THE RELATIONSHIPS BETWEEN RAPID RESPONSE TEAM IMPLEMENTATION AND PATIENT HEALTH OUTCOMES

By

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A dissertation submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

WASHINGTON STATE UNIVERSITY
College of Nursing

DECEMBER 2012

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To the Faculty of Washington State University:

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ACKNOWLEDGMENTS

I owe gratitude and much more to many for their intellectual and personal support throughout my research and writing, starting with my committee.

- To my committee chair Dr. Kenn Daratha, for sharing his wisdom, knowledge and dedication to the highest standards, which provided me with the inspiration and motivation necessary to see this research through to the end; Dr. Ruth Bindler, who has been a lifelong mentor and friend, and someone I have greatly admired and respected throughout my career. Dr. Bindler’s honest and patient editing challenged my scholarly writing abilities and enriched this final product; and Drs. Cindy Corbett and John Roll, whose expertise provided me with thoughtful guidance and gentle rigor throughout the course of my research.

- To all of my colleagues and peers in the nursing doctoral program at Washington State University (WSU). I thank you all for your insight, encouragement and comic relief. I would not have made it without you.

- To each of the nursing faculty at WSU College of Nursing who have positively influence this research as well as my life- I thank you.

Finally, I wish to thank my cherished family and friends for their emotional support. Your collective love and encouragement helped to turn the experience of writing my dissertation into a journey of many blessings. To my dear friend Brian, thank you for always helping me to see the ‘light at the end of the tunnel,’ and helping me to find the humor in even the most difficult moments of this journey. To my sons, Cairo and Nico-
thank you for being my biggest fans, and for always believing that mom could finish this journey. It is a wonderful feeling to arrive at the destination.
THE RELATIONSHIPS BETWEEN RAPID RESPONSE TEAM IMPLEMENTATION AND PATIENT HEALTH OUTCOMES

Abstract

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Few studies examining the relationship between implementation of RRTs and health outcomes have been performed in the United States, and no studies have explored the relationships between RRT implementation and patient health outcomes among multiple, geographically contiguous hospitals. The aim of the study was to describe the differences in patient health outcomes before and after the implementation of RRTs within Washington State tertiary hospitals.

Patients hospitalized at 12 tertiary hospitals were assigned to either a pre-RRT (n=258,843) or post-RRT (n=269,015) cohort based on the RRT implementation timeframe of the individual institutions. Study outcomes included cardiac arrests, cardiac arrest deaths, and in-hospital mortality, prolonged length of stay and 30-day hospital readmission. Binary logistic regression controlling for age, sex, payer, comorbidity, previous hospitalization, primary diagnosis category, and length of stay were completed.

A statistically significant improvement was observed in patient health outcomes in the post-RRT cohort when compared to the pre-RRT cohort; in-hospital mortality (OR=0.89; 95% CI=0.86-0.92; p<0.001), cardiac arrest rates (OR=0.88; 95% CI=0.83-0.93; p<0.001), cardiac arrest deaths (OR=0.75; 95% CI=0.64-0.88; p<0.001), prolonged length of stay
(OR=0.89; 95% CI=0.88-0.91; p<0.001), 30-day re-hospitalization (OR=0.97; 95% CI=0.95-0.98; p<0.001).

This is the first study to demonstrate the relationship between implementation of an RRT and improvement in patient health outcomes within multiple, geographically contiguous hospitals.
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DEDICATION

To my late husband, Cairo Antonio Salvatierra MD, your life was an inspiration and your love a gift. Thank you for sharing both with me- and to our two sons; Cairo Alexander and Nicolas Anthony, you are my very best friends.
Rapid response teams (RRTs) represent one of the more visible and significant responses to the realization that some patients who should not die do die during hospitalization (Berwick, Calkins, McCannon, & Hackbarth, 2006; Kohn, Corrigan, & Donaldson, 1999). Rapid response team (RRT) is the name most frequently given to multidisciplinary teams of nurses, respiratory therapists, physicians and other support personnel who can be summoned at the onset of signs of deterioration in a patient’s condition (Bellomo et al., 2003; DeVita et al., 2006). The goal is to bring to the bedside the best available critical care expertise in order to immediately diagnose and address the root causes of a patient’s decline.

A typical RRT in the U.S. includes a critical care registered nurse (RN), a respiratory therapist, and less frequently a physician. Criteria for activating the RRT may include any acute physiological changes in the patient’s condition recognized before the situation becomes life threatening, or an individual at the bedside who has the intuition that something is wrong with the patient can initiate activation. In almost all cases, initiating an RRT call is a nursing function, though in some hospitals family and even patients themselves have the option to initiate an RRT call.

Prior to 2004, in most U.S. hospitals, when nurses at the bedside encountered a deteriorating patient they had three choices: call the patient’s physician, deal with the patient’s decline using institutional resources at hand, or if and when the decline worsened, call a code. While the term nurse is often used to refer to all types of nurses—
registered nurse (RN), licensed vocational nurse (LVN) and license practical nurse (LPN)—the term as used in this document refers to an RN.

There are problems with each of the three options. Physicians can be slow to respond or may be inaccessible, and are often not supportive of calls about the imprecise symptoms and intuitions that are now known to be precursors of impending cardiopulmonary arrest. Most nursing units are not staffed to support care for deteriorating patients. And while nurses often intuitively know that the patient’s decline will be life threatening, codes are reserved for cardiopulmonary arrests (Goldhill, Worthington, & Mulcahy, 1999).

Historically, no option provided the bedside nurse with additional expertise, consultation, and intervention for deteriorating patients. However, options began to change in 2004, when the Institute for Healthcare Improvement (IHI) launched a campaign to save 100,000 lives at its “Annual Forum on Quality Improvement”. In December 2008 this was extended to a campaign to save five million lives (IHI, 2009). Though focused on such obvious but mundane goals as reducing intensive care unit (ICU) pneumonia and surgical infections, the Institute shined a spotlight on the potential role RRTs could play in the process of saving lives. By January 2009, the RRT concept became the 16th National Patient Safety Goal: “Improve recognition and response to changes in a patient’s condition…by selecting a suitable method that enables health care staff members to directly request additional assistance from specially trained individual(s) when the [patient’s] condition appears to be worsening” (The Joint Commission, 2009). While it might seem that identifying patient deterioration early and intervening with the available resources of an RRT would inevitably lead to improved
patient outcomes among people hospitalized in acute care settings, little research on the topic has been completed and research findings have been surprisingly contradictory or inconclusive (DeVita, et al., 2006).

Intervening at the earliest sign of clinical decline appears to be a logical strategy for avoiding cardiopulmonary arrest and improving patient health outcomes. What is logical and what is demonstrably beneficial, however, have proved to be two different things.

**Early Warning Signs and Responses**

The concept of early intervention rests on a foundation of research that began more than two decades ago. Schein et al. (1990) found that for 85% of the patients who experienced in-hospital cardiopulmonary arrests, physicians had documented new complaints or signs of deterioration within the prior eight hours. Franklin et al. (1994) reported that either the nurse or physician had noted signs of deterioration in 99 of 150 patients (60.6 percent) in the six hours prior to a patient’s cardiac arrest—an event only 9 percent survived (Adelstein et al., 2011; Franklin & Mathew, 1994).

The problem of patients developing complications during hospitalization and suffering morbidity and mortality as a consequence helped give rise to the concept of failure to rescue (FTR). Defined as deaths that result from treatable complications—and that are thus preventable—FTR continues to account for 60,000 deaths each year in the Medicare population alone (Silber et al., 2007). Failure to recognize early signs of patient deterioration continues to be cited as a primary cause of failure to rescue (Clarke & Aiken, 2003). Quality improvement initiatives and health services research focus on improving health care delivery in U.S. hospitals in an effort to minimize devastating consequences.
Cardiopulmonary arrests are an important measure of quality within U.S. hospitals. Approximately 200,000 treated cardiopulmonary arrests occur annually. These events are associated with poor survival rates (Merchant et al., 2011). Cardiopulmonary resuscitation rates have not changed in nearly 30 years and healthcare costs associated with cardiopulmonary resuscitation are estimated to be $1 billion annually (Beaumont, Luettel, & Thomson, 2008; Bristow et al., 2000).

Despite the improvements and technology associated with providing advanced cardiac life support (ACLS), survival-to-hospital-discharge in patients who experience an in-hospital cardiac arrest has not improved in more than 40 years (Beaumont, et al., 2008; Franklin & Mathew, 1994; Niskanen, Reinikainen, & Kurola, 2007).

There is ample evidence that these events are signaled by acute signs of deterioration as much as 20 hours prior to a cardiopulmonary arrest (Bellomo, et al., 2003; Chan, Jain, Nallmoothu, Berg, & Sasson, 2010; Schein, Hazday, & Pena, 1990; Steen, 2010). This evidence, coupled with knowledge of how poor recovery is for those who proceed to cardiopulmonary arrest, adds urgency to the search for a successful intervention strategy and may account in substantial part for the eager acceptance of rapid response teams.

**RRTs in the U.S. and Elsewhere**

Motivated by studies showing distressingly poor outcomes for those experiencing cardiopulmonary arrest, and armed with the knowledge that there are premonitory signs prior to the cardiopulmonary arrest, the first rapid response system (RRS) was launched in Australia in the early 1990s, where it was known as a medical emergency team (MET) (Bellomo, et al., 2003). The MET was introduced as an intensive-care-based, hospital-
wide preventive approach proposed to intervene before the patient arrested (Bellomo, et al., 2003).

Translating the results of earlier MET studies to widespread adoption of RRTs in the U.S. was made with surprising rapidity and minimal evidence. Today, half of the United States hospitals have implemented RRTs in one form or another, yet research studies demonstrating the effectiveness of RRTs in U.S. hospitals remain few in number. Regardless of whether previous studies supported or rebutted the employment of RRTs, their results often suffered from major methodological flaws, contained significant data limitations or may not be applicable to care delivery in U.S. hospitals.

The pace of innovation and adoption of RRTs within the U.S. was stunning, given that RRT adoption was primarily based on a small handful of uncontrolled studies, most of which were performed in other countries with differing medical delivery models. Since the Institute for Health Improvement’s 2004 initiative, the intuitive appeal of RRTs has apparently been overwhelming. During this time there were essentially no dissenting voices.

One of the greatest assenting voices has been that of nurses, who recognized that RRTs were a vital and necessary resource whether or not outcomes such as cardiopulmonary arrest were significantly improved (Shapiro, Donaldson, & Scott, 2010). In the hospital setting, RRTs provide a critically needed intermediate level of consultation and assistance for the nurse—situated below a code but above being left on one’s own.
Increasing Patient Acuity and RRTs

The sharply increased acuity of patients has accelerated the need for medical intervention augmentation. Illness severity among hospitalized patients has increased significantly over the past 20 years (Mark, Salyer, & Harless, 2002).

Increased illness severity is the result of many factors, including an aging population, reimbursement policies, more sophisticated outpatient treatment options, advanced treatment for acute illnesses, and improved identification of multiple comorbidities (DeVol & Bedroussian, 2007; Stanton & Rutherford, 2004). Increased patient acuity places greater burdens on existing nursing resources to provide quality patient care, and fiscal realities dictate that additional resources are unlikely to be widely available.

Despite the increase in patient acuity, the majority of hospitalized patients still receive nursing care on general medical and surgical wards. Only a small percentage of the highest acuity patients are directly admitted to ICUs. Nurse-to-patient ratios are often established based on census rather than illness acuity (Aiken, Clarke, Sloane, Lake, & Cheney, 2008; Buerhaus & Needleman, 2000). Rising patient acuities combined with constrained nursing resources have been recognized as contributing factors in failure to recognize or rescue deteriorating patients.

RRTs: A Nursing Function

Initiation of an RRT call is almost exclusively a nursing function. It is the nursing team that is at the bedside more than any other member of the healthcare team, continuously making sequential observations of measurable vital signs as well as the important yet hard-to-define sense of a patient’s overall well being. There is no official
diagnosis, medical or nursing, for “this patient doesn’t seem right,” but nurses everywhere know the condition exists and is often detectable (Cioffi, 2000; Shapiro, et al., 2010).

A nurse’s ability to recognize patient deterioration frequently includes both objective metrics and subjective perceptions. Recognizing patient deterioration without having the resources to effectively address patient decline is futile and frustrating. Nurses are the key link in a chain of care that results in deployment of an RRT.

**Problem Statement**

Few studies examining the relationship between implementation of RRTs and health outcomes have been performed in the United States, and no studies have explored the relationships between RRT implementation and patient health outcomes among multiple, geographically contiguous hospitals. The aim of this evaluation is to explore differences in health outcomes before and after the implementation of RRTs within tertiary hospitals in Washington State.

The goal of the current study is to examine the relationship between implementation of an RRTs and measurable impacts on specific patient health outcomes. The findings of this study will fill a critical knowledge gap, and confirm or refute the effectiveness of RRTs and their relationship to improved patient health outcomes.
Research Aims

1. Describe the differences in in-hospital mortality rates before and after the implementation of rapid response teams within tertiary hospitals in Washington State.

2. Describe the differences in cardiac arrest rates before and after the implementation of rapid response teams within tertiary hospitals in Washington State.

3. Describe the differences in cardiac arrests death rates before and after the implementation of rapid response teams within tertiary hospitals in Washington State.

4. Describe the differences in prolonged length of stay rates before and after the implementation of rapid response teams within tertiary hospitals in Washington State.

5. Describe the differences in 30-day rehospitalization rates before and after the implementation of rapid response teams within tertiary hospitals in Washington State.

6. Describe the RRT implementation plan, team membership and calling criteria among the selected hospitals.

Research Question

Are there differences in patient health outcomes (i.e. rates of acute cardiac arrests, cardiac arrest deaths, in-hospital mortality, prolonged length of stay and 30-day hospital...
readmission) before and after the implementation of RRTs within Washington State tertiary hospitals?

**Research Hypothesis**

There are improved differences in patient health outcomes (i.e. rates of acute cardiac arrests, cardiac arrest deaths, in-hospital mortality, prolonged length of stay and 30-day hospital readmission) in the post-RRT implementation period when compared with the pre-RRT implementation period within Washington State tertiary hospitals.
CHAPTER 2
LITERATURE REVIEW

The Contextualization of Rapid Response Teams

Demands are being placed on U.S. hospitals to achieve improved outcomes for a population of ever-higher-acuity patients, and to do so with fewer fiscal, physical, and human resources (Buerhaus & Needleman, 2000; Stolldorf, 2008). This research will examine the role of rapid response teams (RRTs) in the context of this demand. The goal of RRT implementation is to improve the outcome, reduce the risk of extending hospital length of stay (LOS) or unnecessary intensive care unit (ICU) admissions, cardiac arrests or mortality, and thus provide better patient care while reducing costs.

The delivery of hospital-based healthcare in America is undergoing rapid transformation. This transformation is being driven by many factors, including technology, location of care delivery, healthcare financing, cost of hospital-based care, steadily increasing demands on nursing resources, increasing acuity of hospitalized patients, and healthcare reform legislation (Bae, 2011; Lynk & Longley, 2002).

Dramatic advances in technology and techniques permit what were once hospital-only procedures to be safely and more efficiently performed in urgent care centers, same-day surgical centers and physicians’ offices. At the same time, technological advances divert from hospitals a significant flow of patients needing less-intensive skilled nursing care. The result is an overall increase in hospitalized patients who require more intensive skilled nursing care (Bae, 2011; Jennings, 2008).
Cost and insurance reimbursement are ubiquitous parts of the healthcare formula. Demands from both private and public insurers to spend less money and deliver better results include an increased insistence on the use of evidence-based protocols for diagnosing and treating diseases as diverse as pneumonia, sepsis, myocardial infarctions (MIs) and cerebrovascular accidents (CVAs). The U.S. now spends more money per capita for healthcare than any other country in the world (Figure 1), yet our outcomes are by many measures far from the best (Keehan et al., 2011; P. W. Stone et al., 2007).

![Figure 1. Total health expenditure per capita, U.S. and selected countries, 2008](image)


The focus of hospitalization is changing because the nature of hospital care is shifting. Hospitals increasingly provide a place for performing only the most serious surgical procedures, treating trauma and other emergencies, dealing with severe, multiple comorbid illnesses, and providing end-of-life care (Stanton & Rutherford, 2004). Patients
are being discharged from the hospital far earlier in their recovery periods, in part to satisfy reimbursement requirements. The increased complexity of hospitalized patients, combined with early discharges, is causing an upward shift in acuity level in hospitals nationwide (DeVol & Bedroussian, 2007).

Patient acuity level in U.S. hospitals is likely to continue rising. Today’s U.S. population is aging at an increasing rate. The first of the nearly 75 million “baby boomers” are just beginning to reach retirement age, representing the largest age-related demographic in the healthcare system (Reither, Olshansky, & Yang, 2011). As this population ages, both the number and percentage of older adults in the U.S. that are living with chronic conditions will begin to accelerate rapidly.

The relationship between aging and overall healthcare care utilization is complex, but generally as people age they tend to use more hospital services (Stolldorf, 2008). Rates of hospitalization for patients aged 65 years and over have remained considerably higher than that of younger age groups for the past 40 years (Hall, De Frances, Williams, Golosinskiy, & Schwartzman, 2010). In 2007, those aged 65 years and over accounted for 37 percent of all hospital discharges, even though they represent just 13 percent of the U.S. population (Hall, et al., 2010).

Another factor influencing the acuity level of patients in U.S. hospitals is an increase in chronic illness. An estimated 125 million U.S. citizens suffer from at least one chronic disease and 60 million suffer from comorbid conditions (DeVol & Bedroussian, 2007). Chronic diseases also include diseases of lifestyle such as obesity, cardiovascular disease and cancer. Acute exacerbations of comorbid conditions often accompany chronic disease, leading to an increase in hospitalizations. The risk of adverse events (AE) within
the hospital setting increases for patients with multiple illnesses. Hospitals are estimated to be responsible for the unnecessary deaths of between 44,000 and 98,000 people annually (Berwick, et al., 2006; DeVol & Bedroussian, 2007).

Nursing has not been exempt from the sea change resulting from an increase in the average acuity of hospitalized patients. In fact, despite expressed concern over the evolving nursing crisis from several organizations including the American Hospital Association (AHA), The Joint Commission (TJC) and the Institute of Medicine (IOM), nursing has in many ways borne the brunt of the changes and challenges in caring for increasingly complex and ill patients in the face of a nursing shortage.

Hospitals have repeatedly attempted to reduce costs by restructuring nurse staffing levels, often substituting unlicensed personnel for RNs and decreasing hospital length of stay (LOS) (Buerhaus & Needleman, 2000). Often, strategies aimed at restructuring and decreasing LOS ultimately diminish the time that nurses have to provide direct patient care, despite higher patient acuity. In fact, nurse-staffing levels have changed very little change in the last several years. Most changes for the better were state-mandated and then in only a few states (Aiken, et al., 2008).

Nursing roles have increased to include the roles of technology manager, case manager, and caregiver (Aiken, et al., 2008; Bae, 2011). There is a recognized link between nurse-to-patient ratios and patient outcomes in the hospital setting, yet nursing resources continue to be constrained at every level (Aiken, et al., 2008; Butler et al., 2011; DeVol & Bedroussian, 2007).

The contextual quadrangle of demands under which RRTs will be considered involves the interface of the increasing acuity of hospitalized patients, the steadily
increasing demands on nursing resources, the challenges in best utilizing technology to improve outcomes and the continued issues associated with financing the exorbitant costs of healthcare in the U.S. RRTs represent a logical response to this quadrangle of demands. As average inpatient age and acuity levels increase, a higher percentage of hospitalized patients experience life-threatening deterioration sometime during their stay. The impetus for the RRT concept was the commonsense notion that earlier recognition of a deteriorating patient’s situation, combined with a rapid, multidisciplinary response and intervention at an the earliest possible time, would produce better outcomes at a lower cost by avoiding costly, prolonged, more intensive, and in many cases futile treatment (Bellomo, et al., 2003; Bristow, et al., 2000; Goldhill, et al., 1999).

**The Conceptual Framework**

The rise of RRTs marked a shift in how hospital care on medical/surgical wards was delivered to patients who deteriorate and are at risk for developing an adverse event. As researchers strive to understand the effectiveness of interventions such as RRTs, there is a need for a reasoned conceptual framework that incorporates the dimensions and causal linkages between the structural attributes of the settings in which care occurs, the processes of care, and the outcomes of that care. RRTs as an intervention represent modifications in care process within the hospital structure with the ultimate goal of improving patient outcomes. Thus, Donabedian’s well-known structure-process-outcome model is a suitable fit for examining RRTs within the hospital setting (Donabedian, 1980; Stolldorf, 2008).
The constructs and assumptions of Donabedian's model posit a theoretical recursive model that explores outcomes as a result of structure and process. Donabedian's quality paradigm has been universally accepted and used as the basis for much of the work addressing quality and outcomes in patient safety research (Figure 2) (Battles & Lilford, 2003; Hammermeister, Shroyer, Sethi, & Grover, 1995; Stolldorf, 2008).

Recognizing that not all adverse outcomes can be blamed on either structure or process, Coyle and Battles enhanced Donabedian’s model to include patient condition (i.e. comorbid conditions and patient acuity) prior to entering the healthcare system, giving rise to the important dimension of antecedent conditions that can affect adverse outcomes (Battles & Lilford, 2003). Embedding the dimension of process within the dimension of structure, changes the relationship from a linear type to one that is more interrelated (Battles & Lilford, 2003).
This revised model presents an understanding of quality in a non-linear and more complex perspective, implying that antecedent conditions confound the structure and process that influence outcomes (Figure 3) (Battles & Lilford, 2003). It is this augmented model that served as the framework for the current study.

![Figure 3. Patient Safety Management Model (Battles & Lilford, 2003)](image)

The *structure* of U.S. hospitals has been characterized as complex, with fragmented systems and inherent risks (born of system and human failures), leading to adverse events (Jonas, Goldsteen, & Goldsteen, 2007). According to Donabedian (P. W. Stone, et al., 2007), the structure of care includes the physical facility and operations related to the array of programs that provide care. The definition of structure can also be applied to the RRT as it relates to team membership and skill set.

According to the model, *process* describes how structure is put into practice or the method by which healthcare care is provided (skill mix of the team and specific interventions). Defining process is a bit more ambiguous, in part because it is concerned with the characteristics of the care provided, including appropriateness, adequacy, technical competence, coordination, and continuity (P. W. Stone, et al., 2007).
Under the selected theoretical framework, RRTs are groups of critical care experts who come to the bedside of a potentially deteriorating patient with the goal of intervening and preventing adverse events (Bellomo, et al., 2003; Bristow, et al., 2000). RRTs signify a modification in the process of how care is delivered to deteriorating patients at risk for developing an adverse event within the structure of the hospital. Within U.S. hospitals, the multidisciplinary RRTs are primarily nurse-led teams with physical support from respiratory therapists, and some type of physician consultation. Outcome refers to the results of the health care provided (both positive and adverse) such as mortality, length of stay and readmission, which might be influenced by the processes in place.

The Patient Safety Management Model expands upon the foundation of Donnabedian’s Structure-Process-Outcome model and includes several essential revisions. First, the process of care has been moved from a linear relationship to one that rests within the structure where it occurs (Battles & Lilford, 2003). Again, the most significant modification was the inclusion of patient conditions (including both comorbid conditions and patient acuity), which the researchers labeled as antecedent conditions (Battles & Lilford, 2003). This adaptation directs that processes be evaluated in agreement with the outcomes they generate, and has considerable applicability to RRTs when examining their effectiveness on improved patient outcomes.

The model further highlights the view that while improved patient outcomes should be the gold standard of measurement in patient safety research, interpreting these outcomes as a result of structure and process without including antecedent conditions may produce findings that will not accurately reflect variations in results (Battles & Lilford, 2003). Antecedent conditions such as comorbid conditions and pre-hospital
acuity have the potential to strongly influence care process and outcomes. This model is in line with the recent change in thinking about adverse outcomes (AEs), which has shifted from blaming individuals for errors to looking beyond the person to the system. Systems should provide controls that serve as a safety net for mistake avoidance (de Vries, Ramrattan, Smorenburg, Gouma, & Boermeester, 2008).

Using the Patient Safety Management Model to guide this approach, efforts to eliminate AEs should be directed toward systems and team-based care delivery. This distinction is important, because AEs are rarely the result of individual failures. They are systems failures that are multifactorial in regard to the patient’s antecedent characteristics, structural shortcomings, or ineffective processes.

**Rapid Response Teams**

*Origin and history of rapid response teams.* Rapid Response Systems (RRS) were first introduced in Australia in the 1990s as a strategy to improve patient outcomes outside of the intensive care unit (ICU) through earlier recognition of patient deterioration (Hillman et al., 2005). Known as medical emergency teams (METs), these physician-led teams sought to deliver rapid medical care to patients experiencing signs of unanticipated clinical deterioration. The impetus for initiation of this team was based on research indicating that unexpected clinical deterioration and failure to rescue is often the precursor of adverse events (AEs) including cardiac arrest and death (Offner, Heit, & Roberts, 2007). The purpose of the MET was not to replace the well-established code team; rather, the purpose was to provide immediate care to patients on the medical/surgical ward who showed signs of physiological instability or clinical deterioration, with the goal of preventing rather than treating cardiopulmonary arrest.
The RRS has been described as an all-inclusive system designed to rescue patients who suddenly become critically ill and are at risk for an AE (Hillman, et al., 2005). The broad overarching term rapid response system describes a system comprised of four components: afferent; efferent; process improvement; and administration (DeVita, et al., 2006). The afferent limb refers to how the RRS is activated, while the efferent limb refers to how the RRS responds. The process improvement and administrative components deal primarily with system costs and evaluation (DeVita, et al., 2006).

Multiple models of the efferent limb exist under a variety of names throughout the world including critical care response team (CCRT) in Canada; medical emergency team (MET) in Australia; critical care outreach team (CCOT) or patient-at-risk team (PART) in the United Kingdom (UK); and rapid response team (RRT) in the U.S. (Butner, 2011; DeVita, et al., 2006). While these terms are often used interchangeably in the literature, the teams do not always function similarly (Goldhill, et al., 1999; Jolley, Bendyk, Holaday, Lombardozzi, & Harmon, 2007). Each of these terms describes a single concept and there are varying components and competencies that comprise the individual teams (Buist & Shearer, 2010; DeVita, et al., 2006).

The primary focus of this dissertation is to examine the effectiveness of nurse-led RRTs on patient outcomes in the acute care setting. Within the U.S., rapid response teams are recognized primarily as a nursing intervention with the opportunity to change the culture of hospitals by giving nurses the autonomy to make assessment and diagnostic decisions that will improve patient care (Jenkins & Lindsey, 2010). Nurses are in a unique position to recognize the early warning signs of patient deterioration because they are at the bedside more than any other care provider in the acute care setting (Beaumont,
et al., 2008). The quality and quantity of nurse staffing have been associated with patient outcomes (Aiken, et al., 2008; Pappas, 2008), further highlighting the importance of the nurse-patient relationship in an acute crisis situation.

Decision making in nursing practice is a complex, multifaceted process based on assessment of the situation while being simultaneously dependent on the nurses’ knowledge, skills and available resources (Seymour, Kinn, & Sutherland, 2003). Until the implementation of the RRT, no process within the hospital setting provided nurses with the institutional resources to intervene before a critical adverse event occurred (Beaumont, et al., 2008; Chan et al., 2008; DeVita, et al., 2006). The RRT as a nurse-led intervention has the capability of providing a viable strategy whereby nurses can access critical resources at the first sign of patient deterioration.

No literature exists to explain why RRTs came to be predominantly nurse-led teams in the U.S., though one obvious possibility is that while every hospital has extensive nurse staff 24 hours a day, the level of house physician staffing varies widely depending on size and type of hospital as well as the time of day. The nurse-led nature of RRTs in the U.S. may also be a function of the fact that early RRTs were nurse-centric, and later efforts simply emulated what was put forward as the model for composition of an RRT. Other contributing factors may be reimbursement issues, liability concerns on the part of non-staff physicians, and sufficient depth to permit adequate coverage if a designated person is on an RRT call.

**Rapid response team composition.** The composition of RRSs and the number of professionals on teams have varied widely from organization to organization. Within the U.S., RRSs are most commonly nurse-led teams referred to as RRTs (Jenkins & Lindsey,
An RRT is predominantly comprised of a group of clinical experts from various disciplines capable of ICU-level care including rapid assessment and basic stabilization (i.e., intravenous line insertion with fluid resuscitation and airway management). This skilled team also provides rapid triage so that patients are expeditiously transferred to a more intensive care unit when appropriate (DeVita, et al., 2006; Thomas, VanOyen, Rasmussen, Dodd, & Whildin, 2007).

The most frequent RRT makeup is an experienced ICU nurse, a respiratory therapist, and other support staff. The lack of standardization in defining the structure, composition and skill set of RRTs is evident in many studies but is beyond the scope of this research. This nurse-led RRT structure has many secondary benefits including being less expensive than its physician-led MET counterpart and less intimidating for beside nursing staff to activate (Donaldson, Shapiro, Scott, Foley, & Spetz, 2009). However, opponents of this structure say that nurse-led teams may compromise immediate definitive treatment including advanced airway management and central venous access placement (Chan, et al., 2010). The most accessible RRTs are prepared to respond quickly 24 hours a day, 7 days a week to deteriorating patient conditions at the request of hospital staff or (in some hospitals) family members.

RRTs may also be referred to as a freestanding RRT, which describes a nurse-led team whose primary responsibility is to answer RRT calls that meet the institution’s calling criteria. Still other RRT models employ ICU nurses who already have a regular patient assignment from which they are called away when they answer RRT calls. Regardless of the model, the RRT is generally activated in a manner similar to that of a code team.
Activation triggers and rapid response team “dose.” One of the key characteristics of the RRS is that the team is summoned to the bedside when a patient meets the calling criteria (DeVita, et al., 2006; Jenkins & Lindsey, 2010). Each hospital generally has a set of warning sign criteria that signify a patient’s condition is deteriorating, and these criteria are used to trigger summoning of the RRT. The goal is to treat these warning signs early so that the patient’s outcome may be improved.

Evidence supports the concept of an RRS syndrome or several RRS syndromes (the most common conditions that triggering the RRS) (D. Jones et al., 2006). The most common physiological triggers include deviations in basic vital signs of respiration, pulse, oxygenation and mental function substantiated as hypoxia, hypotension, tachycardia, and altered consciousness (D. Jones, et al., 2006). Intuition or concern by staff or a family member is also a common trigger and frequent reason for activation of the RRT.

Despite each hospital’s standardized assessment for identifying signs of deterioration, inter-institutional standardization in this area is lacking (DeVita, et al., 2006). The relatively new concept of “dose” within the context of the RRT domain implies that the greater the number of RRT calls (per 1000 patients) within a hospital, the better the outcomes associated with RRT. In a post hoc analysis of data from a cluster randomized controlled trial examining the relationship between the proportion of rapid response system team calls that were early emergency team calls (defined as calls not associated with cardiac arrest or death), for every 10% increase in the proportion of early emergency team calls there was a 2.0 person reduction per 10,000 admissions in unexpected cardiac arrests (D. Jones, DeVita, & Bellomo, 2011).
Barriers to activation of rapid response teams. An RRT is useless if not summoned, and the rate at which nurses summon the RRT has been shown to vary considerably among hospitals. A number of barrier factors have been cited as affecting nurses’ willingness to summon the RRT, including expertise, support by medical and nursing staff, nurses’ familiarity with and advocacy for the patients, and the nurses’ workloads (Cioffi, 2000; Galhotra et al., 2006; L. Jones, King, & Wilson, 2009; Salamonson, van Heere, Everett, & Davidson, 2006). The one consistently substantial barrier to implementation and utilization is lack of education about the criteria and the team.

In this context, education is both knowledge transmission and marketing. Both functions are essential to successful buy-in and consistent utilization of the RRT. Rapid response team education has been considered as both encouraging and inhibiting (L. Jones, et al., 2009). Results from several studies suggested that positively enforced education about the RRT not only improved the recognition of patient deterioration, but also promoted a positive culture change within the organization (Galhotra, et al., 2006; L. Jones, et al., 2009; Shapiro, et al., 2010).

A lack of education, on the other hand, has been associated with unclear roles for the staff nurse, lack of awareness of calling criteria, lack of confidence in performance and reduced activation of the RRT (Cioffi, 2000; L. Jones, et al., 2009). Results from other studies have shown a positive association between years of experience, recognition of deterioration and RRT activation (Salamonson, et al., 2006). Barriers to RRT activation may have important implications for patient safety, as the complexity and acuity of inpatient care on medical/surgical wards continue to increase.
**Adverse Events and Health Outcomes**

Adverse events include acute cardiac arrest, increased length of stay, unplanned admission to the intensive care unit (ICU), and in-hospital mortality. At least half of the adverse events are preventable (Chen, Bellomo, Flabouris, Hillman, & Finfer, 2009). The potential to prevent adverse events and their sequelae was the prime mover behind rapid implementation of RRTs in the U.S.

Although discrepancies exist regarding the prevalence of AEs, consensus suggests that AEs present a serious problem facing the healthcare system today and considerable attention is being devoted to finding solutions that improve patient safety (de Vries, et al., 2008). In 2004, the Institute for Health Improvement’s voice was a voice in the wilderness. Today, it is part of a chorus that includes patients, insurers, policy institutes, and hospitals themselves.

Beyond reporting AEs, studies have begun to identify specific patterns or patient characteristics that possibly contribute to the incidence of *preventable* adverse events (PAEs) (Lessing, Schmitz, Albers, & Schrappe, 2010). To date, the most widely cited estimates of AEs and health outcomes are based on retrospective studies that utilized chart reviews (Christiaans-Dingelhoff et al., 2011; de Vries, et al., 2008). Although a time consuming process, the chart review method is believed to offer the most useful strategy currently available for estimating the rate of AEs among hospitalized patients. However, a well-matched cohort study where the comparison group is very closely matched with the intervention group is another valuable strategy for examining health outcomes.
Most descriptions of AEs use terminology derived from the IOM. The IOM describes AEs as an unintended injury that results in temporary or permanent disability, death, or prolonged hospital stay and is caused by healthcare management rather than by the patient’s underlying disease process. AEs are usually the result of overlapping human and systems failures such as fatigue and lack of knowledge or improper use of technology.

Research suggests that nearly 50% of all AEs are preventable (de Vries, et al., 2008). Further differentiation of AEs includes preventable adverse effects (PAEs); those caused by failure(s) to follow recognized, evidence-based best practices or guidelines at the individual and/or system level and thus avoidable (Attarian, 2008). PAEs might be caused by misdiagnosis, delay in diagnosis or failure to follow up (Attarian, 2008; Berwick, et al., 2006).

Failure to rescue (FTR) is a term that has recently been used to identify patients who die in the hospital following an AE resulting from an avoidable complication (Ashcroft, 2004; L. Jones, et al., 2009). FTR has also become a measure of the overall performance of a hospital with regard to the staff’s ability to recognize clinical instability or deterioration (Schmid, Hoffman, Happ, Wolf, & DeVita, 2007). Problems arise when changes in these physiologic indicators are not recognized, not corroborated or are mismanaged (Ashcroft, 2004).

Excuses for failing to rescue include reports of suboptimal care, lack of clinical expertise and a lack of resources or an unsupportive work environment (Stanton & Rutherford, 2004). Many AEs appear to be the result of failure to rescue, whether medical care was delayed, insufficient or incorrect (D. Jones, et al., 2011). Regardless of the reason for failing to rescue, if patient deterioration is met with failure to rescue by the
hospital staff, and the patient deteriorates to cardiac arrest, his or her chances of surviving to discharge are only 14.7% (Hillman, et al., 2005).

Detection of signs and symptoms of PAEs is essential to averting resultant complications (Beaumont, et al., 2008). In many instances, premonitory signs or symptoms have been present hours prior to an acute AE (Chen, Bellomo, Hillman, Flabouris, & Finfer, 2010; D. Jones et al., 2005). Yet no national or wider ranging standardization of criteria employed to identify early signs of deterioration exists. The criteria that do exist uniformly incorporate objective signs including any acute changes in the patient’s vital signs or cognitive status, thus implying respiratory, neurological or cardiac deterioration.

Many hospitals have adopted their own scoring system to assist staff with early recognition of a patient’s failing condition. In the United Kingdom (UK), RRSs utilize calling criteria based on the Modified Early Warning Score System (MEWS) (DeVita, et al., 2006). MEWS provides a summary score based on the individual vital signs scores. In most Australian and several U.S. hospitals, any single subjective or objective criterion is appropriate for activating the team. No studies to date have compared the usefulness of the various scoring criteria in terms of RRT activation or outcomes. Criteria for summoning the RRT may also include intuitive feelings of a staff member, family member, or even the patient that something is not right and that there is a downward trajectory in the patient’s overall status (Chen, et al., 2010). RRTs represent the healthcare system’s organized response to the increasing severity of illness in the acute care setting by providing rapid and appropriate interventions for patients showing signs of impending deterioration.
State of the Science

The major measures of RRT effectiveness used in most studies have included (but not been limited to) reductions of in-hospital cardiopulmonary arrest, hospital mortality, and unplanned intensive care unit admissions and length of stay (LOS).

In-hospital cardiopulmonary arrest. Evidence demonstrates that RRTs have been inconsistent in decreasing rates of cardiopulmonary arrests in the hospital setting. While RRT implementation is associated with reductions in cardiac arrest rates (Bellomo, et al., 2003; Buist et al., 2002; Dacey et al., 2007; DeVita, 2004), this evidence is derived primarily from early observational studies.

In the most recent systematic review, RRTs demonstrated a significant reduction of non-ICU cardiopulmonary arrests in adults (Chan, et al., 2010). However, a 23-hospital cluster-randomized controlled trial on RRTs failed to corroborate the reduced incidence of cardiopulmonary arrest (Hillman, 2005). A single-center ward cluster-randomized control trial did not report on cardiopulmonary arrest rates (Priestly, 2004).

One explanation for the lack of significant findings may be related to the fact that several definitions for cardiopulmonary arrest exist in the literature and may affect the rates being reported. Definitions include both cardiac and respiratory arrest, only cardiac arrest, and cardiopulmonary arrests (Chan, et al., 2010).

Other inclusion criteria used when reporting cardiopulmonary arrest rates include patients who are labeled do not resuscitate (DNR) or not for resuscitation (NFR). While several studies included all patients regardless of their status, other studies omitted patients with a DNR status (Chan, et al., 2010), revealing an inconsistency in the definition of cardiopulmonary arrest reported.
Hospital mortality. Research findings regarding RRTs’ impact on in-hospital mortality has also been inconclusive. Results from previous systematic reviews indicated that RRTs had a moderate effect on reducing mortality in hospitalized patients (Winters, 2007). Yet the most recent systematic review, which included 17 of the latest RRT studies, was unable to demonstrate a decline in hospital mortality despite the marked reduction in cardiopulmonary arrest (Figure 4) (Chan, et al., 2010).

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Intervention Group</th>
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<tr>
<td>Patients, No.</td>
<td>Deaths, No.</td>
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<td>Adult Studies</td>
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<td>Britswt et al (hospital 1)</td>
<td>13059 66</td>
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<tr>
<td>Britswt et al (hospital 2)</td>
<td>19545 99</td>
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<td>Rosett et al</td>
<td>19537 73</td>
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<td>Bellomo et al</td>
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<td>Korslow et al</td>
<td>53500 139</td>
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<td>Delville et al</td>
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<td>56756 93</td>
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<td>Jones et al</td>
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<tr>
<td>Neary et al</td>
<td>5667 44</td>
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<tr>
<td>Baxter et al</td>
<td>7820 43</td>
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<tr>
<td>Chan et al</td>
<td>24293 167</td>
</tr>
<tr>
<td>Overall Adult (p=0.005, P&lt;0.001)</td>
<td>380969 4176</td>
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| Pediatric Studies | | | | | | | |
| Brill et al | 16255 25 | 9015 6 | 0.25 | 0.41 (0.00-0.86) | | | |
| Shmer et al | 22037 53 | 7257 5 | 2.50 | 0.29 (0.10-0.69) | | | |
| Gern et al | 22561 181 | 15682 60 | 7.72 | 0.54 (0.47-0.87) | | | |
| Hunt et al | 7504 16 | 7503 8 | 2.45 | 0.49 (0.18-1.20) | | | |
| Tibballs and Kinney et al | 104780 20 | 138424 24 | 4.58 | 0.91 (0.50-1.64) | | | |
| Overall Pediatric (p=0.031, P<0.05) | 373137 295 | 174681 103 | 37.51* | 0.62 (0.48-0.84) | | | |
| Overall (p=0.001) | 554106 2058 | 589589 1183 | 100.00 | 0.65 (0.55-0.77) | | | |

CI indicates confidence interval. *Number owing to rounding error for each of the individual pediatric studies.

Figure 4. Pooled relative risks (RRs) of cardiopulmonary arrest outside the intensive care unit for adults and children after rapid response team (RRT) implementation.

Chan’s study incorporated data from 11 adult studies that were published between 2000 and 2009. All 11 studies met inclusion criteria that required they be either a randomized clinical trial (RCT), or that comparisons were made with a control group or a control period while providing quantifiable data on the primary outcome of hospital-wide mortality or the secondary outcome of rates cardiopulmonary arrest outside of the intensive care unit (ICU) (Chan, et al., 2010).

Five of the eleven studies were conducted in Australia, two were conducted in the UK, three were conducted in the U.S., and one study was conducted in Canada. Each of
the studies reported on hospital mortality, but they were inconsistent in their reporting of DNR status. Cluster-randomized control trials of a MET failed to support the benefit of implementation of RRTs for reducing hospital-wide mortality (Hillman; Chan et al. 2008). The ward cluster-randomized controlled trial did reveal a significant effect in reducing the chance of death for patients admitted to the intervention wards (Priestly, 2004).

**Unplanned intensive care unit admissions and length of stay (LOS).** Research remains unconvincing regarding whether RRTs (nurse-led) or medical emergency teams (MET) (physician-led) actually reduce unplanned ICU admissions. Results of earlier studies reported that emergency ICU transfers were significantly reduced following the implementation of an MET (Bellomo et al., 2004), while another study found a 16% reduction in unplanned ICU transfers (Dacey, et al., 2007). However, the 23-hospital cluster-randomized controlled trial of a MET found that a physician-led team did not significantly reduce unplanned ICU admissions or unexpected in-house deaths, but the latest systematic review did not report on this outcome (Chan, et al., 2010).

Length of stay (LOS) has become an important measure of health care utilization and determinant of hospitalization costs (A. Lee, Fung, & Fu, 2003). LOS is also recognized as a quality indicator (A. Lee, et al., 2003). In a pragmatic ward-randomized trial design, Cox proportional hazard models were used to assess the impact of critical care outreach team (CCO) on length of stay (LOS) controlling for the possible influence of other variables. The analysis of LOS in this study implied that when compared with the control, the CCO team cohort had an increased mean LOS (Priestley et al., 2004). However, increased LOS as a complication or undesirable outcome measure may be
more reflective of underlying patient severity than a reflection of poor quality care (Silber, et al., 2007). For example, a patient might be so acutely ill that he or she dies a few days or weeks later, causing the LOS indicator to be skewed.

**Rehospitalization rates.** Considered to be a potential indicator of poor outcome, rehospitalization rates have become an important measure of quality. Yet rehospitalization rates have not been reported in RRT research, despite their use as an outcome indicator for other conditions and interventions. Determining the cause of rehospitalization is important, because unforeseen rehospitalization may be the result of an adverse event during the first admission, or it may be caused by the natural course of the patient’s disease (Daly, Mason, & Goldacre, 2000). Rehospitalizations have been cited as a source of increased health care spending and variations in readmission rates by hospital and geographic region suggests that some hospitals and geographic areas are better than others at containing readmission rates (J. Stone & Hoffman, 2010).

**Identification of Literature Gaps**

Research presents conflicting conclusions about whether identifying deterioration earlier and intervening with the highest-level accessible resources will lead to improved patient outcomes in the acute-care setting (Price & Cairns, 2007; Teplick & Anderson, 2006). Despite overwhelming support for RRTs, as evidenced by the number of hospitals across the U.S. adopting this strategy, their effectiveness remains uncertain. Widespread implementation of RRSs internationally and in the U.S. was predominantly based on the findings of single-centered observational ‘before and after’ studies that were conducted primarily in Australia (Bellomo, et al., 2003; Buist, et al., 2002; A. Lee, Bishop, Hillman, & Daffurn, 1995) and the United Kingdom (Goldhill, et al., 1999).
Buist et al. (2002) conducted a non-randomized, before and after study investigating the impact of a MET on the incidence of cardiac arrest and hospital mortality. The study was conducted in a 300 bed, general urban teaching hospital in Australia over two 12-month periods, and included all patients admitted to the hospital in 1996 (n=19,317) and 1999 (n=22,847). This study used two discontinuous time periods to allow for the two-year implementation period. The incidence of unexpected cardiac arrests was measured prior to (1996) and after (1999) the implementation of the physician-led MET.

The decrease in cardiac arrest was reported as 3.77 per 1000 hospital admissions (73 cases) before the MET intervention and 2.05 per 1000 admissions (47 cases) ($p < 0.001$) after the MET intervention was in place. Subsequent mortality rates also demonstrated a decrease from 77% (56 patients) before the MET to a 55% (26 patients) ($p < 0.001$) after the MET. Utilizing well-defined criteria for recognizing clinical deterioration, the activation of the MET significantly reduced the incidence of and mortality from cardiac arrest in this urban teaching hospital in Australia.

Bellomo et al. (2003) conducted a prospective before and after intervention trial in an acute care tertiary teaching hospital in Melbourne, Australia. The main outcome measures included the number of cardiac arrests, number of patients dying after cardiac arrest, number of post-cardiac-arrest bed-days as well as in-hospital mortality. All patients admitted to the hospital were included in the study, which was divided into three periods: a four-month “before” period; (n = 21,090), 2) a twelve month preparation and education period and a four-month “after” or intervention period (n = 20,921). The effect of seasonal variation was assessed by obtaining data on cardiac arrests and hospital
mortality for the same four months of the year as the intervention period (Bellomo, et al., 2003).

The outcome measures included the number of cardiac arrests; the number of patients who died from cardiac arrest; the number of in-hospital deaths; the number of ICU bed-days occupied by survivors of cardiac arrest; and the number of hospital bed-days occupied by survivors of cardiac arrest. The authors clearly defined the term cardiac arrest, and described how the calling criterion for activating the team were displayed on all of the nursing wards and throughout the hospital (Bellomo, et al., 2003).

The authors discussed an extensive education program put in place during the 12-month implementation period that included all medical, nursing and paramedical staff (Bellomo, et al., 2003). The MET composition and variants of the MET model were also described. The researchers concluded that the incidence of in-hospital cardiac arrest, cardiac arrest death and overall in-hospital mortality decreased after introducing the MET (Bellomo, et al., 2003).

Another study reported by Bristow et al. (2000) used a prospective cohort design to compare a hospital with a MET with two hospitals having only a conventional cardiac arrest team. The hospital settings were not described, other than to say that they were “similarly sized Australian public hospitals” (p. 237). Neither the rollout period nor implementation strategies for the MET was reported. The population included all patients admitted to the three hospitals (n=50,942) age 14 years and older. Outcome variables included all cardiorespiratory arrest calls, deaths, and ICU admissions, which were identified as “events” (n=1510).
Logistic regression was used to model the probability of an event occurring during hospitalization, while adjusting for patient demographics and diagnostic characteristics. The diagnostic categories based on ICD-9-CM codes used the principal diagnosis and the stay diagnosis only (Bristow, et al., 2000). The number of admissions varied between Hospital 1 (with the MET) (n= 18338), Hospital 2 (n=13059) and Hospital 3 (n=19545). Results from 1510 adverse events between the three hospitals revealed a significantly reduced rate of unanticipated ICU admissions at the MET intervention hospital after case-mix adjustment. Both Hospital 2 and Hospital 3 had more unanticipated ICU admissions over a six-month period at 49 (95% CI, 20-87) and 92 (95% CI, 47-146) respectively. There were no statistically significant differences in cardiac arrest rate or death rate after case-mix adjustment between the three hospitals.

Bellomo et al. (2004) utilized the data from their earlier prospective before-and-after intervention trial to evaluate AEs for patients experiencing major surgery, which was defined as any operation associated with a hospital stay greater than 48 hours. Using the same outcome measures (number of cardiac arrests, number of patients dying after cardiac arrest, number of post-cardiac-arrest bed-days as well as in-hospital mortality), the Australian study was divided into three periods: a four-month pre period; (n=1,116 patients received 1,369 operations); a twelve-month preparation and education period; and a four-month post or intervention period where (n=1,067 patients received 1,313 operations).

Results showed that the MET was associated with a 50% decrease in the incidence of AEs in surgical patients. There were 73 inpatient deaths during the pre-MET period compared with 45 deaths during the intervention period (relative risk reduction, 36.6%);
p=.0178). The study results also reported a reduction in duration of hospital stay from 23.8 days during the control to 18.9 days during the intervention (p=.0092). The authors translated this reduction of hospital days to a savings of nearly 4,000 hospital bed-days (Bellomo, et al., 2004).

In the first published report documenting MET implementation in a U.S. hospital, DeVita et al. (2004) examined the incidences of MET responses, cardiopulmonary arrests, and crises with fatal outcomes in a large tertiary teaching institution. This study was also the first to examine dose of the MET (within the U.S.) by comparing triggering of the MET before and after increased training within the same institution that employed a MET team (2004).

The MET intervention was in place during all phases of the study beginning in 1996. However, data indicated that the MET was being underutilized. An educational period in 2000 allowed the study to examine outcomes both before and after increased use of MET. The after period was defined as starting in January 2001 and extending until September 2002. Results of this retrospective analysis indicated that the mean monthly incidence of cardiopulmonary arrests decreased by 17% from 6.5 per 1000 admissions before MET implementation to 5.4 per 1000 admissions after MET implementation (p=0.016).

These earlier studies as well as subsequent trials were predominantly single-center, descriptive, before-and-after non-randomized studies (Buist, et al., 2002; Chen, et al., 2009; Chen, Flavouris, Bellomo, Hillman, & Finfer, 2008), revealing reductions in cardiac arrest, death and ICU admissions and no change between the before and after RTT/MET metrics (Devita et al, 2004; Chan, 2010).
The MERIT trial, which was the only cluster-randomized control trial involving more than one hospital (n=23) did not find any benefit from the MET (Hillman, et al., 2005). The only other cluster randomized study involved randomization within the same hospital at the ward level, where the staggered implementation of the CCO team allowed the same ward to be in both the control and intervention groups (Priestley, et al., 2004).

The remaining studies were single center studies conducted in academic institutions (Chan, et al., 2010). Inclusion criteria for the systematic review required that the studies be conducted between 2000 and 2008 and included studies on both adults (13 studies) and children (5 studies). The majority of reported studies were conducted in countries with divergent and contrasting medical systems, rendering their applicability to such teams here in the U.S. problematic (Chan, et al., 2010; DeVita, et al., 2006).

While the concept of RRTs enjoys broad support in the literature, evidence of effectiveness in improving outcomes continues to be lacking. Virtually all of the studies to date focused on short-term outcomes, with the common endpoint being survival to discharge (Buist, et al., 2002; Jolley, et al., 2007). No studies to date have examined 30-day hospital readmission and prolonged length of stay and no studies on RRTs have examined outcomes among multiple tertiary hospital within the state of Washington.

Limitations

Several limitations are readily identifiable in the research on RRTs.

First, many of the early studies were predominantly descriptive, and subsequent efforts were methodologically flawed or otherwise limited (by small sample sizes, poor or no controls, and/or involving only a single center) (Price & Cairns, 2007; Teplick & Anderson, 2006). The majority of studies used historical controls, indicating that they had
several possible sources of indiscernible bias. Most studies were conducted in academic medical centers. These centers tend to have different physician staffing models (interns, residents, and house staff), potentially limiting the overall applicability of the findings to non-teaching institutions (Kerridge & Saul, 2003; Price & Cairns, 2007).

Several studies reported inconsistent implementation of the RRT, described a very brief duration of the study, or failed to consider the possibility of a Hawthorne effect (Berwick, et al., 2006). Studies examining long-term health outcomes including hospital readmission, long-term mortality and discharge disposition have not been reported. Finally, consistency is lacking in the explanation of team structure and team training between the reported studies, revealing a lack of standardization in team sizes, team skill set, and team membership.

Although debate surrounds the benefits of RRTs, there is agreement that finding a solution that minimizes unnecessary in-hospital morbidity must be a high priority. Opponents of RRTs argue that providing adequate hospital staffing would negate the need for rapid response teams (Litvak & Pronovost, 2010). They posit that patients often deteriorate as a result of inadequate care or improper placement on appropriately staffed wards or wards with inadequate monitoring of patients. Conversely, proponents of RRTs believe that adoption of RRTs makes hospitals safer and helps reduce AEs in the hospital setting.

**Conclusion**

While many hospitals have adopted an RRT system, controversy exists as to whether these teams are measurably effective in achieving improved health outcomes in the clinical setting (Winters et al., 2007). The seemingly-inevitable result of better patient
outcomes where RRTs are employed has been decidedly difficult to document. Results from RRT research to date are conflicting (Sasichay-Akkadechanunt, Scalzi, & Jawad, 2003), and plagued by a host of methodological, operational, and definitional difficulties that may be the root cause of the inconsistent and sometimes-conflicting results. This research was intended to mitigate many of the methodological flaws in order to obtain a more reliable and more definitive answer to the question, “Do patient outcomes improve after RRT implementation?”
CHAPTER 3
RESEARCH METHODS AND METHODOLOGY

Methods Overview

This study was designed to investigate a hypothesized relationship between the implementation of rapid response teams (RRTs) and patient health outcomes among 12 tertiary hospitals within Washington State. In order to examine this research hypothesis, a retrospective observational study with prospective components was designed to understand what happens longitudinally to patients assigned to different cohorts.

In the first phase of this retrospective observational cohort study, a prospectively collected survey titled *Timing and Processes Related To Implementation of Rapid Response Teams* containing questions regarding the implementation and function of the RRT was emailed to the chief nursing executives (CNE) or chief nurse officer (CNO) at each hospital included in the study sample. A copy of the survey is in Appendix A. Surveys were distributed electronically to each hospital’s chief nursing officer, with reminder notices sent at two-week intervals over a 10-week period. Prospective respondents were assured of anonymity for themselves and their institutions.

Completed surveys were returned electronically. Survey data represented the self-reported observations of the CNEs or their designees regarding the implementation of RRTs in their facilities. The survey data were used to evaluate the characteristics of the RRT at the study hospitals.

In order to develop the questions for the survey, a subject matter expert (SME) with knowledge of RRT implementation and process was consulted. The SME had experience in establishing survey-type questions about RRT activities and the experiences of RNs
with RRTs (Donaldson, et al., 2009; Shapiro, et al., 2010). The survey questions were reviewed by the SME, who provided feedback on the composition of questions.

The purpose of the survey was to focus on the common characteristics of RRT activities within the participating hospitals, including descriptions of the timing and processes surrounding RRT design and implementation. The survey was used to describe the history of each hospital’s implementation of an RRT, the education plan for implementation, and the frequency of use of the RRT. The survey provided response options as well free-text boxes for additional comments. Most important, this survey provided the information used to define the pre-implementation, run-in and post-implementation periods of the RRT that was used in the second phase of the study.

In the second phase, a comprehensive, multivariate, observational and pre-post cohort analysis was used to examine the associations between patient health outcomes before and after the RRT implementation.

**Ethical Considerations**

**Phase one.** Approval for conducting Phase One of this study (emailing of the survey) was submitted to the Institutional Review Board (IRB) at Washington State University on the IRB Exempt Application (IRB #12488), entitled, “The Relationships between Rapid Response Team Interventions and Patient Health Outcomes” (Appendix 2). The submitted application was found to be exempt.

**Phase two.** In Phase Two of this study, data were obtained from a publicly available registry of de-identified hospitalization abstracts. This does not qualify as human subjects research. Institutional Review Board (IRB) approval was not required for this phase of the study.
Methods Contextualization

**Phase one.** The use of a survey is one of the most common forms of obtaining information (Creswell, 2007; Streubert & Carpenter, 1999). The primary purpose of the survey was to define the implementation periods for the RRTs at each of the selected hospitals as well as to gain knowledge related to the process and structure of the team. The survey allowed the researcher to obtain consistent data within the designed scope of the research project.

The survey was electronically distributed to the hospital’s chief nursing officers (CNE) at 16 tertiary hospitals throughout the state of Washington. CNEs or RRT champions who did not complete the survey by a predetermined date received a second request and survey via email. This second request was also sent to the CNE or RRT champion. Unanswered second requests prompted a phone call to the CNE to determine how best to distribute the survey. If no response was obtained after the third request, no other attempts to contact hospital personnel were made and the hospital was omitted from the study.
The survey provided an effective tool for exploring the tangible and intangible elements of RRTs such as implementation dates, team membership, calling criteria, and whether the hospital was a robust or reluctant adopter of RRT (Shapiro, et al., 2010). In this study, the survey was used to investigate five main processes (Table 1).

<table>
<thead>
<tr>
<th>Process Name</th>
<th>Process Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRT Membership Selection</td>
<td>Which RRT configuration best describes the one at your hospital/system?</td>
</tr>
<tr>
<td>RRT Education</td>
<td>What was the educational plan for staff?</td>
</tr>
<tr>
<td>RRT Activation</td>
<td>Which configuration of triggers for calling the RRT best describes the one at use in your hospital? Who in your hospital can activate your RRT?</td>
</tr>
<tr>
<td>RRT Response</td>
<td>How does the RRT respond, what equipment do they bring to the bedside? How long does it take for them to respond?</td>
</tr>
<tr>
<td>RRT measure of success-post response documentation</td>
<td>How does your institution measure RRT success?</td>
</tr>
</tbody>
</table>

Table 1. The five main RRT processes investigated

**Phase two.** A randomized controlled trial (RCT) is a research design that measures the effect of a clinical intervention by randomly assigning individuals (or groups of individuals) to a treatment or control (i.e. non-treatment) group (Stanley, 2007). RCTs are the uncontested gold standard for establishing causation between an intervention and resulting outcomes in a treatment cohort (Nallamouth, 2008). The effect of the intervention is established in that control and treatment participants are similar in all attributes thought to influence the outcome(s) under study (Nallamouth, 2008). This randomization of research subjects ensures that any systematic differences between the groups can confidently be attributed to the intervention and not other factors, either measured or not measured (Stanley, 2007). There is persuasive evidence that RCTs are a
superior method for determining whether treatments or interventions are efficacious (Stolberg, Norman, & Trop, 2004).

Although RCTs offer unique advantages through randomization and control of observed and unobserved factors, there are many situations in which RCTs are neither feasible nor practical. In order to evaluate the effectiveness of an RRT intervention using a RCT, deteriorating patients would be matched for a wide variety of factors and would be randomly assigned to treatment (i.e. RRT) and control (i.e. no RRT) groups. Such an experiment would expose patients in the control group to unnecessary and avoidable harm.

It would be unreasonable, if not impossible, to randomize these patients according to their similar characteristics in an attempt to keep the groups comparable on all observable and unobservable factors. Finally, the number of RCTs necessary to determine RRT effectiveness would be immense. Hospitalized patients present with a large number of comorbidities, are hospitalized for a number of reasons, and deteriorate from a variety of causes. In the context of this study, considerations of efficacy, ethics and pragmatic factors required an alternative methodology for assessing RRT effectiveness.

In order to answer the research question, “What are the hypothesized differences in improved patient health outcomes before and after the implementation of RRTs within Washington State tertiary hospitals?” a well-matched cohort, pre-post study was the most ethical, practical and methodologically sound approach. This study served to examine association between the RRT intervention and selected health outcomes.

As previously described, the Patient Safety Management Model (Battles & Lilford, 2003) adds patients’ comorbid conditions and acuity levels to Donnabedian’s (1980)
existing structure, process and outcomes model, and highlights the importance of these antecedent conditions, which ultimately influence patient health outcomes. The Patient Safety Management Model (Battles & Lilford, 2003) had considerable applicability to this study for controlling covariates when examining the effect of an RRT on patient outcomes.

A well-controlled observational study often provides a more realistic expectation for outcomes in real-world environments, because it does not restrict inclusion to patients who are only randomly different from one another (Stuart, 2010). Observational prognostic studies are the best method for understanding the association between the intervention and health outcomes in different clinical settings and in broader patient populations (Nallamothu, Hayward, & Bates, 2008).

While this pre-post implementation study examined whether there were differences in patient health outcomes before and after the implementation of RRTs, it did not answer the question of whether patients’ improvements or deterioration would have occurred despite the implementation. Assigning causation with this type of study design would have led to potentially erroneous conclusions about the effectiveness of RRTs. An observational cohort study in which the phenomenon is observed and no variables are manipulated was the most appropriate design for the assessing the effectiveness of RRT implementation.

Six questions have been recognized for their importance in guiding the evaluation of the validity of an observational cohort study and the relevance of the study for clinical practice (Straus & Haynes, 2009). These six questions were used to create the design of the study, and are presented and answered in the subsequent sections.
1. Did the study include a representative sample of patients?
2. Did the study address the issue concerning whether all patients come into the study at a common point in their disease?
3. Was there adequate follow-up time?
4. Were the outcomes measured objectively?
5. How did the researcher handle other prognostic factors that increase the risk of adverse events?
6. How were the findings of this study internally validated?

**Cohort Definition**

In health care research, a cohort is defined as a group of patients with a common characteristic or experience (Aschengrau & Seage, 2007). A cohort design was an appropriate choice in this study because it follows groups with common characteristics (such as pre-RRT implementation and post-RRT implementation) over time to determine the incidence of health outcomes. The use of a cohort design allows the examination of multiple health outcomes and allows for the inclusion of a broader population of patients than can be obtained in an experimental study (Aschengrau & Seage, 2007).

In this study there were two cohorts, both defined according to the date of the RRT implementation at each pre-selected hospital. Sixteen geographically contiguous tertiary hospitals were targeted for this analysis. Outwardly similar in size, these 16 hospitals were selected based on their total discharge volume, and collectively they represented 51.8% of the state’s total hospital discharges. Only the 12 hospitals that returned the survey were included in the study. The discharge information was obtained from the Comprehensive Hospital Abstract Reporting System (CHARS).
At each hospital, a pre-RRT implementation period was identified during the first phase of this study. Patients hospitalized during this pre-RRT implementation period were placed in the ‘historical’ pre-RRT cohort. Hospitalizations during the run-in time period of RRT implementation were not included in this study’s analysis. At each hospital a post-RRT implementation period was identified during the first phase of the study. Patients hospitalized during this post-RRT implementation period were placed in the “contemporary” post-RRT cohort.

Data Sources

Phase one. Data were obtained from surveys that were completed anonymously by the RRT champion or designee selected by the organization’s CNE or CNO. Survey data were kept in a locked cabinet in a faculty office at the College of Nursing at Washington State University.

Phase two. The data source for the second phase of this study was the CHARS dataset. CHARS is a state-based integrated clinical data repository developed for the purpose of examining and improving patient health outcomes (Health, 2011). The CHARS dataset includes electronically abstracted encounter information from each acute care hospital discharge in Washington State. Payer, diagnoses and procedures codes are included in this dataset.

Inclusion Criteria

Phase one. The surveys were completed by the RRT champion or designee, which was determined by the chief nursing executives (CNEs) or their designees from each of the 12 hospitals included in the study sample (Appendix A).
**Phase two.** The observational cohort study included de-identified data from January 1, 2003 through December 31, 2010 for all adult patients ≥18 years of age who were hospitalized in one of the 12 selected tertiary acute care facilities in Washington State that had fully implemented an RRT by June 30, 2009. The implementation date limit reflects the need to provide an acceptable assessment period for the contemporary cohort.

*Did this study include a representative sample of patients? The broad inclusion of all hospitalized patients in this study provides the most inclusive and diverse study population that adequately addresses clinical relevancy.*

**Study Definitions**

**Phase one.** Although this was a multicenter retrospective observational cohort study, the quantitative technique utilized in this study did not provide the necessary information about specific RRT implementation dates at each hospital. The survey was used to obtain this data for the pre- and post-implementation periods as well as the *run-in* period.

**Run-in period.** The run-in period was defined as the phase of RRT implementation that included hospital staff education, plus 90 days from the time the RRT was fully implemented. This added 90 days was designed to control for possible bias related to the initial rollout of the RRT. The run-in period was driven by three questions: When did hospital education regarding RRT implementation begin? What date was the RRT first used in some form? When was the RRT implemented house-wide? The survey provided insight into factors relating to patterns of RRT implementation at each hospital.

**Phase two.** A multicenter retrospective observational cohort study was conducted among patients ≥18 years of age hospitalized in Washington State between January 1, 2003 and December 31, 2010. The parameters in this study are defined below and include
index hospitalization; look-back period, assessment period, and follow-up period; patient outcomes including index hospitalization length of stay, index hospitalization mortality, rehospitalization; covariates including age, gender, categorization of index hospitalization primary diagnosis, previous 12 month hospitalization, and comorbidities.

**Index hospitalization.** The term *index hospitalization* refers to the earliest hospitalization for each patient within an assessment period (i.e. patients in both the pre-RRT implementation and post-RRT implementation period) for each hospital. The index hospitalization marks the date of entry of a research subject into the observational study.

*Did the study address the issue concerning whether all patients come into the study at a common point in their disease? Systematically identifying the earliest hospitalization within an assessment period provides a common point of entry of research subjects into the study.*

**Look-back period.** Patients recently hospitalized are at increased risk for adverse outcomes. Accordingly, each hospital’s cohort (i.e. patients in both the pre-RRT implementation and post-RRT implementation period) included a *look-back period* of 12 months. In this manner, the number of hospitalizations within the previous 12 months of enrollment for each patient in the study was established. The look-back period was also used to define patients’ comorbidities (antecedent conditions).

*Were patients assembled at a common point in their disease? Systematically controlling for previous hospitalizations and comorbidities (index hospitalization and 12 month previous hospitalization) provides a common point of entry of research subjects into the study.*
Assessment period. An assessment period was defined for each hospital in the study. Based on input from the survey, an assessment period was defined for both the pre-RRT implementation and post-RRT implementation periods. Patients hospitalized during the assessment period were analyzed for both index hospitalization and longitudinal outcomes.

Follow-up period. A minimum follow-up period was defined for each hospital included in the study. Assessment periods were terminated early enough to allow all research participants to be followed for a minimum of 90 days after discharge from the index hospitalization.

Were patients followed completely for a sufficiently long period of time? In order to compare the effectiveness of the RRT implementation on longitudinal outcomes, all patients will be followed for at least 90 days following index hospitalization discharge. This study design represents the most complete data capture in that any subsequent hospitalizations in Washington State were captured.

Patient outcome-index hospitalization length of stay. Length of stay (LOS) during the index hospitalization is an easily available indicator of hospital activity used to measure adverse outcomes. LOS is calculated by subtracting the index hospitalization admission date from the discharge date. LOS values are asymmetrical in their distribution. Accordingly, LOS was measured as a continuous variable in days with median and inter-quartile ranges reported for both the pre-RRT implementation and post-RRT implementation period.

Patient outcome-index hospitalization mortality. Index hospitalization mortality is a primary outcome measure used in previous RRT research (DeVita, et al., 2006). Within
the current observational cohort study, the mortality status of each hospitalized patient was determined by examining discharge status on each index hospitalization record. Index hospitalization mortality was recorded as a dichotomous variable representing either discharged alive, or discharged due to death.

**Patient outcome-30 day-rehospitalization.** Although not previously included in RRT research, this study examined the patient outcome of 30-day rehospitalization. Rehospitalization may be defined using various time frames from 30 days to 365 days. This study included rehospitalization up to 90 days post-discharge, which allowed for a broad inclusion of rates. Particular attention has been given to 30-day rehospitalizations as the most critical interval and the greatest opportunity for improvement in outcomes (Gore et al., 2010; van Walraven et al., 2010).

Defined as a discharge from followed by an admission to an acute care hospital within a specified period of time, rehospitalization rates are calculated after excluding from the denominator patients who died during the initial or index admission (van Walraven, et al., 2010). The current study defined rehospitalization using the index admission diagnosis (obtained from initial admission) and thus defined rehospitalization in terms of type of admission (emergent, elective, or direct admission), diagnostic specificity, 30-day and 90-day time periods chosen within which events must occur, and excluding patients who were transferred on the day of discharge to another acute care hospital.

**Covariate–age.** Patient outcomes are expected to vary with age. *Age at discharge* from the index hospitalization was recorded as a continuous variable.
**Covariate—gender.** Gender differences are expected in patient outcomes and was a dichotomous variable determined at the index hospitalization.

**Covariate—categorization of primary diagnosis.** Patients are hospitalized for a variety of reasons. Patient health outcomes differ depending on the reason for hospitalization. Broad categories for classification of reasons of hospitalization will be defined, based on the primary diagnosis of the index hospitalization, according to the International Classification of Disease, 9th revision, Clinical Modification (ICD-9-CM).

**Covariate comorbidities.** Comorbidities are underlying conditions patients bring to their index hospitalization. Comorbid conditions also represent an important concept within the patient safety model, the framework that is the theoretical scaffolding for the proposed study (Battles & Lilford, 2003). This model cautions that interpreting patient outcomes without including antecedent conditions may produce findings that will not reflect variations in results accurately (Battles & Lilford, 2003).

Because they are important clinical characteristics of patients, comorbidities were defined, measured and controlled in this study. When administrative data are used for such research, comorbidity coding algorithms are essential for defining comorbidities (Southern, Quan, & Ghali, 2004). There currently exist two dominant comorbidity measurement tools by which to measure the burden of disease within administrative data—the Charlson and the Elixhauser methods (Southern, et al., 2004). While both techniques have been adapted for use with ICD-9, there are important differences that favor use of the Elixhauser methodology.

The Charlson method, which defines 17 comorbidities that can be used to predict outcomes such as mortality, was designed as a weighted index and was originally
developed on a small cohort of 559 medical patients. It treats all comorbidities as if they are the same (Charlson, Pompei, Ales, & Mackenzie, 1987). This method creates a singular scalar value that does not provide the level of disease specificity sought for this study.

The Elixhauser model includes a more comprehensive list of 30 comorbid conditions, allowing for the inclusion of 7000 diagnostic codes (ICD-9) that have been categorized into broader diagnoses groupings and assigned to each case according to the reason for hospitalization. This method controls for covariates and adjusts outcomes as if the severity of illness of patients in all cohorts was comparable. The increased number of defined comorbidities provided by the Elixhauser model creates a greater opportunity for identifying and controlling for comorbidities and provides better outcome prediction, and for those reasons it has was selected for this study.

According to the description provided by Elixhauser (1998), a comorbid condition is described as “a clinical condition that exists before a patient’s admission to the hospital, is not related to the principal reason for the hospitalization, and is likely to be a significant factor influencing mortality and resource use in the hospital” (p. 10). In observational studies where the sample population is predominantly heterogeneous, it is important to control for the burden of comorbidity as an outcome predictor (D. Lee, Meyer, & Clouse, 2001). The ability to distinguish between comorbid conditions that are present on admission has implications for understanding RRT outcomes within the hospital setting.
Analytical Plan

Phase one. There were two parts to the analytical plan in Phase one. The first was concerned with identification of the run-in period at each selected hospital. This information was ascertained from the survey results.

It was believed there would be differences in the effects of RRT implementation on patient outcomes between the selected hospitals in this study. The second part of the analytical plan involved describing differences in RRT membership, RRT calling criteria, and individual institutional measures of RRT success.

The data from the surveys were assigned within the appropriate categories related to implementation dates, run-in periods, team membership, selected calling criteria, and calls per month. Findings were recorded and described. Information that was ambiguous was re-read and placed under the category with the best fit.

Although this analysis allowed further examination of expected differences in the implementation pre- and post-RRT implementation, the primary purpose of this phase of the study was to define the run-in period. While information regarding team membership, selected calling criteria, and status as adopters of RRT (robust or reluctant) might have provided additional insights regarding RRTs, including but not limited to understanding the standardization of membership and calling criteria on patient outcomes, the primary focus of this study was to understand pre-post RRT implementation on selected patient outcomes.

Phase two. For each study variable, transforming the data to z-scores identified univariate outliers. Cases with univariate outliers more than three standard deviations
from the mean were removed on the assumption that these values were errors that could not be corrected.

Binary logistic regression is a technique commonly used in clinical research and is well suited for describing and testing hypotheses about relationships between a categorical outcome variable and one or more categorical or continuous predictor variables (LaValley, 2008a). Binary logistic regression is an accepted tool in observational studies when adjustment is needed to reduce the potential bias resulting from differences related to group comparison (LaValley, 2008a).

Logistic regression is useful for prediction of group membership and calculates the probability or success over the probability of failure providing the results of the analysis in the form of an odds ratio (Peng, Lee, & Ingersoll, 2002). Logistic regression also provides knowledge of the relationships and strengths among the variables (e.g., increased age, admission through the ED, prior hospitalization) putting a patient at higher risk for in-hospital mortality. Logistic regression determines which coefficients are significant for inclusion or elimination from the model through a series of different techniques with the goal of correctly predicting the category of outcome for individual cases using the most parsimonious model.

The effectiveness of the logistic model was supported by significance tests of the model against the null model, the significance test of each predictor, descriptive and inferential goodness-of-fit indices, and predicted probabilities. Internal validation of main study findings was completed using split-file validation whereby the analysis was completed a second time after cases were randomly assigned to derivation and validation cohorts.
Summary

This study was designed to explore a hypothesized relationship between the implementation of rapid response teams (RRTs) and improved patient health outcomes among 12 tertiary hospitals within Washington State. This multi-method study was conducted in two phases and was the first of its kind to explore RRTs within multiple hospitals concurrently. Phase One included results of a survey designed to gather valuable information regarding RRT characteristics at each hospital. This information aided in establishing boundaries and parameters for Phase two of the study.

Phase two consisted of an observational matched-cohort design to explore the research questions. De-identified data were obtained from the CHARS database, a statewide-integrated clinical data repository developed for the purpose of examining and improving patient health outcomes. The sample included all adult patients \( \geq 18 \) years of age who were hospitalized in each of the selected tertiary acute care facilities that had fully implemented an RRT by June 30, 2009. SPSS version 20 was used to calculate descriptive statistics and perform binary logistic regression model calculations.
Summary of Hospital Survey Findings

In support of this observational study of pre-implementation and post-implementation of RRTs a survey was designed to collect data on RRT implementation dates, processes and structures. Both processes and structures are key elements within the Patient Safety Management Model, which provided the framework for this study. As previously described, the survey was electronically distributed to the hospital’s chief nursing officer (CNE) at 16 tertiary hospitals throughout the state of Washington and the 12 hospitals that responded were included in this study. Because of the promised anonymity, it was not possible to ascertain the credential or title of the responders.

The 12 hospitals (75% of eligible institutions) included in this study represent 13% of all general acute hospitals in Washington State in 2009. Tertiary hospitals were selected based on the similarities in medical services offered. For example, each of the selected hospitals offered a full complement of services and is fully departmentalized and equipped with the service capabilities needed to support medical specialists and other licensed physicians rendering services in the field of medicine, pediatrics, obstetrics and gynecology, surgery, orthopedics, neurology, cardiology, pulmonary, radiology and ancillary services. All facilities held the title of designated stroke center, one hospital was a level-1 trauma center and two hospitals were teaching hospitals with medical residents and interns on staff. Collectively, the hospitals in this study accounted for 40.4% of the statewide annual discharges in 2009.
Hospitals included in this study have long embraced RRTs as evidenced by their RRT implementation dates. All but one hospital had implemented an RRT by 2006. Based on survey results, all 12 hospitals have used RRTs for at least five years (Table 2).

<table>
<thead>
<tr>
<th>Hosp ID</th>
<th>Year RRT went live</th>
<th>Team Membership</th>
<th>RRT calls/1000 discharges</th>
<th>Who can activate RRT</th>
<th>Calling criteria</th>
<th>How is RRT success measured?</th>
<th>Goal for response in minutes</th>
<th>% annual D/C 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2005</td>
<td>CCRN, ED RN, RT, MD</td>
<td>1.2</td>
<td>Anyone</td>
<td>clinical &amp; qualitative indicator</td>
<td>Cardiac arrest</td>
<td>5</td>
<td>3.2%</td>
</tr>
<tr>
<td>B</td>
<td>2006</td>
<td>CCRN, EDRN RT</td>
<td>44.3</td>
<td>Anyone</td>
<td>Clinical &amp; qualitative indicator</td>
<td>Cardiac arrest</td>
<td>5</td>
<td>3.6%</td>
</tr>
<tr>
<td>C</td>
<td>2007</td>
<td>CCRN RT</td>
<td>34.5</td>
<td>Anyone</td>
<td>Any Concern</td>
<td>Cardiac arrest</td>
<td>5</td>
<td>2.8%</td>
</tr>
<tr>
<td>D</td>
<td>2006</td>
<td>CCRN, EDRN RT</td>
<td>263</td>
<td>Anyone</td>
<td>Clinical &amp; qualitative indicator</td>
<td>Cardiac arrest</td>
<td>5</td>
<td>4.7%</td>
</tr>
<tr>
<td>E</td>
<td>2006</td>
<td>CCRN, EDRN RT</td>
<td>50.1</td>
<td>Anyone</td>
<td>Clinical &amp; qualitative indicator</td>
<td>Cardiac arrest</td>
<td>15</td>
<td>3.2%</td>
</tr>
<tr>
<td>F</td>
<td>2004</td>
<td>CCRN, EDRN RT</td>
<td>51.8</td>
<td>Anyone</td>
<td>MEWS</td>
<td>Other</td>
<td>10</td>
<td>2.6%</td>
</tr>
<tr>
<td>G</td>
<td>2006</td>
<td>CCRN, EDRN RT</td>
<td>48.9</td>
<td>Anyone</td>
<td>Clinical &amp; qualitative indicator</td>
<td>Other</td>
<td>10</td>
<td>2.7%</td>
</tr>
<tr>
<td>H</td>
<td>2004</td>
<td>Dedicated CCRN RT</td>
<td>79.6</td>
<td>Anyone</td>
<td>**“Gut” of bedside nurse</td>
<td>Other</td>
<td>10</td>
<td>3.7%</td>
</tr>
<tr>
<td>I</td>
<td>2005</td>
<td>CCRN, EDRN RT MD</td>
<td>32.9</td>
<td>Anyone</td>
<td>Clinical &amp; qualitative indicator</td>
<td>Other</td>
<td>5</td>
<td>3.0%</td>
</tr>
<tr>
<td>J</td>
<td>2006</td>
<td>CCRN, EDRN RT MD</td>
<td>16.7</td>
<td>Anyone</td>
<td>Clinical &amp; qualitative indicator</td>
<td>in-hospital mortality</td>
<td>5</td>
<td>2.5%</td>
</tr>
<tr>
<td>K</td>
<td>2005</td>
<td>CCRN RT</td>
<td>222</td>
<td>Anyone</td>
<td>MEWS</td>
<td>Cardiac arrest</td>
<td>10</td>
<td>2.7%</td>
</tr>
<tr>
<td>L</td>
<td>2005</td>
<td>CCRN EDRN RT</td>
<td>16.42</td>
<td>Anyone</td>
<td>clinical &amp; qualitative indicator</td>
<td>Cardiac arrest</td>
<td>15</td>
<td>5.7%</td>
</tr>
</tbody>
</table>

Survey Title: ‘Timing and Processes Related to Implementation of Rapid Response Teams’
Key: CCRN=critical care registered nurse; EDRN=emergency department registered nurse; RT= respiratory therapist; MD= medical doctor; D/C=discharge. MEWS = Modified early warning systems  *Results copied verbatim from survey

Table 2. Summary of RRT survey sent to each hospital

While each of the hospitals shared similar experience with RRTs in terms of duration of RRT existence, there were also several notable differences. For example, the use of the
modified early warning system (MEWS) to identify deteriorating patients was only used in two of the twelve hospitals, while the other hospitals reported using varying combinations of qualitative and quantitative triggers to assess patients for signs of deterioration.

Six of twelve hospitals reported that they use in-hospital cardiac arrest as their primary measure of RRT success; one of twelve reported in-hospitals mortality rates; four of twelve indicated ‘other’ as their measurement of RRT success and one of the hospitals indicated ‘no formal measurement’ of RRT success. The RRT staffing model used most often was an ICU RN and respiratory therapist. Three hospitals (one of which was a teaching hospital) included a physician member. While the hospital reporting improvements in all five outcomes had a physician on the team, the two hospitals reporting improvements in only one outcome also had a physician team member.

Response related to the implementation educational plan included four of twelve hospitals reporting mandatory education, four of twelve reporting informal education (posting of flyers), three of twelve reporting both formal and informal education and one hospital reporting education for RRT members only.

Notable differences existed in RRT standardization, primarily in the areas of the educational plan used for the RRT implementation and the current average number of RRT calls per 1000 discharges. The original education plan for RRT implementation
varied between mandatory or formal classes (four hospitals) and informal education such as staff meetings and flyers posted in staff lounges (four hospitals). All 12 hospitals reported their number of RRT calls per month, which were converted to calls per 1000 discharges, and varied from 1.2 to 263 calls/1000 discharges (Table 2).

**Patient Characteristics of Cohorts**

Outcome measures examined in this study were influenced by age, gender, payer, admission through the emergency department (ED), length of stay and reason for hospitalization documented by categorization of primary diagnosis. Most such patient characteristics of the pre- and post-RRT cohorts were statistically different (Table 3).

<table>
<thead>
<tr>
<th>Index Hospitalization</th>
<th>Pre-RRT Cohort</th>
<th>Post-RRT Cohort</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=258,843</td>
<td>n=269,015</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>59.1 ± 18.5</td>
<td>59.5 ± 18.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of stay (LOS)</td>
<td>3 (2-5)</td>
<td>3 (1-5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>% LOS &gt;3 days</td>
<td>100,223 (38.7)</td>
<td>100,657 (37.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male</td>
<td>122,598 (47.4)</td>
<td>129,486 (48.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Female</td>
<td>136,245 (52.6)</td>
<td>139,529 (51.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Admission through the ED</td>
<td>128,435 (49.6)</td>
<td>136,826 (50.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Primary Insurance Payer</td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>Medicare</td>
<td>105,349 (40.7)</td>
<td>110,565 (41.1)</td>
<td></td>
</tr>
<tr>
<td>Medicaid</td>
<td>23,296 (9.0)</td>
<td>24,211 (9.0)</td>
<td></td>
</tr>
<tr>
<td>Commercial/HMO</td>
<td>115,185 (44.5)</td>
<td>119,173 (44.3)</td>
<td></td>
</tr>
<tr>
<td>Self-pay</td>
<td>7,764 (3.0)</td>
<td>8,070 (3.0)</td>
<td></td>
</tr>
<tr>
<td>Top five primary diagnostic categories (ICD9-CM)</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Circulatory diseases (390-459)</td>
<td>56,686 (21.9)</td>
<td>56,762 (21.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Musculoskeletal diseases (710-739)</td>
<td>31,892 (12.3)</td>
<td>34,706 (12.9)</td>
<td></td>
</tr>
<tr>
<td>Digestive diseases (520-579)</td>
<td>32,873 (12.7)</td>
<td>32,550 (12.1)</td>
<td></td>
</tr>
<tr>
<td>Injury (800-999)</td>
<td>34,108 (13.2)</td>
<td>36,735 (13.7)</td>
<td></td>
</tr>
<tr>
<td>Neoplasm (140-239)</td>
<td>25,108 (9.7)</td>
<td>25,913 (9.6)</td>
<td></td>
</tr>
</tbody>
</table>

The pre-RRT and post-RRT cohorts are defined as the 27 months before and after implementation of the RRT. A nine-month range around the hospital-identified implementation date of RRT defines the RRT implementation period.

Table 3. Characteristics of cohorts among Washington State study hospitals
The average age of study participants for the pre- and post-RRT cohorts at index hospitalization was 59.1 and 59.5 years respectively (p<0.001). The mean length of stay (LOS) differed between the cohorts (p<0.001), indicating that over time patients were discharged sooner. Admission rates through the ED were also statistically different between the two cohorts (p<0.001). In the pre-RRT cohort, 47.4% (n=258,843) of the patients were admitted through the ED, while in the post-RRT cohort the figure was higher at 50.9% (n=269,015) potentially indicating a higher level of severity of illness and injury. Reasons for hospitalization as measured by categorization of primary diagnosis also differed between the two cohorts (p<0.001). No cohort differences in payer were observed (p=0.10). More than 44% of patients in each cohort had public-source payers of Medicare or Medicaid at index hospitalization. The pre-RRT cohort was defined by the 27-month pre-RRT implementation period, outside of the nine-month range based on the hospital-identified implementation date of the RRT. The post-RRT cohort was defined by the 27-month period after implementation of the RRT.

**Study Outcomes Overview**

The aim of the study was to describe the differences in patient health outcomes (i.e. rates of cardiac arrests, cardiac arrest deaths, in-hospital mortality, prolonged length of stay and 30-day hospital readmission) before and after the implementation of RRTs within Washington State tertiary hospitals. As depicted within the Patient Safety Management Model, improved patient outcomes serve as a determinant of improved or effective processes and structures (Battles & Lilford, 2003). The next section describes
the results of a robust multivariate model used to examine differences between the pre-
implementation and post-implementation cohorts.

Binary logistic regression analysis was used for predicting the odds of dichotomous
study outcome variables based on a cohort variable and multiple covariates. Logistic
regression is especially useful for analysis of observational data when adjustments are
needed to reduce the potential bias resulting from differences in the groups being
compared (LaValley, 2008b). Each of the study outcomes (cardiac arrests, cardiac arrest
deaths, in-hospital mortality, prolonged length of stay and 30-day hospital readmission)
reported in this section was examined using binary logistic regression, using the enter
method for entering variables into this model. Based on observed cohort differences
multiple covariates including age, gender, and previous hospitalization, admission
through the ED, comorbidities and reason for hospitalization were controlled in this
analysis.

Hospitals’ specific study results are presented to describe and demonstrate the
outcome variability that occurred between the 12 hospitals included in this study. It is
important to interpret outcomes for individual hospitals with caution; each of the
outcomes occurring at the individual hospitals was notably underpowered. Previous
studies that draw population samples from single hospitals have repeatedly failed to show
differences because they too suffered from insufficient power. Previous evidence has
estimated that a sample size of 150,000 patients in both the before and after RRT
implementation cohorts would be required to achieve 80% power to detect a 5%
reduction in hospital mortality rates (Chan, et al., 2008). While the current study was
sufficiently powered for aggregated data analysis, individual hospital sample sizes were
not adequately powered to detect outcome differences between the pre-implementation and post-implementation cohorts.

**Outcome: In-hospital Mortality**

In-hospital mortality declined in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model (Table 4). Results show that patients in the post-RRT implementation cohort were less likely to experience in-hospital death than patients in the pre-RRT cohort (OR=0.89; 95% CI=0.86-0.92; p<0.001). Compared to the pre-RRT cohort, the absolute number of in-hospital deaths declined in the post-RRT cohort. There were 7178 deaths observed in the pre-RRT cohort (2.8%) and 7028 deaths observed in the post-RRT cohort (2.6%), representing a number needed to treat (NNT) of 625 patients. The NNT is an aggregate measure of benefit that represents the number of patients who would need to be treated to prevent one additional in-hospital death.

<table>
<thead>
<tr>
<th></th>
<th>In-hospital mortality</th>
<th>Sample (n)</th>
<th>%</th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-RRT cohort</td>
<td>In-hospital mortality</td>
<td>7178</td>
<td>2.8%</td>
<td>0.89</td>
<td>0.86 - 0.92</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Sample</td>
<td>258,843</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-RRT cohort</td>
<td>In-hospital mortality</td>
<td>7028</td>
<td>2.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sample</td>
<td>269,015</td>
<td></td>
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</tr>
</tbody>
</table>

Fully adjusted binary logistic model controlling for age; sex; admission through the Emergency Department, length of stay, and primary payer; 12-month count of previous hospitalizations; and Elixhauser comorbidity variables. Pre-RRT cohort defined as 27 months before the RRT implementation period. Post-RRT cohort defined by 27 months after the RRT implementation period. RRT implementation period defined by a nine-month range around hospital-identified implementation date of RRT.

Table 4. In-hospital mortality by cohorts among study hospitals in Washington State
Rates of in-hospital deaths varied among hospitals included in this analysis (Figure 5). In-hospital mortality was lower in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model in six hospitals. Compared to the pre-RRT period, none of the participating hospitals demonstrated an increased risk for in-hospital mortality in the post-RRT period.

Figure 5. The fully adjusted odds ratio (OR) of in-hospital mortality before and after RRT implementation.
**Outcome: Cardiac Arrests**

Cardiac arrests declined in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model (Table 5). Results show that patients in the post-RRT implementation cohort were less likely to experience cardiac arrests than patients in the pre-RRT cohort (OR=0.88; 95% CI=0.83-0.93; p<0.001).

Compared to the pre-RRT cohort the absolute number of cardiac arrests declined in the post-RRT cohort. There were 2493 cardiac arrests observed in the pre-RRT cohort (1%) and 2193 cardiac arrests observed in the post-RRT cohort (0.8%), representing a numbers needed to treat (NNT) of 667 patients.

<table>
<thead>
<tr>
<th>Cardiac arrest</th>
<th>Sample (n)</th>
<th>%</th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-RRT cohort</td>
<td>2493</td>
<td>258,843</td>
<td>1.0%</td>
<td>0.88</td>
<td>0.83 - 0.93</td>
</tr>
<tr>
<td>Post-RRT cohort</td>
<td>2193</td>
<td>269,015</td>
<td>0.8%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fully adjusted binary logistic model controlling for age; sex; admission through the Emergency Department, length of stay, and primary payer; 12-month count of previous hospitalizations; and Elixhauser comorbidity variables. Pre-RRT cohort defined as 27 months before the RRT implementation period. Post-RRT cohort defined by 27 months after the RRT implementation period. RRT implementation period defined by a nine-month range around hospital-identified implementation date of RRT.

Table 5. In-hospital cardiac arrests by cohort among study hospitals in Washington State
Figure 6. The fully adjusted odds ratio (OR) of cardiac arrests before and after RRT implementation

Rates of cardiac arrests varied among hospitals included in this analysis (Figure 6). Cardiac arrest rates declined in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model in five individual hospitals. Four of the hospitals reporting a reduction in cardiac arrests were the highest volume hospitals included in the study. The range of cardiac arrests in the top four hospitals for volume was 191-626 in the pre-RRT and 192-519 in the post-RRT cohort. One high volume hospital demonstrated an increased risk for cardiac arrests after the implementation of the RRT (Figure 6). The frequency of cardiac arrests among all 12 of the hospitals ranged from 38 to 626 in the pre-RRT cohort and 27 to 519 in the post-RRT cohort.
**Outcome: Cardiac Arrest Deaths**

The incidence of cardiac arrest deaths declined in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model (Table 6). Results show that patients in the post-RRT implementation cohort were less likely to experience a cardiac arrest death than patients in the pre-RRT cohort (OR=0.75; 95% CI=0.64-0.88; p<0.001). Compared to the pre-RRT cohort the absolute number of in-hospital deaths declined in the post-RRT cohort. There were 362 cardiac arrest deaths observed in the pre-RRT cohort (0.1%) and 282 cardiac arrest deaths observed in the post-RRT cohort (0.1%), representing a numbers to treat (NNT) of 2855 patients.

<table>
<thead>
<tr>
<th>Cardiac arrest deaths</th>
<th>Sample (n)</th>
<th>%</th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre RRT cohort</td>
<td>362</td>
<td>258,843</td>
<td>0.1%</td>
<td>0.75</td>
<td>0.64 - 0.88</td>
</tr>
<tr>
<td>Post RRT cohort</td>
<td>282</td>
<td>269,015</td>
<td>0.1%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fully adjusted binary logistic model controlling for age; sex; admission through the Emergency Department, length of stay, and primary payer; 12-month count of previous hospitalizations; and Elixhauser comorbidity variables. Pre-RRT cohort defined as 27 months before the RRT implementation period. Post-RRT cohort defined by 27 months after the RRT implementation period. RRT implementation period defined by a nine-month range around hospital-identified implementation date of RRT.

Table 6. In-hospital cardiac arrest deaths by cohort among study hospitals in Washington State

Cardiac arrest deaths declined in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model in four hospitals. The four hospitals reporting a reduction in cardiac arrests ranged from the third highest volume hospital to the lowest volume hospital included in the study.
The range of cardiac arrest deaths among the four significant hospitals ranged from 12 to 60 in the pre-RRT and 9 to 48 cardiac arrest deaths in the post-RRT cohort. No individual hospitals reported an increased risk for cardiac arrest death after the implementation of the RRT (Figure 7). The frequency of cardiac arrests deaths among all 12 of the hospitals ranged from 2 to 76 in the pre-RRT cohort and 4 to 64 in the post-RRT cohort.

Figure 7. The fully adjusted odds ratio (OR) of cardiac arrest deaths before and after RRT implementation
**Outcome: Prolonged Length of Stay**

In the fully adjusted binary logistic regression model, prolonged length of stay (PLOS) declined in the post-RRT cohort when compared with the pre-RRT cohort (Table 7). Results indicate that patients in the post-RRT implementation cohort were less likely to experience PLOS than patients in the pre-RRT cohort (OR=0.89; 95% CI=0.88-0.91; p<0.001). There were 100,223 patients who experienced PLOS in the pre-RRT cohort (38%) and 100,657 patients who experienced PLOS in the post-RRT cohort (37.4%).

<table>
<thead>
<tr>
<th>Prolonged length of stay (PLOS)</th>
<th>Sample (n)</th>
<th>%</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-RRT cohort</td>
<td>100,223</td>
<td>258,843</td>
<td>38%</td>
<td>.89</td>
<td>.88 - .91</td>
</tr>
<tr>
<td>Post-RRT cohort</td>
<td>100,657</td>
<td>269,015</td>
<td>37.4%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fully adjusted model controlling for age; sex; admission through the Emergency Department, length of stay, and primary payer; 12-month count of previous hospitalizations; and Elixhauser comorbidity variables. Pre-RRT cohort defined as 27 months before the RRT implementation period. Post-RRT cohort defined by 27 months after the RRT implementation period. RRT implementation period defined by a nine-month range around hospital-identified implementation date of RRT.

Table 7. Prolonged length of stay (length of stay 4+ days) by cohort among study hospitals in Washington State in a fully adjusted binary logistic model
A total of eight hospitals showed a statistically significant decline in PLOS in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model (Figure 8). Three out of the twelve hospitals showed a statistically significant increase in PLOS in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model. Hospital I (OR=0.70; 95% CI=0.67-0.73; p<0.05) and J (OR=0.68; 95% CI=0.64-0.71; p<0.05) showed the biggest decline in PLOS in the post-RRT cohort when compared with the pre-RRT cohort. Of the hospitals included in this study, Hospital I represents a middle range volume hospital while Hospital J represented the lowest volume hospital in the study.

Figure 8. The fully adjusted odds ratio (OR) of prolonged length of stay (PLOS) before and after RRT implementation
**Outcome: 30-Day Rehospitalization**

The rate of 30-day rehospitalization declined in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model (Table 8). Results demonstrated that patients in the post-RRT implementation cohort were less likely to experience 30-day rehospitalization than patients in the pre-RRT cohort (OR=0.97; 95% CI=0.95-0.98; p<0.001).

<table>
<thead>
<tr>
<th></th>
<th>30-day rehospitalization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 day rehospitalization</td>
</tr>
<tr>
<td>Pre-RRT cohort</td>
<td></td>
</tr>
<tr>
<td>Post-RRT cohort</td>
<td></td>
</tr>
</tbody>
</table>

**Table 8.** Thirty-day rehospitalization rates by cohort among study hospitals in Washington State in a fully adjusted binary logistic regression model

Compared to the pre-RRT cohort, the absolute number of 30-day rehospitalizations decreased in the post-RRT cohort. There were 143,750 30-day rehospitalizations observed in the pre-RRT cohort (55.5%) and 120,111 30-day rehospitalizations observed in the post-RRT cohort (44.6%).
Rates of 30-day rehospitalization varied among hospitals included in this analysis (Figure 9). Thirty-day rehospitalization declined in the post-RRT cohort when compared with the pre-RRT cohort in the fully adjusted binary logistic regression model in five hospitals. The variations in statistically significant rehospitalization rates did not appear to be influenced by hospital volume; the four hospitals represented low, middle and high volume. Compared to the pre-RRT period, none of the participating hospitals demonstrated an increased risk for 30-day rehospitalization in the post-RRT period.

Figure 9. The fully adjusted odds ratio (OR) rehospitalization before and after RRT implementation.
Overview and Summary

In the U.S., RRTs are a nurse-summoned, nurse-led function. This reflects not only operational imperatives and practicalities, but also the unique knowledge and bedside presence of nurses. The study reported here should be a bridge to the next generation of studies on RRTs, and these studies can and should have as principal investigators or senior collaborators nurse clinicians and nurse researchers. The nurse is the crucial component of the RRT process, from call to leadership, and understanding the complex, interacting variables that enhance RRT performance will best be understood by in-depth involvement of nurses.

There can be no doubt of the need for additional research to more fully understand RRTs. Based on initiatives from several healthcare organizations such as the Institute for Healthcare Improvement, the American Medical Association, and the Joint Commission (Commission, 2009; IHI, 2009), RRTs have become an expected standard of care. Despite that expectation, and the fact that RRTs have been in widespread use for more than seven years nationally, there is a surprising paucity of data about their effectiveness in the context of U.S. hospitals and the U.S. healthcare system. Few studies examining the relationship between implementation of RRTs and health outcomes have been performed in the United States, and no studies have explored the relationships between RRT implementations and patient health outcomes among multiple, geographically contiguous hospitals while controlling for multiple confounding variables.
A major strength of this study was the comprehensiveness of the data set used, which included information on index hospitalization, patient comorbid conditions, outcome measures, hospital demographics, combined with a survey that provided baseline organizational climate related to RRT implementation and utilization.

Data were gathered and analyzed for 527,858 inpatients before and after the implementation of RRT at 12 tertiary Washington State hospitals. Collectively, the hospitals in this sample were responsible for 40.4% of the state's discharges in 2009. Utilizing a fully adjusted binary logistic regression model, this study examined patient health outcomes pre- and post-RRT implementation for five major measures of patient outcomes: cardiac arrest, cardiac arrest death, in-hospital mortality, 30-day rehospitalization, and prolonged length of stay.

Findings from this research related to hospital readmission should be carefully considered based on the geographic context in which this study was conducted. Within Washington State, patients fare much better on readmission rates compared to patients hospitalized in other states (Goodman, Fisher, & Chang, 2011). For example, nationally, 20% of patients on Medicare are readmitted to the hospital within 30 days, while Washington State 30-day readmission rate is 14%. The results of improved patient outcomes after RRT implementation found in this study suggested that states with poorer patient outcomes could benefit even more from RRT implementation.

All five selected patient outcomes showed a statistically significant collective improvement (measured as a reduction) in the post-RRT cohort when compared to the pre-RRT cohort. These results provide the first empirical and most definitive verification
of what has been widely assumed but inconsistently documented in U.S. hospitals—that implementation of RRTs is associated with improved patient outcomes.

**Improved Outcomes at Select Hospitals**

The frequency of cardiac arrests among all 12 of the hospitals ranged from 38 to 626 in the pre-RRT cohort and 27 to 519 in the post-RRT cohort. The wide variation in range of cardiac arrests between individual hospitals might be explained by variations in hospital size, in the inclusion of do-not-resuscitate (DNR) cardiac arrests, as well as in varying coding practices used at individual hospitals. These considerations were beyond the scope of this study. Hospital ‘J,’ with only 38 reported cardiac arrests, was the smallest hospital while Hospital ‘D’ was the largest. The robust statistical methods used in this study controlled for covariates such as hospital size that might have otherwise affected reported outcomes.

The rates of cardiac arrest deaths also varied among hospitals included in this analysis and ranged from 2 to 72 in the pre-RRT cohort and 4 to 64 in the post-RRT cohort. Again, although the wide variation in range might be explained by both variations in hospital size and coding practices at individual hospitals, they cannot be validated within the parameters of this study. Hospital ‘C’ with only two reported cardiac arrest deaths was among the smallest hospitals while Hospital ‘D’ was the largest. It is important to understand that the statistical methods used in this study were adopted because of their capability to control for covariates such as hospital size.

Numerous factors have been identified as influencing the successful implementation and usage of RRTs (Bruckell, 2006). The commitment of the team members and the organizational and philosophical support from the hospital administration have been
shown to affect how an RRT is viewed by the staff, and may also influence how often the RRT is activated (Sakai & Devita, 2009). Whether hospitals were robust or challenged adopters of RRTs has also been linked to the concept of dose (Donaldson, et al., 2009; D. Jones, et al., 2006), which refers to the number of RRT calls. Other than a study question about education for RRT on the Phase 1 survey, this study did not measure the robustness of RRT adoption.

Results of previous research have demonstrated an association between the number of RRT calls within a hospital and better patient health outcomes (DeVita et al., 2004b). The calls per 1000 admissions reported in this study varied from 1.2 to 263 calls per1000 admissions. While the RRT utilization rates in the current study were similar, there were three notable exceptions. Hospitals ‘A’ ‘K’ and ‘D’ fell far outside the median of 47 calls per 1000 admissions, with 1.2; 222 and 263 calls per1000 admissions, respectively. The variance in calls at these institutions could not be attributed to hospital size. Rather, the variance in RRT calls signals that something is clearly different about the purpose being served by their RRTs, the criteria for summoning them, or the cultural norms within these hospitals related to RRTs. The results of this study were not designed to examine the pattern between RRT dose and improved patient health outcomes.

Research has shown that each hospital has its own local rules, which are part of the hospital culture. These rules can either amplify or dampen tendencies to summon the RRT (Shapiro, et al., 2010). Although many hospitals have adopted a scoring system to assist in early recognition of a patient’s deteriorating condition, there remains a dearth of evidence as to which system (if any) is the best predictor of risk in a deteriorating patient (Burch, Tarr, & Morroni, 2008). While some hospitals are attempting to utilize the
patient-level data found in electronic medical records (EMR), others continue to use paper-charted clinical indicators to track signs of patient deterioration. Unlike the standardized algorithms utilized in advanced cardiac life support (ACLS) to recognize and treat abnormal heart rhythms, wide variations in crisis detection currently exist within U.S. hospitals.

This study revealed useful and valid findings, and answered the research question related to the effectiveness of RRTs. A major strength of this study was its sample size, which provided adequate power to detect reductions in the patient health outcomes. Another strength was the geographic homogeneity of the sample. This study found statistically significant reductions in all five of the outcome measures in the post-RRT cohort, despite the fact that the five outcome measures varied between and among the individual institutions.

It is important to reiterate and emphasize that only the aggregated data had sufficient statistical power to reach these conclusions. Individually, none of the hospitals had a sample size large enough to have adequate power to detect even a modest improvement in any of the five patient health outcomes being examined in this study.

**Major Contributions to the Literature**

The concept of RRTs originated outside the U.S. and many of the early studies of effectiveness of these teams were performed in non-U.S. hospitals. The extensibility of such studies to the U.S. context is questionable, given the considerable differences in the methods and means by which medical care is delivered in healthcare systems outside the U.S. Many of the studies are now more than a decade old, further calling into question their applicability in the context of contemporary U.S. medical practices.
This study was designed to answer the need for research about the impact of contemporary RRTs on patient outcomes in U.S. hospitals. The choice of a group of 12 geographically contiguous Washington State hospitals for which there was an extensive, existing database of patient outcomes permitted a study design that provided a valid statistical base while minimizing confounding variables that would have resulted from selection of hospitals across a broader geographic area or a more complex socioeconomic mix.

It was estimated that a sample size of 150,000 patients in both the before and after RRT implementation cohort would be required to have 80% power to detect a 5% reduction in hospital mortality rates (Chan, et al., 2008). The current study exceeded this recommended quantitative threshold and included nearly as many patients \((n=527,858)\) as all of the combined studies previously included in the systematic review and meta-analysis \((n=604,475)\) by Chan et al. (2010). The sample size at the individual hospitals ranged from 29,774 to 70,967 patients before and after implementation of an RRT. This study selected cases in a contemporary time period with all hospitals having implemented their RRTs between 2004 and 2007, further strengthening the study findings.

RRTs are an example of an approach to care that was widely adopted based less on support in the research literature than on support by policy-influencing foundations, accreditation agencies, and others who became convinced of the inherent logic of RRT benefits. Acceptance of RRTs occurred long before any such benefits were shown by data being gathered, evaluated and published. Early identification and intervention for patients experiencing deterioration made sense conceptually and fueled the intuitive
appeal of RRTs. The results of this study provide the most statistically valid evidence to date that RRTs are effective in improving patient outcomes.

Previous studies used inconsistent, unmatched, or short pre- and post-RRT implementation periods (Bellomo, et al., 2003, 2004; Buist, et al., 2002; DeVita et al., 2004a). For example, one study chose a five-year pre-RRT period and a 1.8 year post-RRT period when measuring cardiac arrest and cardiac arrest death rates (DeVita, et al., 2004a). Although a longer time period is useful when considering contemporaneous confounding variables due to secular trends, there are numerous improvements in care that occur during a five-year period that could have influenced the improvement in patient health outcomes besides the implementation of the RRT. The majority of studies used follow-up periods that were less than eight months in duration, and thus did not adjust for seasonal variations in event rates (Bellomo, et al., 2003, 2004; Bristow, et al., 2000; Priestley, et al., 2004). The inclusion of a long-term (27-month) post-implementation follow-up with identical pre-implementation and post-implementation periods further strengthened the design of this study.

Hospitalized patients differ in their severity of illness, and increased severity of illness is associated with an increased risk of adverse health outcomes (DeVol & Bedroussian, 2007). Among the most prominent adverse health outcomes addressed in the general literature are cardiac arrest, in-hospital mortality, prolonged length of stay and 30-day readmission (Chen, et al., 2009; Daly, et al., 2000). In the RRT literature the most common reportable outcomes include cardiac arrest, in-hospital mortality, and unnecessary admission to the ICU (DeVita, et al., 2006).
Patient safety research has focused on finding solutions that improve patient outcomes while discriminating between the natural course of a patient’s condition and a potentially reversible adverse event (Daly, et al., 2000; de Vries, et al., 2008). Recognizing and controlling for severity of illness (referred to antecedent conditions) is also an important characteristic in the Patient Safety Management Model. Controlling for measures of comorbid conditions is critical in the design of a robust study. No studies prior to this one used a robust method such as the Elixhauser (Elixhauser, Steiner, Harris, & Coffey, 1998; Southern, et al., 2004) to measure the burden of comorbid conditions on study outcomes.

The results confirmed what has been found in some studies, while contradicting or in some cases clarifying what other studies reported about specific outcome variables. In many cases, direct comparisons are difficult or impossible owing to differences in medical systems (U.S. vs. non-U.S.), methodology, outcome measures, depth of information, RRT team composition, calling criteria, and other factors (see “Limitations of the Study,” below).

Although RRTs have been widely embraced in practice, research results on their effectiveness have been varied and often conflicting, as shown above. Varying results regarding RRT effectiveness is hardly a surprise. RRTs are medically and organizationally complex undertakings subject to substantial variations in their implementation, adoption, and utilization within and between hospital cultures. In addition, there is no consensus or enforced standard on the criteria to be used for data collection and analysis of outcomes related to RRT implementation. This makes comparisons either difficult or impossible, especially with the time periods involved...
being so lengthy that medical practice and standards of care were subject to potential pre-
post substantial change. Explanations for the conflicting results may also be found in the 
varying study designs intended to measure RRT effectiveness.

For the five outcome variables evaluated in this study, the findings and their 
confirmation or refutation of the literature were as follows:

**In-hospital mortality.** The results of this study validated the work of several 
previous studies that reported a reduction of in-hospital mortality after the 
implementation of a RRT (Bellomo, et al., 2003; Hillman, et al., 2005; Priestley, et al., 
2004), while refuting the findings of studies that have found little or no evidence of such 
a reduction (Buist, et al., 2002; Hillman, et al., 2005). In this study, the data demonstrated 
a statistically and clinically significant reduction in mortality in the post-RRT cohort 
when compared with the pre-RRT cohort (OR=0.89; 95% CI=0.86-0.92; p<0.001). These 
findings contradicted the most recent RRT meta-analysis, which showed no overall effect 
on hospital mortality (Chan, et al., 2010) as well as the MERIT study, a cluster 
multicenter RCT in Australia, which failed to show a significant benefit of METs on 
cardiac arrest, unplanned ICU admissions, or unexpected death (Hillman, et al., 2005).

**Cardiac arrests.** The results of this study supported the work of several previous 
studies, which reported a reduction in cardiac arrest rates after implementation of an RRT 
(Bellomo, et al., 2003; Goldhill, et al., 1999). This study found a statistically significant 
reduction in rates of cardiac arrests within the post-RRT cohort (OR=0.88; 95% CI=0.83-
0.93; p<0.001) when compared with the pre-RRT cohort.

The first published report documenting MET implementation in a U.S. hospital was a 
retrospective analysis of cardiac arrest rates comparing the five-year pre- and 1.8 year
post-MET time periods. The results showed that an increased use of MET was followed by a significant decrease in the incidence of cardiac arrests (DeVita, et al., 2004a). Utilizing a case mix adjustment to control for secular trends demonstrated no significant difference in case mix severity among study patients.

A small six-month prospective study reported the results of 69 patient-at-risk team (PART) assessments on 63 patients. There was only one cardiac arrest in a patient seen by the PART, while there were 21 such events for those in a group of comparable size not seen by the PART. However, the PART study had significant limitations including insufficient power, unadjusted rates, no control of comorbid covariates, poorly defined implementation period and no acknowledgement of any limitations (Goldhill, et al., 1999)

While previous studies had similarities to the current study in terms of observing reductions in cardiac arrests after the implementation of an RRT, there are important methodological differences. Previous studies did not utilize comorbidity risk adjustment methods to account for the comorbid conditions and severity of illness covariates that are not related to RRT effectiveness. There was also inconsistency in the length of the pre- and post–MET time periods.

This study also challenged early studies that did not show a difference in cardiac arrests after the implementation of a MET (RRT). Bristow et al. (2000) used a prospective cohort design to compare a hospital with a MET (RRT) and two hospitals that had only conventional code teams. The rollout period or implementation strategies for the MET were not reported. The study did, however, adjust for patient demographics and diagnostic characteristics based on ICD-9-CM codes used for the principal diagnosis
and the stay diagnosis only. The number of admissions between the hospital with the MET and the two hospitals without a MET were not well matched, and the hospital settings were not described or compared. There were no statistically significant differences in cardiac arrest rates after case-mix adjustment between the three hospitals. However, results did indicate a significantly reduced rate of unanticipated ICU admissions at the hospital with the RRT.

The present study utilized data from a single database to examine outcomes from 12 similarly functioning tertiary hospitals in Washington State. This study, representing a fairly homogeneous sample in terms of facility characteristics, was designed to measure improvement over a comparatively long period of time (27 months prior to implementation of RRT and 27 months after RRT implementation). The length of this time period provided a consistent and well-defined criterion for the pre- and post-RRT cohort assignment at all hospitals.

**Cardiac arrest deaths.** The findings of this study found a significant reduction in cardiac arrest deaths among patients in the post-RRT cohort (OR=0.75; 95% CI=0.64-0.88; p<0.001) when compared to the pre-RRT cohort. In a prospective (four month) before-and-after trial in a single tertiary referral hospital, findings demonstrated a reduction in the unadjusted rates for cardiac arrest deaths after the introduction of a MET (Bellomo, et al., 2003). The authors considered the effect of seasonal variation by obtaining data on cardiac arrests and hospital mortality for the same four months, two years before introduction of the MET (Bellomo, et al., 2003).

**Prolonged length of stay.** This current study found a significant reduction in prolonged length of stay (PLOS) in the post-RRT cohort (OR=0.89; 95% CI=0.88-0.91;
p<0.001) when compared with patients in the pre-RRT cohort. Length of stay is recognized as an important measure of health care consumption and a substantial driver of hospitalization costs (A. Lee, et al., 2003). A reduction in hospital length of stay has important implications for reducing the risk of adverse events occurring in the acute care setting. PLOS is a complex concept that implies a longer-than-usual hospital stay (Silber et al., 2009) and may be a consequence of either patient complications, deficiencies in care delivery, unclear or imprecise discharge criteria, or local practices including legacy attitudes on the part of a limited number of physicians.

Two earlier studies conducted outside the U.S. examined the relationship between a MET/CCO and length of stay as a primary outcome measure and found that LOS was increased in the post-MET/CCO cohort (Buist, et al., 2002; Priestley, et al., 2004). More than a decade ago, another study examined the incidence of LOS after being seen by a patient-at-risk team and did not find a statistical difference in LOS between the groups (Goldhill, Worthington, & Mulcahy, 1999). No previous studies have examined the effect of RRT implementation on PLOS while controlling for multiple confounding variables.

**Thirty-day rehospitalization.** The results of this study are the first to report a decline in 30-day rehospitalization in the post-RRT cohort (OR=0.97; 95% CI=0.95-0.98; p<0.001) compared to patients in the pre-RRT cohort. No previous studies examined RRT implementation with the patient health outcome of rehospitalization or 30-day rehospitalization.

One explanation for the lack of previous reporting is that rehospitalization is a difficult measure to capture. For example, although it is relatively easy to examine rehospitalization to the same hospital, it is far more challenging to following a patient’s
return to any hospital within the state, and previous studies have not had access to such data sets (Bellomo, et al., 2003, 2004; Bristow, et al., 2000; Buist, et al., 2002; Priestley, et al., 2004). The use of the CHARS data set allowed the inclusion of rehospitalization to any hospital within the state of Washington, providing a clinically more meaningful look at this outcome measure than has previously been reported in the literature.

Another explanation for the lack of reporting may be that RRTs were introduced as a strategy to anticipate and prevent cardiac arrests (DeVita, et al., 2006). Identification of rehospitalization has important implications, because unforeseen rehospitalization may be the result of an adverse event during the initial admission (Daly, et al., 2000). Also, with an increased emphasis in the U.S. on preventing rehospitalization, it is important to understand the role RRTs play in achieving that endpoint.

Clinical Implications and Application of Theoretical Model

The findings of this study were well guided by the Patient Safety Management Model, where the RRT represents a modification in a care process within the hospital (structure) where care is provided, with the ultimate goal of improving patient outcomes while taking into consideration all of the comorbid and antecedent conditions that influence outcomes outside of changes in process or structure (Battles & Lilford, 2003).

While previous evidence on RRT effectiveness was conflicting, it is clear that RRTs are an initiative that is here to stay. This study provided observational clinical verification of improved patient health outcomes in hospitals where RRTs were utilized, and provided a baseline of evidence against which it is possible to measure the time, effort, and economic investments required to implement and sustain RRTs.
The Role of Nursing in RRTs

Nurses are the core element in the majority of RRTs in the U.S. What happens in terms of RRT utilization will have a major impact on nurses and nursing. RRTs might very well represent one of the biggest innovations in nursing history. RRTs have given nurses a new and commanding leadership role in treating critically-ill patients outside of the ICU; they have created new treatment paths and options for floor nurses; and they have the potential to improve patient outcomes.

The implementation of RRTs within the U.S. has put nurses in a crucial leadership role and has redefined their role within the healthcare hierarchy. This leadership role highlights a major theme in the Institute of Medicine’s report—that the individuals involved in the delivery of healthcare have not kept up with the rapidly changing world of medical science and technology. Much of the lag in delivery has been attributed to clinicians not remaining current with the latest science and best practices (Iglehart, 2009; Salmond, 2007).

There is no argument about the need for a paradigm shift from an opinion-based practice to one that is evidence-based. RRTs as they exist today represent more the former than the latter. The RRT findings in this study point to an opportunity for nursing to take a leading role in the clinical decision-making of critically ill patients. This line of thinking is congruent with the new IOM report (Committee on the Robert Wood Johnson Foundation Initiative on the Future of Nursing, 2011) which makes it clear that nurses should be practicing to the full extent of their education, recognizing that certain competencies are necessary for sustained improvement in both the quality and safety of our health care systems.
The existence of an RRT has the potential to improve the entire nursing workflow, because nurses have an option for higher-level assistance that did not previously exist in the hospital setting. RRTs are positioned to assure and reassure the nurses on the floor that they are not alone and do not have to wait until someone is so compromised that the only choice is to call a code.

RRTs enhance the importance of a floor nurse's decisions and autonomy. Their very existence should encourage nurses to intervene earlier and more aggressively, because now they have an option for doing so. RRTs represent a patient-centered approach to care that depends on teamwork, collaboration, evidence-based practice, and informatics–each of which is a key element in the IOM report (2011). The authors of the IOM report acknowledge the need for developing competencies within new care delivery models. RRTs represent a relatively new care delivery process whose effectiveness has the potential to be strengthened from standardization in the area of calling criteria and competencies of those that use them. This makes the role of both the RRT and the floor nurse more important, because they are linked in a tight feedback loop in which neither succeeds without the success of the other.

Aimed at promoting the best patient outcomes, evidence-based practice has been defined as “the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual or groups of patients” (Sackett, 1996). This multidisciplinary definition challenges everyone involved with delivery of care to incorporate clinical expertise with clinical evidence. This definition has considerable applicability to RRTs and nursing. With RRTs representative of a predominantly nurse-
led intervention, nursing must continually strive to combine the latest science with the best practice.

The clinical implications of the RRT from a nursing standpoint extend beyond just assisting in emergency situations. RRT nurses are in a position to also provide education and support for nurses on best responses to specific clinical situations. In this role, RRTs serve as a mobile educational resource from which every nurse can learn, thus offering another real-life venue for education and skill improvement. To this end, there is a need for future research in the area of determining well-defined criteria for summoning the RRT that calls upon the knowledge and expertise of nurses; development of ongoing education supporting and expanding this knowledge and expertise and the effects of RRT on nursing workflow (process) and outcomes.

The Patient Safety Management Model also proposes a reciprocal relationship between the impact of RRTs on patient outcomes and RRTs impact on nurses. While it is everyone's goal to have optimal outcomes, the selected model allows for the understanding that sometimes death is an optimal outcome (Battles). Future RRT success will be determined by the attitudes and investment of the nursing profession. Where RRTs are accepted, supported, and seen as a valued part of the team there will be quicker adoption, better use of resources, and better outcomes for patients. The nursing profession can serve its own ends best by leading the way in RRT research.

**Limitations**

There are methodological and analytical limitations in this study that must be understood in order to properly evaluate the study findings. This study used observational data, so it is difficult to exclude the possibility that unmeasured confounding factors
might have influenced study results. For example, improved outcomes in the post-RRT time period might have been the result of changes in patient care and improvements in technology and treatment options; which might have influenced the improvement in outcomes observed during later time periods in this study. However, the impact of these phenomena was minimized by selecting cases in a contemporary time period influenced by the knowledge that all study hospitals implemented their RRTs between 2004 and 2007.

The use of a contemporary cohort further strengthens the study findings. The use of retrospective data forgoes the ability to define variables and standardize data gathering. The retrospective nature of these data also makes it difficult to exclude hidden biases. For example, the CHARS database did not have unique identifiers for the particular patients who received RRT interventions. As a result, the improved outcomes could not be linked to actual patients who received an RRT intervention, nor was it possible to identify which patients who died in the hospital had an existing do not resuscitate (DNR) status, which may explain some of the variation in number of cardiac arrests and cardiac arrest deaths at the individual hospitals.

However, controlling for multiple comorbidities with the use of the Elixhauser method (Elixhauser, et al., 1998) did not negate the impact of RRTs on the selected patient health outcomes. The index hospitalization was limited to the study timeframe and did not necessarily reflect an actual first hospitalization. The analysis of outcomes at multiple hospitals provided a sufficiently powered sample size, and internal validation using a split-file analysis to randomly assign derivation and validation cohorts lessened these limitations and increased confidence in the findings.
Although outcomes may have improved over time, it is also well known that patient acuity has continued to rise and patients hospitalized today are sicker than those hospitalized in the past. Patients are living longer, which means that they are often living with multiple comorbid conditions (Aiken, et al., 2008). Generally speaking, many of the patients on general medical wards today would have been in the ICU 20 years ago, and many of the critically ill patients alive in an ICU today would have died 20 years ago. In order to account for changes in patient acuity and severity of illness, the current study controlled for severity of illness (comorbidities, admission through the ED, length of stay, reason for hospitalization), providing further confidence in the reported findings.

The limitations described here are characteristic of the limitations confronted when analyzing administrative data sets. However, such analyses offer a persuasive design for evaluating the effectiveness of RRTs on improving patient health outcomes in the hospital setting. The study findings should be helpful to hospital administrators, rapid response team members and local healthcare policymakers as they endeavor to improve the standardization and effectiveness of these teams.

**Future Research Directions**

This study found that implementation of RRTs was associated with substantial improvements in five patient health outcomes. The results of this study suggested that RRTs may be an effective strategy for improving patient health outcomes in the acute care setting. One of the ultimate goals for RRTs should be standardization, because with that comes best practices, consistency, trainability, optimal outcomes for all, and a standard against which to evaluate any specific hospital and the performance of its RRT. However, RRTs are not going to achieve national standardization until there is more
thorough assessment and data gathering on the processes associated with RRTs. It would be unreasonable to focus on standardization of RRTs without first knowing what the standard should be, or without determining what works and what does not work. These decisions must be based on evidence-based practices combined with expert clinical experience.

Until now, decisions about RRT effectiveness have been based on methodologically-compromised research or have rested heavily on studies done in other countries that use different healthcare delivery models. Previous studies are thus of questionable utility in shaping what RRTs in the U.S. should be. This study is significant because it takes us past one of the highest hurdles, which is answering the question, "Are RRTs associated with better outcomes?" They are, at least in the setting of tertiary hospitals in Washington State and given the limitations of the study previously discussed.

The improved patient outcomes associated with this study pave the way for future research to examine the structure and processes of RRTs in an attempt to answer the following questions:

- How should we monitor vital signs in hospitals to ensure early identification of 100% of the patients who are at risk of deterioration?
- What should be the necessary skills and experience of the responding clinicians?
- What is the reliability of the various calling criteria?
- What is the credentialing and scope of practice of the lead RRT responders?
- What is the training and ongoing education of those activating the RRT?
The findings of this study are also primed for future comparative effectiveness research (CER) for the purpose of comparing alternative methods used to improve the delivery of care (Freburger & Carey, 2010). Comparative effectiveness research has several future directions with respect to addressing the various characteristics associated with RRT standardization and the effect on patient health outcomes. Studies linking actual patients who have received an RRT intervention with actual outcomes may let us answer the questions above through further examination of team membership, calling criteria, and organizational structure and processes.

A future study designed to look at the credentialing, scope of practice and ongoing education would yield valuable information regarding RRT structure and process. Studies designed to examine interventions specific to patient conditions and the use of treatment algorithms may provide standardization among the interventions that can be provided by the RRT. Studies designed to explore the area of electronic notification based on commonly captured patient level data in the EMR might reveal valuable information related to physiological monitoring of patients in danger of clinical deterioration.

Finally, studies in other geographical locations such as states with poorer patient outcomes and studies that examine other hospital contexts, such as lower-volume facilities, rural facilities, and hospitals serving lower-acuity patients are needed. Research that include standardized data categories and collection methods would enhance our understanding of RRT effectiveness. Performing such studies between Magnet, in-process (hospitals seeking Magnet recognition), and non-Magnet organizations may also reveal differences in RRT structure, process or effectiveness. The current research should be replicated in hospital settings that vary by size, patient acuity level, and geography.
Conclusion

Do RRTs save lives or reduce morbidity? It seems a remarkably straightforward question, as well as a profoundly important one. Yet it is a question that has proved extraordinarily challenging to answer in a definitive manner and that to date has not been adequately answered for U.S. hospitals. This study fills some of the knowledge gaps, resolves or explains some of the inconsistencies in the conclusions of prior studies, and identifies what would be needed to move us closer to knowing whether RRTs are attaining their objectives.

This study is the first to show statistically significant associations between implementation of an RRT and improvement in five important patient health outcomes: in-hospital mortality, cardiac arrest, cardiac arrest death, prolonged length of stay and 30-day rehospitalization rates. As such, this research provides some degree of resolution about the conflicting data that have appeared to date, and provides a strong positive signal that there is value in RRTs that make them worth creating and sustaining.
Bibliography


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Appendix
Appendix A
Institutional Review Board Certification of Exemption

Hello Kenn Daratha and Gail Salvatierra,

This is to notify you that the IRB Exempt Application, IRB #12488, entitled, "The Relationships between Rapid Response Team Interventions and Patient Health Outcomes" does not require IRB oversight. This determination was made for the following reason:

The study does not involve human participants. At 45 CFR 46.102(f), 'Human Subject' is defined as: 
"... a living individual about whom an investigator (whether professional or student) conducting research obtains
(1) Data through intervention or interaction with the individual, or
(2) Identifiable private information."

The data you are collecting is about hospital and RRT policies, procedures and methods of evaluation, not about the respondent or other living individuals.

You may perform the study, as it was submitted, without IRB oversight. The application has been withdrawn from IRB consideration. The department and faculty will have the responsibility to oversee the study.

IMPORTANT: This study has NOT been approved by the IRB. Please remove all statements of IRB approval from study materials.

If you have questions or concerns, please call me.

Thank You,
Institutional Review Board
Patrick Conner

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3/27/2012
March 28, 2012

To Whom It May Concern:

I am a faculty member at the Washington State University College of Nursing. I am guiding Ms. Gail Salvatierra in her doctoral research examining health outcomes for hospitalized patients before and after implementation of Rapid Response Teams (RRT) in Washington State hospitals. We would both greatly appreciate you taking a few moments to tell us about the implementation of RRT in your hospital. If you have any questions concerning this research please contact me at kdaratha@wsu.edu or (509) 324-7405.

My name is Gail Salvatierra and I am a nursing doctoral student at Washington State University. I am studying the implementation and standardization of rapid response teams in Washington State hospitals. The participation of each hospital is vital to the success of this project, and your support of this research effort would be very greatly appreciated.

I have attached the short survey that contains questions regarding the implementation and function of your rapid response team. Please forward this survey to your institution’s rapid response team champion, or the person most familiar with this team. The individual completing the survey should do so anonymously. At our request, the results of the research will be shared with your institution upon completion of the project.

Thank you very much for your time and consideration. Please do not hesitate to contact me if you have any questions or comments.

Sincerely,

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Appendix C
Rapid Response Survey Titled *Timing And Processes Related To Implementation Of Rapid Response Teams*

Timing and Processes Related To Implementation of Rapid Response Teams

Hospital name

Thank you for taking the time to answer the following questions. Please answer the questions as completely as possible.
You can type your responses in the shaded areas, save the document, and email the completed document to gail.salvatierra@email.wsu.edu. You can also print the document and mail a hard copy to Gail G. Salvatierra PO Box 1724, Silverdale, WA 98383. Feel free to contact me if you have any questions about this questionnaire.

1. What month and year was your hospital’s RRT team first implemented?
   - Month ___________________ Year __________

2. What was the RRT implementation educational plan for the staff?
   - [ ] Formal mandatory classes
   - [ ] Informal classes (i.e. staff meetings)
   - [ ] Hospital newsletters, e-newsletters, flyers
   - [ ] Other (explain) ___________________________

3. Who can activate the RRT?
   - [ ] Anyone (including patients and families)
   - [ ] Anyone except patients and families
   - [ ] Only professional personnel, e.g. RN, MD, RT, PT, etc.
   - [ ] Other (describe) ___________________________

4. Which of the following personnel is/are normally part of the RRT team?
   - [ ] Critical care or ED nurse
   - [ ] Respiratory therapist
   - [ ] MD (including house staff)
   - [ ] ACLS (or equivalent) certified nurse
   - [ ] Other (describe) ___________________________
5. Which triggers for calling the RRT best describes the one in use at your hospital?
   □ Modified early warning system (MEWS)
   □ Clinical indicators only
   □ Both clinical and qualitative indicators
   □ Other (describe) ____________________________

6. How is the RRT initiated?
   □ Cell phone
   □ Pager
   □ Overhead page
   □ Other (describe) ____________________________

7. What equipment does the RRT team initially bring to the bedside?
   □ None
   □ Crash cart only
   □ Crash cart and EKG machine
   □ Other (describe) ____________________________

8. What is the goal for response time?
   □ <5 minutes
   □ < 10 minutes
   □ Other (describe) ____________________________

9. How many RRT calls does your institution average per month? ____________

10. How does your institution measure RRT success?
    □ In-hospital cardiac arrests
    □ In-hospital mortality
    □ Unnecessary transfers to the ICU
    □ Other (describe) ____________________________________________

11. Does your institution use failure to rescue as a quality indicator?
    □ Yes
    □ No

    If yes, how do you measure this?
    ________________________________
12. Do you have a committee within your institution that examines all code events and code outcomes?

☐ Yes
☐ No

If yes, please describe the committee and its purpose.

13. Is there anything else you’d like to tell me about your hospital’s RRT implementation?