and low CINC could be used to examine the causal effect of CINC on patient outcomes. Alternatively, one could conduct a case-controlled cohort study to observe the impact of CINC on patient outcomes.

Future research would also benefit from the refinements of some of the variables used in this study. In particular, the development of a comprehensive measure of CINC that captures the degree of the patient-nurse relationship and the extent of knowing the patient would be useful. One option is to measure different attributes of CINC (e.g. degree of patient-nurse relationship) and then rely on factor analysis to group the variables.

A nursing acuity measure based on the Synergy Model would help nurses determine the amount of care that patient require. This is important because mortality risk does not fully capture nursing care needs. Similar to how PIM2 and PRISM3 were constructed, one way is to develop a prediction model of the extent of continuous nursing. In this model, the underlying assumption is that charge nurses are aware of the importance of CINC and their nurse assignments reflect actions to optimize patient outcomes. With the predicted variable being CCI, predictor variables can then be identified using the Synergy Model. CCI can then be regressed on various characteristics of the patients and their family to determine the weighting on each characteristic.

Future studies could also investigate how organizational features affect the relationship between CINC and patient outcomes. For example, Jackson (2005) found through the narratives of novice nurses that more competent care could be achieved if nurses fully understood their patient both at a personal level as well knew about their care and condition. Hence, it would be interesting to investigate whether CINC has a larger impact on patient outcomes in units with more novice nurses. It might also be interesting to explore the impact of nurse staffing on CINC, with the use of travelers as a proxy for the lack of staffing level in the unit (Tibby et al., 2004).

In conclusion, this dissertation provides new information of the relationship between CINC and patient outcomes in an ICU setting, a setting where high quality nursing care is important to achieving good patient outcomes. More CINC was found to be associated with an increased risk of longer MSICU stay and of longer duration of mechanical ventilation. The findings were similar when additional analyses were conducted for CCI in groups of quartiles. The match between nurse expertise and predicted mortality risk did not moderate the association between CINC and patient outcomes. More research is needed to understand the nature of the relationship between CINC and patient outcomes.

Appendix A

Definitions of Three Types of MSICU-Acquired Infections

Site of Infection	Definitions
Catheter-Associated Blood Stream Infection	A laboratory-confirmed bloodstream infection must meet at least 1 of the following criteria: <u>Criteria:</u> Patient has a recognized pathogen cultured from ≥ 1 blood cultures. ***and*** Organism cultured from blood is not related to an infection at another site. Patient has at least 1 of the following signs or symptoms: fever (>38^{o}C), chills, or hypotension. ***and*** Signs and symptoms and positive laboratory results not related to an infection at another site. ***and*** Common skin contaminant (i.e. diphtheroids, Bacillus, viridians group streptococci is cultured from ≥ 2 blood cultures drawn on separate occasions. Patient ≤ 1 year of age has at least 1 of the following signs or symptoms: fever (>38^{o}C, rectal), hypothermia (<37^{o}C rectal), apnea, or bradycardia. ***and*** Signs and symptoms and positive laboratory results not related to an infection at another site. ***and*** Common skin contaminant (i.e. diphtheroids, Bacillus, viridians group streptococci is cultured from ≥ 2 blood cultures drawn on separate occasions.
Ventilator-Associated Pneumonia	Patients ≤ 1 year of age without underlying diseases has ≥ 2 serial x-rays with ONE of the following: - New or progressive and persistent infiltrate. - Consolidation. - Cavitation. - Pneumatoceles in ≤ 1 year old. ***and*** Worsening gas exchange (exchange (e.g. oxygen desaturation (pulse oximetry reading <94%), increasing oxygen requirements, or increase ventilation demand). ***and*** at least THREE of the following signs or symptoms: - Temperature instability with no other recognized cause - Leucopenia (< 4,000 WBC/mm^3) or leukocytosis (≥ 15,000 WBC/mm^3).

- New onset of purulent sputum or change in character in sputum or increase respiratory secretions, or increase in suctioning requirements.
- Apnea, tachypnea, nasal flaring with retraction of chest wall, or grunting.
- Wheezing, rales, or rhonchi.
- Cough.
- Bradycardia (<100 beats/min) or tachycardia (>170 beats/min).

Patients > 1 year or ≤ 12 year of age without underlying diseases has ≥ 1 serial x-rays with ONE of the following:

- New or progressive and persistent infiltrate.
- Consolidation.
- Cavitation.

and

Patients > 1 year or ≤ 12 year of age has at least THREE of the following signs or symptoms:

- Fever (> 38.4^{o}C) with no other recognized cause.
- Leucopenia (< 4,000 WBC/mm^3) or leukocytosis (≥ 15,000 WBC/mm^3).
- New onset of purulent sputum or change in character in sputum or increase respiratory secretions, or increase in suctioning requirements.
- New onset or worsening cough, or dyspnea, apnea, or tachypnea.
- Rales or bronchial breath sounds.
- Worsening gas exchange (e.g. oxygen desaturation (pulse oximetry reading <94%), increasing oxygen requirements, or increase ventilation demand).

Catheter Associated-Urinary Tract Infection

A symptomatic urinary tract infection must meet at least 1 of the following criteria:

Patient has at least 1 of the following signs or symptoms: fever (>38^{o}C), urgency, frequency, dysuria, or suprapubic tenderness

and

Patient has a positive urine culture that is ≥ 105 microorganisms per cubic centimeter of urine with no more than 2 species of microorganisms.

or at least 1 of the following:

- Positive dipstick for leukocyte esterase and/or nitrate.
- Pyuria (specimen with ≥ 10 white blood cell [WBC]/mm^3 or ≥ 3 WBC/high-power field of unspun urine).
- Organisms seen on Gram's stain of unspun urine.
- At least 2 urine cultures with repeated isolation of the same uropathogen (gram-negative bacteria or Staphylococcus saprophyticus) with ≥ 10^2 colonies/mL in non-vioded specimens.
- ≥ 10^5 colonies/mL of a single uropathogen (gram-negative bacteria or S ssaprophyticus) in a patient being treated with an effective antimicrobial agent for a urinary tract infection.
- Physician diagnosis of a urinary tract infection.
- Physician institutes appropriate therapy for a urinary tract infection.

Patient ≤ 1 year of age has at least 1 of the following signs or symptoms with no other recognized cause: fever (>38^{o}C rectal), hypothermia (<37^{o}C rectal), apnea, bradycardia, dysuria, lethargy, vomiting.
and
Patient has a positive urine culture, that is, ≥ 10^5 microorganisms per cubic centimeter of urine with no more than two species of microorganisms.
or at least 1 of the following:

- Positive dipstick for leukocyte esterase and/or nitrate.
- Pyuria (specimen with ≥ 10 white blood cell [WBC]/mm^3 or ≥ 3 WBC/high-power field of unspun urine).
- Organisms seen on Gram's stain of unspun urine.
- At least 2 urine cultures with repeated isolation of the same uropathogen (gram-negative bacteria or Staphylococcus saprophyticus) with ≥ 10^2 colonies/mL in non-vioded specimens.
- ≥ 10^5 colonies/mL of a single uropathogen (gram-negative bacteria or S ssaprophyticus) in a patient being treated with an effective antimicrobial agent for a urinary tract infection.
- Physician diagnosis of a urinary tract infection.
- Physician institutes appropriate therapy for a urinary tract infection.

Note. Definitions obtained from Horan, T. C., Andrus, M., & Dudeck, M. A. (2008). CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. *American Journal of Infection Control*, 36, 309-332.

Appendix B

Proportional Hazard Regression Models of Patient Outcomes and CINC in Quartiles

	Length of Stay (N = 292)			Ventilator Days (N = 198)		
Parameter	HR	95% CI	p-value	HR	95% CI	p-value
CCI quartile 2 (quartile 1: ref)	0.45	[0.32, 0.63]	**<0.001**	0.54	[0.35, 0.85]	**0.01**
CCI quartile 3	0.43	[0.30, 0.62]	**<0.001**	0.59	[0.37, 0.93]	**0.03**
CCI quartile 4	0.46	[0.33, 0.66]	**<0.001**	0.53	[0.33, 0.87]	**0.01**
PIM2	0.98	[0.96, 1.00]	**0.03**	0.97	[0.95, 1.00]	**0.05**
Age	1.01	[0.99, 1.03]	0.30	0.99	[0.97, 1.02]	0.54
Female (male : ref)	0.67	[0.52, 0.86]	**0.002**	0.79	[0.58, 1.07]	0.13
Diagnosis: respiratory (others: ref)	0.89	[0.66, 1.20]	0.44	0.77	[0.53, 1.12]	0.17
Diagnosis: neurologic	1.00	[0.68, 1.48]	1.00	0.99	[0.59, 1.66]	0.97
Diagnosis: oncologic	1.45	[0.91, 2.32]	0.12	1.52	[0.81, 2.85]	0.20
Diagnosis: genetic	0.63	[0.38, 1.05]	0.08	0.70	[0.39, 1.24]	0.22
Unscheduled admission (scheduled: ref)	1.26	[0.91, 1.74]	0.16	1.32	[0.87, 2.00]	0.20
Medical case (surgical: ref)	0.78	[0.58, 1.05]	0.11	0.75	[0.50, 1.12]	0.16

Note. Hazard ratio value refers to every 1 unit increase in CCI. Sensitivity analyses were conducted using negative binomial regressions. The results remained similar. CCI quartile 1 = CCI < 0.29. CCI quartile 2 = 0.29 ≤ CCI < 0.36. CCI quartile 3 = 0.36 ≤ CCI < 0.43. CCI quartile 4 = CCI ≥ 0.43. Abbreviations: HR = Hazard ratio. CI = confidence interval. ref = reference group.

Appendix C

Logistic Regression Models of Patient Outcomes and CINC in Quartiles

	Adverse Event (N = 332)			Infection (N = 332)		
Parameter	OR	95% CI	p-value	OR	95% CI	p-value
CCI quartile 2 (quartile 1: ref)	1.39	[0.71, 2.74]	0.34	2.14	[0.62, 7.33]	0.23
CCI quartile 3	1.48	[0.72, 3.06]	0.29	3.74	[1.07, 13.01]	**0.04**
CCI quartile 4	1.43	[0.69, 2.96]	0.33	1.98	[0.54, 7.23]	0.30
PIM2	1.03	[1.0, 1.070]	0.07	1.05	[1.02, 1.09]	**0.001**
Age	1.03	[0.99, 1.07]	0.10	0.97	[0.91, 1.03]	0.33
Female (male : ref)	1.46	[0.88, 2.41]	0.14	0.52	[0.23, 1.16]	0.11
Diagnosis: respiratory (others: ref)	0.67	[0.37, 1.23]	0.20	1.09	[0.41, 2.89]	0.86
Diagnosis: neurologic	0.45	[0.21, 1.00]	0.05	2.64	[0.85, 8.20]	0.09
Diagnosis: oncologic	0.72	[0.29, 1.83]	0.49	0.30	[0.03, 2.68]	0.28
Diagnosis: genetic	0.82	[0.28, 2.43]	0.72	1.61	[0.46, 5.68]	0.46
Unscheduled admission (scheduled: ref)	1.37	[0.68, 2.74]	0.38	0.63	[0.25, 1.59]	0.33
Medical case (surgical: ref)	0.71	[0.37, 1.38]	0.31	0.50	[0.20, 1.21]	0.12
MSICU length of stay	1.03	[1.02, 1.05]	**<0.001**	1.01	[1.00, 1.01]	0.11
Constant	0.34		**0.02**	0.09		**0.001**

Note. Odds Ratio value refers to every 1 unit increase in CCI.CCI quartile 1 = CCI < 0.29. CCI quartile 2 = 0.29 ≤ CCI < 0.36. CCI quartile 3 = 0.36 ≤ CCI < 0.43. CCI quartile 4 = CCI ≥ 0.43. Abbreviations: OR = Odds ratio. ref = reference group.

Appendix D

Proportional Hazards Regression Models of Patient Outcomes on CINC among Survivors, Adjusting for PRISM3

	Length of Stay (N = 238)			Ventilator Days (N = 166)		
Parameter	HR	95% CI	p-value	HR	95% CI	p-value
CCI	0.10	[0.04, 0.28]	**<0.001**	0.22	[0.06, 0.83]	**0.03**
PRISM3	0.98	[0.97, 0.99]	**<0.001**	0.98	[0.97, 0.99]	**0.003**
Age	1.01	[0.99, 1.03]	0.60	0.99	[0.97, 1.02]	0.44
Female (male : ref)	0.76	[0.58, 0.99]	**0.04**	0.85	[0.61, 1.17]	0.32
Diagnosis: respiratory (others: ref)	0.79	[0.56, 1.11]	0.17	0.71	[0.47, 1.08]	0.11
Diagnosis: neurologic	1.02	[0.67, 1.57]	0.92	1.08	[0.62, 1.88]	0.80
Diagnosis: oncologic	1.99	[1.16, 3.41]	**0.01**	1.99	[1.03, 3.85]	**0.04**
Diagnosis: genetic	0.63	[0.36, 1.10]	0.11	0.81	[0.44, 1.50]	0.50
Unscheduled admission (scheduled: ref)	1.53	[1.06, 2.20]	**0.02**	1.63	[1.04, 2.56]	**0.03**
Medical case (surgical: ref)	0.68	[0.49, 0.94]	**0.02**	0.61	[0.40, 0.93]	**0.02**

Note. Hazard Ratio less than 1 implies a longer length of stay and longer ventilator days compared to baseline. Sensitivity analyses were conducted using negative binomial regressions. The results remained similar. Abbreviations: HR = Hazard ratio. CI = confidence interval. ref = reference group.

Appendix E

Logistic Regression Models of Nurse-Sensitive Adverse Event and CINC

	Nurse-Sensitive Adverse Event (N = 332)					
Parameter	OR	95% CI	p-value	OR	95% CI	p-value
CCI	1.46	[0.26, 8.19]	0.67	2.41	[0.38, 15.20]	0.35
CCI x Match	N/A			0.001	[0.00, 0.91]	**0.05**
PIM2	1.00	[0.98, 1.03]	0.86	0.99	[0.96, 1.02]	0.36
Age	1.02	[0.99, 1.06]	0.26	1.02	[0.99, 1.06]	0.23
Female (male : ref)	1.03	[0.65, 1.64]	0.90	1.00	[0.62, 1.61]	1.00
Diagnosis: respiratory (others: ref)	1.09	[0.62, 1.92]	0.76	1.09	[0.61, 1.93]	0.77
Diagnosis: neurologic	0.80	[0.38, 1.72]	0.57	0.70	[0.32, 1.53]	0.37
Diagnosis: oncologic	2.42	[0.98, 5.98]	0.06	2.39	[0.95, 6.00]	0.06
Diagnosis: genetic	1.70	[0.64, 4.54]	0.29	1.75	[0.64, 4.81]	0.28
Unscheduled admission (scheduled: ref)	1.12	[0.59, 2.13]	0.73	1.13	[0.58, 2.18]	0.72
Medical case (surgical: ref)	0.92	[0.50, 1.68]	0.79	0.88	[0.48, 1.64]	0.70
MSICU length of stay	1.02	[1.01, 1.03]	**<0.001**	1.02	[1.01, 1.03]	**<0.001**
Percent Level II/III nurses	N/A			1.01	[0.99, 1.02]	0.31
Match (mismatch: ref)	N/A			31.74	[1.48, 678.60]	**0.03**
Constant	0.36		**0.03**	0.28		**0.01**

Note. Odds Ratio value refers to every 1 unit increase in CCI. Abbreviations: OR = Odds ratio. ref = reference group. N/A = not applicable.

Appendix F

Logistic regression models of nurse-sensitive adverse event and CINC in quartiles (N = 332)

Parameter	OR	95% CI	p-value
CCI quartile 2 (quartile 1: ref)	0.87	[0.46, 1.64]	0.66
CCI quartile3	0.79	[0.40, 1.57]	0.49
CCI quartile 4	1.23	[0.62, 2.43]	0.55
PIM2	1.00	[0.98, 1.03]	0.90
Age	1.02	[0.99, 1.06]	0.23
Female (male : ref)	1.02	[0.64, 1.64]	0.92
Diagnosis: respiratory (others: ref)	1.08	[0.61, 1.90]	0.79
Diagnosis: neurologic	0.78	[0.37, 1.67]	0.53
Diagnosis: oncologic	2.40	[0.97, 5.94]	0.06
Diagnosis: genetic	1.75	[0.65, 4.66]	0.27
Unscheduled admission (scheduled: ref)	1.08	[0.57, 2.07]	0.81
Medical case (surgical: ref)	0.96	[0.52, 1.77]	0.90
MSICU length of stay	1.02	[1.01, 1.03]	**0.00**
Constant	0.43		**0.04**

Note. Odds Ratio value refers to every 1 unit increase in CCI. Abbreviations: OR = Odds ratio.CI = confidence interval. ref = reference group.

Appendix G

Abbreviations used throughout text

Abbreviation	Full form
CA-BSI	Catheter-associated bloodstream infection
CA-UTI	Catheter-associated urinary tract infection
CCI	Continuity in nursing care index
CI	Confidence interval
CINC	Continuity in nursing care
HR	Hazards ratio
ICU	Intensive care unit
IQR	Interquartile range
MSICU	Medical/surgical intensive care unit
OR	Odds ratio
PIM2	Pediatric index of mortality version 2
PRISM 3	Pediatric risk of mortality version 3
SD	Standard Deviation
VAP	Ventilated-associated pneumonia

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