DISSERTATION

# RISK ADJUSTED CRITICAL CARE PATIENT OUTCOMES:

# A COMPARATIVE ANALYSIS OF CRITICAL CARE STAFFING,

# TELE-ICU ADOPTION, AND ICU PERFORMANCE IN RELATION TO

# BEDSIDE STAFFING AND ENGAGEMENT WITH TELE-ICU

Submitted by

Helen Allison Hawkins

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Doctoral Committee:

Advisor: Marlene Strathe

Thomas Chermack
Gene Gloeckner
Travis Maynard

ABSTRACT

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Telemedicine in a hospital intensive care unit, or tele-ICU, allows board-certified, critical care intensivist physicians and nurse practitioners to monitor multiple ICU patients twenty four hours a day, seven days a week (24/7) via a remote command center equipped with a network of audio-visual equipment and computer systems that provide real time access to patient data (Goran, 2012). Hospitals implement tele-ICU to address the increasing scarcity of trained intensivist resources (Jarrah & Van der Kloot, 2010), to provide improved safety through redundancy, and to enhance outcomes through standardization (Goran, 2010; Rufo, 2011).

Whether at the bedside or via tele-ICU, staffing an ICU with board certified intensivist physicians is a best practice recommendation that has been shown to improve patient outcomes such as mortality and length of stay (Young, Chan, Lu et al., 2011). The purpose of this study was to evaluate multiple ICUs from a single U.S. hospital system in 2012 to determine if there were significant differences in the levels of adoption of tele-ICU and if so, assess the impact of varying levels of adoption on patient outcomes, specifically risk adjusted length of stay and observed versus expected mortality. Tele-ICU adoption was defined as the decision of ICU staff to make full use of tele-ICU resources to proactively co-manage patient care and ensure best practice adherence. Other ICU organizational factors such as bedside intensivist staffing pattern, ICU leadership effectiveness, and ICU employee engagement were also evaluated.

Study results indicated significant differences in the level of adoption across the eight ICUs in the study. ICUs with low tele-ICU adoption had less than one order per patient stay compared to nearly 10-12 orders per patient stay for the ICUs with the highest levels of adoption. Significant differences were also found in both ICU and hospital observed versus expected patient lengths of stay based on level of tele-ICU adoption. A calculation was proposed and used to assess the observed versus expected mortality at the patient level across the groups based on level of adoption. Although the results mirrored the trend found in the length of stay results, differences were not significant. The study also found that ICUs with the lowest level of tele-ICU adoption and the longest lengths of stay were the ICUs staffed with intensivists at the bedside 24/7.

Findings from this study suggested that the level of adoption of tele-ICU should be taken into account in future studies that evaluate patient outcomes. Future research should also evaluate the root causes of lack of tele-ICU adoption, and attempt to validate the findings in this study that patient outcomes are better when tele-ICU is fully adopted. Future studies should also attempt to measure and validate the costs and benefits of tele-ICU in conjunction with ICU staffing patterns, best practice adherence, and other organizational performance constructs that impact both the bedside and tele-ICU staff such as teamwork, culture, climate, communications, and collaboration. Studies that evaluate the optimal mix of ICU intensivist staffing should take into account the existence of tele-ICU, along with the level of adoption by bedside staff, as a component of the overall ICU staffing model.

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## DEFINITION OF TERMS

APACHE®: Acute Physiological and Chronic Health Evaluation. Predictive scoring system for assessing patient outcomes that is commonly used to measure ICU performance. Includes severity-adjusted mortality and length of stay predictions based on the acute physiology score in conjunction with the admission source, admission diagnosis, age and chronic health items.

CPOE: Computerized Physician Order Entry. Electronic order entry system used by physicians to order any procedures, tests, etc. for patients. The time, date, initiator, and details of the order are captured as part of the patient's electronic medical record.

EMR: Electronic Medical Records. Computerized medical record created in an organization that delivers care, such as a hospital that can be easily viewed, shared, and updated by the various providers for a patient.

ICU: Intensive Care Unit. Department within a hospital that delivers critical care to patients.

IDN: Integrated Delivery Network. An integrated network of healthcare facilities and providers that work together to offer a continuum of care to a specific market or geographic area.

Patient Protection and Affordable Care Act (PPACA): U.S. legislation that puts in place comprehensive health insurance reforms that will hold insurance companies accountable, lower costs, guarantee choice, and enhance quality health care for all Americans.

Tele-ICU: Telemedicine for intensive care units. Remote delivery of critical care by trained intensivists using audio, video, and electronic links from a central command center to assist bedside caregivers in patient monitoring, best practice adherence, and delivering care plans using a standard series of guidelines for treating critical care conditions.

# CHAPTER ONE: INTRODUCTION

With the Supreme Court's ruling to uphold the Patient Protection and Affordable Care Act (PPACA), healthcare reform in the United States is inevitable. The rising demand for healthcare, the aging population, the need for improved technology and services, labor costs, and legal issues are among the many factors that continue to drive increases in U.S. healthcare costs (Appleby, 2012). PPACA has provisions that focus on reducing healthcare spending while improving the quality of care by addressing issues such as the inefficiencies that lead to patient complications and hospital readmissions (Council of Economic COEA, 2013). Many U.S. hospitals have long focused on ways to increase efficiency and quality in healthcare delivery in an effort to improve patient outcomes and reduce costs.

Telemedicine has been gaining popularity as a cost effective method of delivering quality patient care. The American Telemedicine Association suggested that PPACA will accelerate the development, adoption, and deployment of telemedicine and similar technologies. For example, funding for major telemedicine initiatives by the Center for Medicare and Medicaid Innovation (CMMI), which has invested heavily in telemedicine in recent years, is still available through PPACA since telemedicine is considered crucial for programs such as managed and accountable care (American Telemedicine Association, 2012).

According to the Society of Critical Care Medicine (SOCCM), critical care medicine costs in 2005 represented approximately 13.4% of hospital costs, 4.1% of national health expenditures, and 0.66% of U.S. gross domestic product (SOCCM, 2013). Most critical care patients are treated in an Intensive Care Unit (ICU), one of the most expensive cost centers in hospitals and a primary target for quality initiatives that can improve patient outcomes. When suggesting interventions to revolutionize the quality of care in the ICU, Bauman and Hyzy

(2012) noted that bringing quality improvements to the ICU is especially challenging due to the complexities of the ICU organization and the high frequency of death and suffering. Areas for improvement must be proactively identified, meaningful clinical outcomes must be defined, and the effectiveness of change must be measured. ICU management and staff should be held accountable for patient outcomes and adherence to quality standards. They should implement evidence-based best practices, such as checklists, protocols, and care bundles, along with state of the art health care information technologies (HIT), and ensure the efficient organization of care delivery. HIT has the potential to improve the quality of care in the ICU by improving safety, increasing efficiency, decreasing clinician workload, and ultimately reducing costs (Bauman & Hyzy, 2012).

Telemedicine in the ICU (tele-ICU) is considered a form of HIT that allows board-certified, critical care intensivist physicians and critical care nurse practitioners to monitor multiple ICU patients twenty four hours a day, seven days a week (24/7). Tele-ICU is generally delivered via a remote command center equipped with a network of audio-visual equipment and computer systems that provide real time access to patient data. This includes a camera that can be controlled by the tele-ICU practitioner, enabling them to view an ICU patient in their room (Goran, 2012; Kahn, Hill, Lilly et al., 2011; Khunlertkit & Carayon, 2012; Moeckli, Cram, Cunningham et al., 2013). When given the authority to do so, tele-ICU intensivists can monitor patient instability and lab results, make diagnoses, order treatments, and even implement patient interventions through the control of life-support devices (Kumar, S., Merchant, & Reynolds, 2013).

Some of the main reasons for implementing tele-ICU are to address the increasing scarcity of trained intensivist resources (Jarrah & Van der Kloot, 2010), to provide improved safety through redundancy, and to enhance outcomes through standardization (Goran, 2010; Rufo, 2011). The benefit of tele-ICU should be assessed based on the value provided to the patients being served and how it is utilized to change or improve processes of care that positively impact patient outcomes (Lilly & Thomas, 2010).

Although the cost of tele-ICU is substantial, and the impact on hospital costs and profitability is still unclear (Kumar, G., Falk, Bonello et al., 2013), a meta-analysis of 13 before-and-after studies involving 35 ICUs indicated that tele-ICU coverage is associated with lower ICU mortality and ICU length of stay (Young, Chan, Lu, et al., 2011). Since ICU length of stay (LOS) is the most important determinant of variable cost in the ICU (Rapoport, Teres, Zhao et al., 2003), shortening LOS without compromising patient outcomes is one area where tele-ICU might enable cost savings.

The Leapfrog Group, a member's collective focused on improvements in the safety, quality, and affordability of health care in the U.S., and the American College of Critical Care Medicine (ACCM) have both made best practice recommendations for staffing the ICU with board-certified critical care intensivist physicians (Bauman & Hyzy, 2012; Society of Critical Care SOCCM, 2013; The Leapfrog Group, 2011). Research has indicated that board-certified intensivist staffing can reduce the risk of patients dying in the ICU by 40% (The Leapfrog Group, 2011).

In a review of 27 studies comparing patient outcomes in high intensity, closed ICUs (mandatory intensivist physician on staff, meets Leapfrog standards) versus low intensity, open ICUs (no intensivist on staff or elective intensivist consultation), it was found that high intensity staffing was associated with reduced mortality and length of stay in both the hospital and ICU (Pronovost, Angus, Dorman et al., 2002). When looking specifically at the benefits of nighttime intensivist staffing along with high-intensity daytime staffing, a more recent study did not show any reduction in risk-adjusted in-hospital mortality, and suggested that despite the recommendations of the Leapfrog Group, a blanket endorsement of 24/7 onsite intensivist coverage was premature (Wallace, Angus, Barnato et al., 2012).

Many U.S. hospitals will face difficulty adhering to the recommended best practice for ICU staffing due to the shortage of intensivist physicians in the U.S., a trend that is expected to worsen as demand for ICU care increases primarily due to the expanding aging population (Kumar, S., Merchant, et al., 2013). Fewer than 15% of ICUs in the U.S. today are able to provide intensivist care (Goran, 2010). Assuming certain requirements are met (shown in Appendix A), tele-ICU intensivists can be used to achieve compliance with the Leapfrog ICU Physician Staffing (IPS) standard and ACCM recommendations (NEHI, 2007). Tele-ICU can also deliver much needed high-level expertise to remote and rural areas that have minimal availability of intensivists (Bauman & Hyzy, 2012).

Tele-ICU can transform an ICU organization and effect processes, teamwork, communications, and climate in ways that can be beneficial or harmful (Kahn et al., 2011). Groves, Holcomb, and Smith (2008) suggested several ways that tele-ICU re-engineers ICU care with continuous 24/7 monitoring and intensivist availability, and a proactive focus on potential adverse patient trends that can be addressed before they occur. With immediate availability, especially at night, the tele-ICU physician augments the traditional relationship between physician, nurse, and patient (Groves et al., 2008). Some studies, however, have revealed situations where ICU bedside staff had low levels of delegation of patient care to tele-ICU clinicians, which can severely limit the ability of tele-ICU to positively impact patient care processes and outcomes (Bauman & Hyzy, 2012; Khunlertkit & Carayon, 2012; Thomas, Lucke, Wueste et al., 2009).

According to the theories of E.M. Rogers from *The Diffusion of Innovation* (2003), the term "adoption" as it relates to innovation "refers to the decision of potential users to make full use of an innovation as the best course of action available," and rejection is a decision "not to adopt an innovation," (p. 177, 2003). How members of a social system perceive the characteristics of an innovation will determine the rate of adoption, and innovations are considered fully adopted when they are utilized by the majority of potential users (Rogers, 2003; Zanaboni & Wootton, 2012).

Tele-ICU may be considered both a technological innovation as well as an alternative way to supplement the staff in an ICU. A deeper understanding of how to define and measure adoption of tele-ICU, determine the root cause of lack of adoption, and remove barriers that inhibit adoption and acceptance can help inform ways to maximize the benefits of tele-ICU and improve patient outcomes.

## Problem Statement

Tele-ICU has gained popularity since the first commercial implementation in a U.S. hospital in 2000 (Kumar, S., Merchant, et al., 2013). According to Kahn, Cicero, Wallace et al. (2014), the use of tele-ICU has grown from only 16 U.S. hospitals in 2003 to 213 hospitals in 2010, but the growth rate has slowed in recent years. They suggested the key questions were not whether tele-ICU should be applied, but how and where it can be applied efficiently and effectively, and what organizational factors are associated with its success or failure (Kahn et al., 2014).

Many studies have compared severity-adjusted mortality and length of stay (LOS) before-and-after a tele-ICU intervention to determine if these patient outcomes improved. In a review and meta-analysis of 13 eligible before-and-after studies involving 35 ICUs, Young, Chan, Lu, et al. (2011) concluded that tele-ICU coverage was associated with lower ICU mortality and ICU LOS, but not with lower in-hospital mortality or hospital LOS. The analysis suggested that changes in how care was delivered in the ICU as a result of tele-ICU might have been eroded once patients were discharged to the hospital, which could explain the lack of improvement in severity-adjusted in-hospital patient outcomes (Young, Chan, Lu, et al., 2011). In another meta-analysis by Wilcox and Adhikari (2012) of 11 before-and-after tele-ICU studies, tele-ICU was shown to reduce both ICU and hospital mortality and LOS in critically ill patients, and in some cases best practice adherence also improved.

One issue raised in the Young, Chan, Lu, et al. (2011) meta-analysis was heterogeneity across the ICU units studied, which can compromise external validity and the ability to generalize results to a broader population. There was an unsuccessful attempt to address heterogeneity across the 13 studies, however, leading to notable differences between study settings on factors such as hospital type (i.e. academic vs. community), staffing model (i.e. open vs. closed), level of monitoring by tele-ICU (i.e. round the clock vs. evening/weekend), and the impact of the tele-ICU coverage (Young, Chan, Lu, et al., 2011).

In an observational before-and-after tele-ICU study of 6 ICUs by Thomas et al. (2009) that did not show significant improvements in patient outcomes, the ICU units did not share a unified electronic medical records (EMR) system, and notes were faxed and re-keyed into computer workstations, which introduced a delay in patient information sharing and the potential for human error with manual data re-entry. The lack of an integrated EMR can impact the interoperability between tele-ICU and the bedside (Berenson, Grossman, & November, 2009), and can be the single greatest impediment to a fully proactive tele-ICU program (Willmitch, Golembeski, Kim et al., 2012). In contrast, in an observational before-and-after tele-ICU study of two ICUs by Kohl, Fortino-Mullen, Praestgaard et al. (2012), an EMR system was introduced along with tele-ICU, making it difficult to distinguish how the new EMR may have influenced the study results. The study and comparison of ICUs that use pre-established HIT systems such as EMR can eliminate such variations.

Another inconsistent factor identified in the Young et al. (2011) meta-analysis was variation in the staffing models employed. Several studies have shown that the ICU staffing model (i.e. closed/high intensity versus open/low intensity) can impact the quality of care and patient outcomes (Garland & Gershengorn, 2013; The Leapfrog Group, 2011). ICU staffing models should be taken into consideration when evaluating differences in patient outcomes where tele-ICU is present since the tele-ICU intensivist can supplement the bedside staff. For example, the addition of tele-ICU to an open system that did not previously have dedicated intensivist resources would likely yield a greater improvement in patient outcomes when compared to a closed system with dedicated intensivists. In contrast, a closed system may be more reluctant to delegate authority over patient care to tele-ICU since bedside intensivists have already been overseeing patient care, suggesting that the addition of tele-ICU might have little impact on patient outcomes (Young, Chan, Lu, et al., 2011). Current evidence does not yet provide a coherent view of the optimal ICU intensivist staffing model, nor does it strongly support the superiority of 24/7 onsite intensivist staffing (Garland & Gershengorn, 2013). Research should help inform the optimal intensivist staffing mix inclusive of tele-ICU, especially in light of the shortage of intensivists and the ability for tele-ICU to meet the Leapfrog Group IPS standard for intensivist staffing (The Leapfrog Group, 2011).

According to Lilly and Thomas (2010), the level of benefit or improvement of patient outcomes may be due to the level of bedside staff acceptance of tele-ICU. Bedside and tele-ICU teams must work together to ensure best practice initiative adherence and collaborate to make the right patient care decisions in order for the tele-ICU care team to facilitate improved outcomes (Lilly, Cody, Zhao et al., 2011). Young, Chan, and Cram (2011) conducted a systematic review of 23 eligible studies looking at staff acceptance of tele-ICU. The review found several terms that were used to describe staff acceptance including perception, experience, buy-in, receptiveness, and attitudes. For purposes of this study, staff acceptance is considered to be a form of adoption of tele-ICU, assuming that if bedside staff has not accepted or embraced tele-ICU, they are likely not using it to the fullest extent possible or gaining the maximum benefit from it, and therefore it would not be considered fully adopted.

Staff acceptance of tele-ICU has been linked to ICU performance. Tele-ICU is often perceived as more beneficial in ICUs that have poorer baseline performance (Berenson et al., 2009), but may lead to resistance where performance is already perceived as exemplary (Young, Chan, & Cram, 2011). Physician resistance to change, which can act as a barrier to adoption of tele-ICU, can stem from their belief that the current level of care in the ICU is adequate, that tele-monitoring is simply ‘policing,’ and that they should have autonomy in their care delivery (Celi, Hassan, Marquardt et al., 2001). Lack of tele-ICU adoption has been found in situations where advice from the tele-ICU attending physician differed from the bedside physician, where tele-ICU monitoring fostered resentment, or where it was perceived to increase workload and interruptions (Young, Chan, & Cram, 2011).

Many studies have noted that collaboration between the bedside ICU staff and tele-ICU, including mutual respect and acceptance of tele-ICU by the bedside team, is necessary in order for the best patient outcomes to be achieved (Bauman & Hyzy, 2012; Chu-Weininger, Wueste, Lucke et al., 2010; Goran, 2012; Jarrah & Van der Kloot, 2010; Lilly & Thomas, 2010; Ries, 2009; Thomas et al., 2009; Young, Chan, Lu, et al., 2011). Two before-and-after tele-ICU studies that noted minimal or no delegation of authority to tele-ICU intensivists, indicating low levels of collaboration between bedside and tele-ICU, also did not show improvements in severity-adjusted patient outcomes.

In the first study by Thomas et al. (2009), two thirds of the physicians in the study chose minimal delegation to tele-ICU, which may have contributed to the lack of reduction in overall hospital mortality, thus preventing tele-ICU staff from having a significant impact on care processes, best practice adherence, and patient outcomes. In the second study of four ICUs within two hospitals, tele-ICU staff was restricted from providing care based on bedside clinician preference (Morrison, Cai, Davis et al., 2010). Primary physicians were allowed to choose the extent to which tele-ICU could provide care based on four pre-defined levels. This was done to reassure the primary physicians that they still had ultimate control over the management of their patients. Physician utilization of tele-ICU was at the low level for almost 79% of physicians in wave 1 and over 50% in wave 2. Study discussion suggested that optimum function and utilization of tele-ICU may not have occurred due to the low levels of tele-ICU delegation (Morrison et al., 2010). Future studies need to take into account the level of adoption and utilization of tele-ICU prior to inferring the impact it may have on patient outcomes.

Elements of organizational structure, such as the operational protocol for tele-ICU (i.e. proactive, reactive, or mixed), may also influence the level of tele-ICU adoption. For example, a proactive protocol allows for autonomy of the remote tele-ICU site to direct patient care if the bedside team is unavailable to respond to patient alerts or alarms, whereas when the reactive protocol is used, the bedside team will contact the remote tele-ICU site for assistance. A mixed model combines both (Kumar, G., Falk, et al., 2013). The decision of which protocol to use is sometimes left to the discretion of ICU staff. Studies that have reported improved patient outcomes have tended to allow more proactive tele-ICU participation, while those with little change in patient outcomes have tended to allow less proactive tele-ICU participation (Willmitch et al., 2012). Future studies should ensure they use a standardized lexicon when reporting the attributes of tele-ICU including the operational protocol, type of technology, timing of monitoring, and the role of the tele-ICU clinicians to clearly specify the process and structure of tele-ICU so generalizability of study outcomes can be applied appropriately (Kahn et al., 2011).

According to Kahn et al. (2011), the value of tele-ICU is not in the technology itself, but how it is leveraged by ICU clinicians and how it affects workflow and team integration. Tele-ICU can transform an ICU organization, affect teamwork and communications, and cause disruptions in the chain of command or workflow patterns in ways that can be beneficial or harmful (Kahn et al., 2011). People who are directly or indirectly involved in patient care in the ICU are at risk of making errors resulting from cooperation-communication failures (Guidet & González-Romá, 2011). A team-oriented climate and culture of safety and quality is a necessity in an ICU setting, but can be hindered by issues such as lack of mutual respect, dictatorial behavior, or the fear of being stigmatized (Guidet & González-Romá, 2011). Tele-ICU can lead to complex cultural and technical interventions that can be perceived as a threat to existing ICU culture and processes so staff perceptions of tele-ICU are important to achieve success (Romig, Latif, Gill et al., 2012; Sapirstein, Lone, Latif et al., 2009; Young, Chan, & Cram, 2011).

The before-and-after tele-ICU study by Willmitch et al. (2012) that evaluated patients from five ICUs (*n* = 24,656) showed improved outcomes with statistically significant decreases in severity-adjusted hospital LOS (14.2%), ICU LOS (12.6%), and relative risk of hospital mortality (23%), indicating the addition of tele-ICU led to improvements in quality. The authors noted that the deployment of tele-ICU was a complex process that required building trust and acceptance amongst the members of the new extended care team. Overall, the tele-ICU implementation led to the creation of a new culture for management of ICU patients. They found it was important to educate bedside clinicians on tele-ICU processes, ensuring the bedside staff that existing patient consulting patterns would not be altered, and that tele-ICU would instead facilitate the broader application of evidence-based best practices (Willmitch et al., 2012).

Lack of tele-ICU program acceptance and comprehensive integration is unlikely to be cost effective (Jarrah & Van der Kloot, 2010). If improvements in severity-adjusted mortality can be achieved along with reductions in both ICU and hospital LOS with the usage of tele-ICU, the overall cost of medical care should be reduced (Willmitch et al., 2012). Although this study will not be investigating the costs of tele-ICU, it will address the impact of lack of tele-ICU adoption on patient outcomes such as length of stay, which is the most important determinant of variable cost in the ICU (Rapoport et al., 2003).

Tele-ICU research has suffered from conceptual and methodological limitations suggesting the need for more high-quality research to ensure the value of tele-ICU can be achieved (Kahn et al., 2011), especially given the conflicting evidence about its effectiveness and the costs and resources associated with its implementation (Thomas et al., 2009). Focusing on ICU organizational structure and processes, and addressing issues found in previous research related to heterogeneity across study subjects, such as variations in staffing patterns, HIT systems, levels of delegation to tele-ICU, and other organizational and cultural variables, can address some of these limitations.

Although most studies since 2000 have used a before-and-after tele-ICU design, these designs are not necessarily applicable for study subjects that are years beyond the initial implementation of tele-ICU. New study designs are needed that can help develop strategies to optimize the effectiveness of a mature tele-ICU implementation. An understanding of what constitutes full adoption of tele-ICU long after the initial deployment, and the impact of lack of adoption on patient outcomes, can help uncover reasons why some tele-ICU programs derive improvement and others do not (Lilly & Thomas, 2010).

## Purpose of the Study

The main purpose of this comparative, quantitative study was to determine if significant differences existed in risk adjusted patient outcomes for mortality and length of stay across eight ICUs from the same health system in 2012 based on variations in the level of tele-ICU adoption. Executive leaders at the health system believed the full capabilities and benefits of tele-ICU were not being realized in some of the ICUs due to lack of full adoption by ICU bedside staff.

In addition to measuring patient outcomes based on the level of tele-ICU adoption, patient outcomes were also measured based on the staffing pattern (inclusive of tele-ICU) at each of the eight ICUs. Both tele-ICU adoption and ICU staffing pattern were evaluated to determine if they acted as predictors of patient outcomes. For example, if the study results revealed a positive correlation between tele-ICU adoption and outcomes, meaning the higher the level of adoption the better the patient outcomes, it would suggest that the level of adoption impacts the ability for tele-ICU to improve patient outcomes.

Finally, since the results of an all employee survey conducted by the health system were readily available, employee perceptions of engagement and leadership effectiveness were compared across the ICUs based on the level of tele-ICU adoption. Survey results could have indicated general organizational perceptions amongst ICU staff during the time of the study, such as burnout as a result of large caseloads or dissatisfaction with unit leadership effectiveness.

Although this study was not a before-and-after design, there was an attempt to remove limitations found in past studies related to heterogeneity. All eight ICUs belonged to the same health system and were similar with respect to factors such as hospital type (seven community, one community/academic), centralization of the ICU management structure, the use of standardized patient care models and best practice protocols, the use of centralized, shared HIT systems (EMR, CPOE, etc.), and the availability of the same tele-ICU technology and protocol for operations. Each of the ICUs had a closed staffing model with either 24/7 or 12/7 intensivists on site. Tele-ICU was fully deployed and available in all eight ICUs no later than January of 2011. No major, differentiating interventions took place in any of the eight ICUs during the 2012 study period.

For purposes of this study the term “adoption” was defined as “the decision of ICU staff to make full use of tele-ICU resources as the best course of action available by allowing tele-ICU to proactively co-manage patient care and ensure best practice adherence” (Rogers, 2003; Zanaboni & Wootton, 2012). Tele-ICU adoption encompassed other terms found in tele-ICU research to describe full use of tele-ICU including acceptance, engagement, delegation of authority, and buy-in.

In order to measure tele-ICU adoption, it was hypothesized that the mean ratio of patient orders initiated by the tele-ICU intensivists per patient ICU stay would provide an indicator of the level of tele-ICU adoption at a given ICU. If the ratio of orders placed per patient stay was higher, it was assumed that bedside staff had delegated to tele-ICU, or otherwise allowed tele-ICU to participate in a higher level of care of patients. If the ratio was lower, it was assumed that bedside staff assigned a lower level of responsibility for patient care to tele-ICU, or disregarded tele-ICU recommendations (Khunlertkit & Carayon, 2012).

Mean tele-ICU adoption ratios that included all four quarters of 2012 were used to group each of the eight ICUs in rank order based on significant differences (i.e. high, medium, or low tele-ICU adoption). Risk adjusted patient outcomes for mortality and length of stay were then compared across these groups to determine if significant differences existed, and to determine if the level of adoption acted as a predictor of patient outcomes.

## Research Questions

This quantitative analysis answered the following research questions:

1. Is there a difference between the eight ICUs in the ratio of patient orders initiated by tele-ICU physicians to total patient unit stays?

*NOTE:* If there is a difference, it is assumed that sites that have higher levels of tele-ICU initiated orders also have a higher level of adoption of tele-ICU personnel as an essential member of the bedside critical care team.

2. Is there a difference in APACHE IV risk-adjusted patient outcome measures for mortality and length of stay between the ICUs based on the level of tele-ICU adoption?

3. Is there a difference in APACHE IV risk-adjusted patient outcome measures between the ICUs based on different intensivist staffing patterns (24/7 versus 12/7)?

4. Is there an association between ICU intensivist staffing patterns (24/7 versus 12/7) and the level of tele-ICU adoption in predicting APACHE IV risk adjusted patient outcome measures?

5. Is there a difference between the ICUs with high versus low levels of tele-ICU adoption and the average scores of ICU employees for engagement and leadership effectiveness as measured by the annual all employee survey in Q3 of 2012?

Additional details regarding how data were gathered and which statistical methods were used to answer these research questions can be found in Chapters 3 and 4.

## Conceptual Framework

This study was organized around two basic conceptual frameworks. The first was the Donabedian (1988) framework for healthcare quality of care. The second was a framework for adoption of tele-ICU based on theories of diffusion of innovations (Rogers, 2003; Zanaboni & Wootton, 2012).

### Framework for Quality of Care in Healthcare

The Donabedian (1988) framework for healthcare quality of care included three interrelated domains: structure, process, and outcome. Good structure increases the likelihood of good process, and good process increases the likelihood of good outcomes, and the relationship between these must be established prior to assessing quality. Pronovost, Sexton, Pham et al. (2009) suggested a fourth important new domain for context, which for critical care is the creation of a safety culture. Figure 1.1 shows a proposal for ICU telemedicine evaluation based on this framework (Kahn et al., 2011; Pronovost et al., 2009).

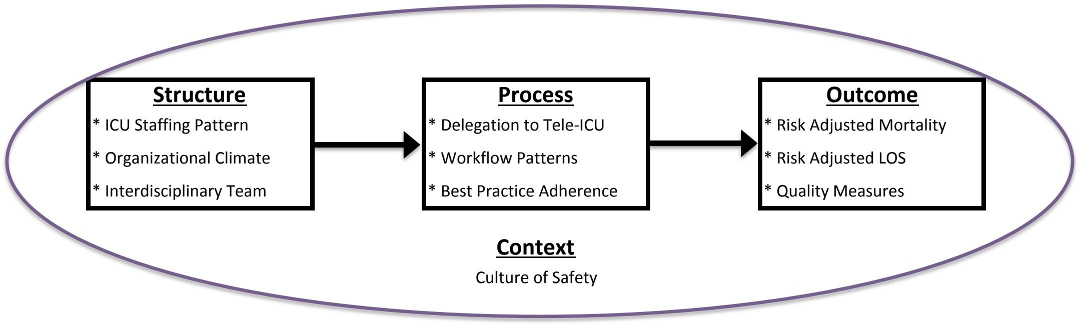


Figure 1.1: Proposed framework for tele-ICU evaluation based on the Donabedian healthcare quality framework (Kahn et al., 2011; Pronovost et al., 2009)

Knowledge about the relationship between attributes of the interpersonal process and the outcome of care should be derived from the behavioral sciences, while knowledge about the relationship between technical care and outcomes would be derived from health sciences (Donabedian, 1988). For example, the reasons why bedside staff may not adopt tele-ICU would be based in behavioral or organizational science, while the technical measure of patient outcomes (using the APACHE IV algorithms to develop the patient predictions for mortality and length of stay) comes from health sciences.

ICU structure refers to the settings in which care occurs and the components necessary to ensure care is effective (Donabedian, 1988). In the ICU this would include the interdisciplinary critical care team (bedside and tele-ICU), the staffing model, the equipment that supports collaboration with tele-ICU such as the bedside camera, and shared EMR and CPOE systems (Kahn et al., 2011; Pronovost et al., 2009).

ICU process refers to what is actually done in the giving and receiving of care including a practitioner's activities in diagnosing or treating a patient (Donabedian, 1988). Specific processes include how tele-ICU changes, disrupts, or enhances the existing workflow patterns of the critical care team, how evidence-based practices can be incorporated, adhered to, or improved by tele-ICU, how patients can remain the central focus in care delivery, how tele-ICU communicates with bedside clinicians and patients and responds to alerts and alarms, how knowledge transfer is facilitated, and the appropriateness, timeliness, and effectiveness of the tele-ICU recommendations (Kahn et al., 2011).

ICU outcomes refer to the effect of care on the health status of patients and populations, and the degree of the patient's satisfaction with care (Donabedian, 1988). Outcomes apply to the patient, provider, health care system, and party paying for care. Risk-adjusted mortality is the most important outcome from the perspective of the patient, but others include quality of life, patient satisfaction, family satisfaction, accuracy and timeliness of diagnosis and treatment, and prevention of adverse events and outcomes. The provider is interested in ICU operational outcomes such as length of stay, readmission rates, and ICU staff engagement and satisfaction. The healthcare system is generally concerned with how tele-ICU impacts quality and whether or not it is cost effective (Kahn et al., 2011).

Pronovost et al. (2009) proposed that organizational culture is a relatively new measure of context that is becoming increasingly important since culture and communication shortcomings are frequently being cited as contributing factors to sentinel events. Culture in the ICU can be assessed using new tools that survey staff regarding their perceptions of teamwork and safety (Pronovost et al., 2009)

This study incorporated all four of the domains in this framework. Elements of structure were fairly homogeneous across the eight ICUs. These included the hospital type (seven community, 1 community/academic), the tele-ICU system (all ICUs had the same equipment, resources, and capabilities), the length of time tele-ICU had been available (minimum of 1 year prior to the start of the study), the tele-ICU team (same competency levels), and the defined tele-

ICU responsibilities (co-management of care, monitor adverse trends, support best practice compliance, measure performance).

The staffing model was a structural factor that differed across the ICUs. Two of the eight ICUs had a 24/7 closed staffing model, while five ICUs had a 12/7 closed staffing model. One ICU had a hybrid of both models. ICUs were grouped based on the staffing pattern (an independent variable in the study), and patient outcomes (the dependent variable) were compared across these groups.

Elements of process were also generally the same across the eight ICUs in the study. Tele-ICU availability of services was the same in all cases. For example, intensivists were available 24/7 and acute care nurse practitioners were available 12/7 during the night. The same operational protocols and guidelines were defined for tele-ICU across all eight ICUs (although how they were used may have differed based on level of adoption at each ICU). The same quality indicators were captured and reported at regular intervals. It was hypothesized that the level of delegation of patient care to tele-ICU differed across the eight ICUs, which was an independent variable (tele-ICU adoption) that was measured for this study.

The main outcome measure reported in this study was used by all eight ICUs. The same processes and algorithms were used to capture patient information and calculate the predictions for both ICU and hospital mortality and length of stay using the Acute Physiology and Chronic Health Evaluation (APACHE IV) methodology, which is part of a proprietary predictive modeling solution from Cerner Corporation (Manganaro, 2010). Although additional patient outcome measures were captured by all eight ICUs, only mortality and length of stay were in scope for this study.

Although no formal measures of climate or culture were conducted during the time of the study, study outcomes indicated there might be slight differences in the unit level culture across the eight ICUs, and it was hypothesized that these differences may have influenced the level of tele-ICU adoption.

**Framework for Adoption of Telemedicine**

Many theories have been developed that explore why human beings may or may not adopt new technology or innovations. One such theory outlined by Rogers (2003) suggested that adoption refers to the decision of potential users to make full use of an innovation as the best course of action available. Adoption of technology occurs while moving through the stages of acquaintance, persuasion, decision, initial adoption, and diffusion as shown in Figure 1.2.

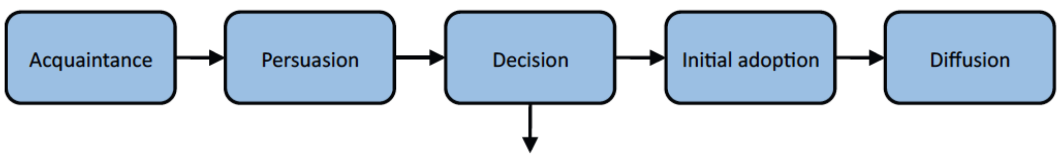


Figure 1.2: Framework for technology adoption based on Rogers (2003), adapted from Zanaboni and Wootton (2012).

The eight ICUs in this study were past the **acquaintance** phase since the health system made the decision to invest in and deploy tele-ICU prior to 2011. In the second stage, **persuasion**, individuals or the organization form a favorable or unfavorable opinion about the technology. Communications on the health system website and other sources indicate highly favorable opinions about tele-ICU, so it is assumed that unfavorable opinions were limited to certain users.

The next phase is where the **decision** is made to adopt the technology. In this study the attending physicians and to some extent nurses at the bedside had the authority to make this decision by controlling the level of delegation to tele-ICU. Other examples of this were indicated in the study by Thomas et al. (2009), where in some cases, physician delegation to tele-ICU was defined as minimal delegation, meaning tele-ICU could only intervene for life threatening situations, versus full delegation, meaning tele-ICU could issue routine orders, change treatment plans, etc. Likewise, in a study by Morrison et al. (2010), the primary physician chose the extent to which tele-ICU could provide care for their patients based on four pre-determined categories. This was done to provide reassurance to the physicians that they still had ultimate control over the management of each patient's care.

The fourth phase is initial **adoption**, which for this study is considered full utilization of tele-ICU services. In the Morrison et al. (2010) study, the highest level of delegation allowed the tele-ICU physician to initiate new therapies and place patient orders.

It was hypothesized that initiation of patient orders would be an indicator of the extent to which the tele-ICU physicians were being fully utilized. Orders initiated by tele-ICU physicians were extracted from the CPOE system, totaled by ICU and by quarter in 2012, then compared to the overall number of patient stays per quarter for each ICU. A mean ratio was calculated using all four quarters for each ICU. This mean ratio was then used to stack rank and group all eight ICUs from the lowest to highest level of adoption.

The final stage in the framework is **diffusion**, which is referred to as the widespread implementation of the technology. Adoption decisions can be reversed at the diffusion stage or replaced by new technologies. It is important for research to understand how early adopters differ from late adopters so that late adopters can be targeted in advance to speed up adoption (Rogers, 2003).

Although research specifically focused on the adoption of telemedicine is limited, various theoretical models have been used to predict its adoption including the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Kowitlawakul, 2011; Whitten, Holtz, & Nguyen, 2010). For example, studies using TAM for telemedicine adoption have identified critical factors such as ease of use and perceived usefulness as predictors of adoption (Zanaboni & Wootton, 2012). Unfortunately for this retrospective study there was no opportunity to use these tools to predict adoption.

In summary, even if an organization attempts to adopt a technology or innovation such as tele-ICU, certain users can prevent full adoption and the ability to gain the intended benefits (Bauman & Hyzy, 2012; Young, Chan, & Cram, 2011; Young, Chan, Lu, et al., 2011). Even if tele-ICU were not considered a technology or innovation, but rather a way to supplement ICU staff, these conceptual frameworks could still apply, and if barriers to adoption of tele-ICU impact patient outcomes, a better understanding of their root cause is an essential next step.

## Significance of the Study

Despite suggestions that the ability for tele-ICU to affect patient outcomes and improve quality is dependent on the full adoption of tele-ICU by bedside staff (Goran, 2012), few studies have isolated different levels of tele-ICU adoption to determine if patient outcomes differ. This study attempted to do so by evaluating eight ICUs with tele-ICU in 2012, yielding a large sample size ($N$ = 14,362).

One of the underlying factors believed to cause lack of adoption of tele-ICU is the intensivist staffing pattern. An ICU with 24/7 intensivist led care may not believe performance can be improved with the addition of tele-ICU (Young, Chan, & Cram, 2011). This study evaluated ICUs with both 24/7 and 12/7 intensivist staffing (inclusive of tele-ICU at varying levels of adoption) to determine if significant differences in patient outcomes existed. Other organizational factors were also measured to see if they differed based on varying levels of tele-ICU adoption.

Results of this study can guide future researchers and practitioners towards areas that require additional focus, such as increasing the readiness for change for future implementations of tele-ICU, determining and addressing cultural barriers to change, educating ICU staff on the proven benefits of tele-ICU, and determining the most cost effective and beneficial mix of intensivist staffing inclusive of tele-ICU.

**Study Assumptions/Limitations/Delimitations**

One assumption of this study is that the information provided by the health system was accurate and complete with respect to patient stays, patient outcomes, and outcome predictions. The accuracy of patient predictions and patient outcome data is dependent on the quality of the data captured by staff at the hospitals (Manganaro, 2010). The method and accuracy of data capture were not evaluated as part of this study, but hospital management stated their processes were very accurate and consistent.

Because of confidentiality, no references were cited regarding sources of information specific to the study site. It is assumed that the information provided herein with respect to the health system and the eight ICUs in the study are accurate (see Chapter 3 – Study Site).

The study was a non-experimental, comparative study of hospitals in one single health system with no controlled interventions. Although there was an attempt to compare units that were homogeneous for other relevant variables, the results do not indicate causality. Generalizability of the results would be limited to U.S. health systems that are similar to the study site.

One ICU had to be removed from the study because it was being remodeled during two quarters of 2012 and patient level data were not available. Also, some doctors worked at both the bedside ICU and tele-ICU. Due to the difficulty distinguishing which role a physician was acting in when placing orders, the orders for these physicians were removed from the dataset. This only impacted the ranking of the ICUs from low to high adoption, and health system management does not believe the removal of these orders significantly altered the study results.

A mixed methods study design that allowed the researcher to interview or survey ICU staff would have made this study stronger. If access were allowed, the interviews would have been retrospective and may have contained inaccuracies due to the passage of time. Although the use of the all employee survey was considered a limitation in that it was not directly measuring constructs related to adoption of tele-ICU or unit climate, it was the only measure readily available that assessed differences in staff perceptions across units. Although the study site does conduct a climate survey, it is conducted every other year, and was not conducted in 2012.

The study of a single hospital system could be considered a delimiting factor in that the researcher wanted the best like-for-like comparison of ICUs in an attempt to control for factors other than level of adoption and staffing pattern. This in turn limited the generalizability of the study results.

## Summary

This chapter provided an overview of challenges faced by hospital intensive care units related to achieving optimal performance with the usage of tele-ICU and various staffing models. The specific study problem statement and purpose were outlined including the quantitative research questions and the conceptual framework. Study significance was then discussed along with assumptions, limitations, and relevant terminology. The upcoming chapters will review the literature that is relevant to this study (Chapter 2), discuss the research design and methodology (Chapter 3), outline the results of the statistical analysis (Chapter 4), then conclude with a discussion of the relevance and limitations of the findings and suggestions for future research (Chapter 5).

# CHAPTER TWO: REVIEW OF LITERATURE

This review of relevant literature will begin by looking at general aspects of quality in healthcare, then more specifically at how health information technologies (HIT) support quality. Quality and best practices in the ICU will be reviewed, including the use of closed, high intensity staffing patterns. Tele-ICU will be described in general, and then tele-ICU effectiveness and adoption will be covered. Finally, an overview of organizational effectiveness in the ICU including climate, culture, employee engagement, leadership effectiveness, communications, and teamwork will be provided.

## Healthcare Quality

Donabedian (1988) defined healthcare quality based on three categories: structure, process, and outcome. Structural quality focuses on health system capacities and the settings in which healthcare occurs. Process quality focuses on the interactions between clinicians and patients, or what is done in the giving and receiving of care. Process improvements are supported by research evidence and formulating criteria and standards that can lead to better patient outcomes. Outcomes focus on effects of care on the health status of patients and populations, including improvements in patient knowledge, behavior, and satisfaction. Outcomes offer evidence that the patient's health status has changed, and the best outcome measures are linked to processes over which healthcare systems have control. Good structure increases the likelihood of good processes, which in turn increase the likelihood of good outcomes, so it is important to create a relationship between the three categories when attempting to improve quality in healthcare (Donabedian, 1988).

A report issued in 2000 by the Institute of Medicine (IOM) entitled *To Err is Human* (Kohn, Corrigan, & Donaldson, 2000) suggested that as the system that delivers healthcare becomes more complex, opportunities for error increase, driving the need for safety to be designed into processes of healthcare. The report demanded change in healthcare delivery in the U.S., citing that the majority of medical errors, which may take the lives of more than 98,000 people annually, are preventable if the right systems and processes are in place and if hospital staff follows those processes. Based on evidence gathered, the report recommended five principles useful for the design of safe healthcare: (1) providing leadership; (2) respect for human limits in the design process; (3) promoting effective team functioning; (4) anticipating the unexpected; and (5) creating a learning environment (Kohn et al., 2000).

In 2001 the IOM issued a follow up report called *Crossing the Quality Chasm: A New Health System for the 21st Century* (Richardson, Berwick, Bisgard et al., 2001). The report was a call to action to improve the U.S. health care delivery system as a whole, suggesting that health care should be safe, timely, effective, efficient, equitable, and patient-centered. New rules to redesign healthcare included knowledge is shared and information flows freely, decision making is evidence-based, transparency is necessary, and cooperation among clinicians is a priority (Richardson et al., 2001).

## Performance Measurement: Patient Outcomes

Two common performance measures that are used to monitor and improve patient outcomes during a stay in either the hospital and/or the intensive care unit are severity-adjusted mortality and length of stay. When intensivists oversee patient care in the ICU, studies have shown improvements in both of these measures (Pronovost et al., 2002; Rufo, 2011). Health systems in the U.S. have demonstrated improved length of stay and other safety outcomes following the adoption of information technology and redesigned work processes, and since many hospitals publically report their quality of care measures, it is becoming more popular for financial incentives to be linked to the quality of care (Rufo, 2011).

Although there are several methods for measuring the severity-adjusted patient outcomes in an ICU, one common measure is the Acute Physiology and Chronic Health Evaluation, also known as APACHE®. Actual ICU outcomes can be compared with the predicted outcomes to understand if outcomes are better or worse than predicted, or for comparison with national standards (Zimmerman, Kramer, McNair et al., 2006).
According to Cerner Corporation (2010), APACHE IV predictive equations include the score, the patient's length of stay in the hospital prior to admission, the patient's exact ICU admission disease classification, the patient's chronic health conditions, the patient's origin immediately prior to ICU admission, and a measure of practice patterns to provide probability estimates for various outcomes on a daily basis. The APACHE III score, which is calculated based on the patient's physiology, chronic health, and age scores, is a component in the APACHE IV predictive equation, which produces risk estimates of the patient's mortality and length of stay. These estimates are then compared with the actual outcomes for the patient once they have been discharged from the ICU or hospital (Manganaro, 2010).

APACHE scoring for severity-adjusted length of stay and mortality were two of several internal APACHE quality indicators used by the ICUs in this study. Figure 2.1 shows the entire process for generating the APACHE IV predictive equation including how the APACE III score is generated and used.

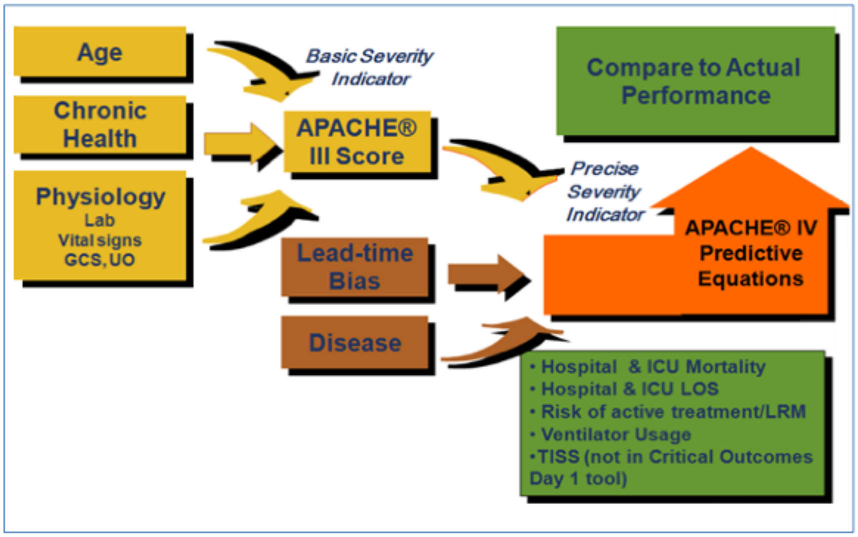


Figure 2.1: Inputs and process for calculating APACHE IV predictive equations (Cerner Corporation, 2010, p. 7).

**Health Information Technology for Quality Improvement**

The importance of health information technology (HIT) was recognized in the IOM report in 2000 as a way hospitals can increase efficiency of hospital operations, improve quality of care, and improve patient outcomes. The report recommended that there should be an increased effort to include information technology in the delivery of patient care and the improvement of patient safety (Kohn et al., 2000). Common examples of HIT in hospitals include electronic medical records (EMR), computerized physician order entry (CPOE) systems, and telemedicine.

A study that investigated the implementation of EMR systems indicated they could improve safety, help accelerate the treatment of patients, and reduce redundant care, thereby keeping patients healthier (Hillestad, Bigelow, Bower et al., 2005). According to Maslove, Rizk, and Lowe (2011), CPOE can have a substantial positive impact on patient outcomes in the ICU due to the complexity of the workflow and the potential for error. Telemedicine has played a key role in health reform, and is seen as an integral component of a more rational organization of health care in the U.S. with the ability to reduce disparities in access to care and improve care coordination (Lerouge & Garfield, 2013).

**Adoption of HIT and Telemedicine**

Adoption and acceptance of some health information technologies, including telemedicine, has not been high enough to fully yield the potential benefits (Li, Talaei-Khoei, Seale et al., 2013; Zanaboni & Wootton, 2012). In his book *Diffusion of Innovations,* Rodgers (2010) stated that the innovation-decision making process can either lead to adoption, and making full use of an innovation as the best course of action, or rejection, by deciding not to adopt an innovation. Innovation is an idea, practice or object that is perceived as new, while diffusion is the way an innovation is communicated through various channels over time to the members of a social system, leading to a mutual understanding. If an individual perceives it as new, it is an innovation. Technology is considered a design for "action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome" (Rogers, 2010, p. 28).

The perceived attributes of an innovation impact its rate of adoption, and according to Rogers (2010) even though the benefits of an innovation may be obvious, obtaining adoption of that idea is a difficult and lengthy process. So organizations will look for ways to speed up adoption. Usually when an innovation reaches about 10-20% adoption and interpersonal networks have been activated, the critical mass of adopters begin using it, although a certain innovation may be feasible and desirable for one adopter in one situation but not in another. Discontinuance can also take place when an individual becomes dissatisfied with an innovation or finds a preferable alternative. The innovation decision process is a five step information seeking and information-processing activity shown in Figure 2.2 (Everett, 2009; Rogers, 2010).

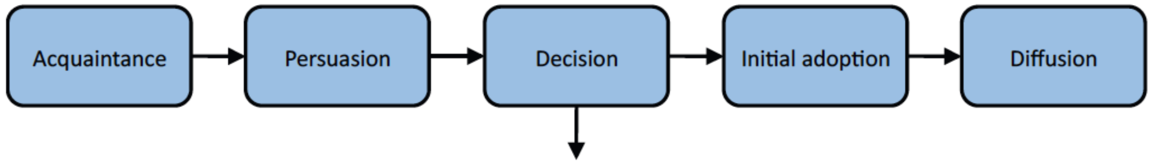


Figure 2.2: Framework for technology adoption based on Rogers (2003), adopted from Zanaboni and Wootton (2012).

Individual innovativeness is affected by the characteristics of an individual as well as the nature of the social system the individual is a part of. Norms are the established behavior patterns for the members of a social system that serve as a guide for what behavior is tolerable, and these norms can also act as barriers to change (Rogers, 2010). Different hospitals within a single a system may have different norms based on locale, size, leadership, history, and culture leading to varying barriers to change.

Quantitative data on the adoption of telemedicine are lacking, although some theoretical models, such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) have been used to evaluate user acceptance. Factors such as perceived ease of use, perceived usefulness, performance expectancy, effort expectancy, voluntariness of use, healthcare provider characteristics, and social influence can all impact the adoption of healthcare technologies (Zanaboni & Wootton, 2012). One study noted that the use of TAM confirmed a direct relationship between perceived usefulness and behavioral intention, as well as perceived usefulness and attitude, among the physician population. No support for the component ease of use was found, however, likely because physicians tend to be of above average intelligence and are not as influenced by ease of use when compared to an average person (Yarbrough & Smith, 2007). Perceived usefulness of tele-ICU was noted as a barrier to adoption in several studies where ICU staff already believed performance was exemplary (Young, Chan, & Cram, 2011) or already adequate (Celi et al., 2001).

Motivational readiness, which is the perceived need or pressure to change, personal attributes of leaders and staff members, and the organizational climate are all important factors that influence change and the adoption of new technologies, but may not be sufficient for change to effectively occur. Ensuring alignment with the core mission and culture of the organization, and not change for the sake of change, is also key (Lehman, 2002). Decision makers in the health care setting need to systematically understand facilitating forces and inhibiting factors that act as barriers to the adoption of tele-ICU, and proactively introduce interventions aimed to achieve improved adoption.

## ICU Best Practices

Because the ICU handles a high volume of critically ill patients, and is one of the most expensive units in hospitals, a focus on quality and adherence to best practices in order to improve patient outcomes is essential. Although there is a vast amount of literature pertaining to critical care quality, this review will focus on ICU staffing and how it can be supplemented by tele-ICU.

### ICU Staffing Practices

Studies have indicated that greater use of intensivists in ICUs leads to reductions in ICU and hospital mortality and patient lengths of stay (Pronovost et al., 2002), but several factors inhibit the full utilization of intensivists in the U.S. One key factor is the shortage of available intensivists and critical care nurses, a trend that is expected to intensify as the demand for critical care increases due to lifespan increases, the growing aging population, and the increasing complexity of meeting patient needs (Groves et al., 2008; Pronovost et al., 2002; Young, Chan, & Cram, 2011).

The Leapfrog Group is a member supported initiative endorsed by the National Quality Forum that formed following the 1999 Institute of Medicine report *To Err is Human* (Kohn et al., 2000). The Leapfrog Group focused on developing best practices, or making 'leaps' to improve healthcare safety, quality, and patient value, that can significantly reduce preventable medical mistakes. The group defined four leaps related to quality and safety practices, and claimed that if all hospitals in their consortium implemented the first three out of four leaps, 57,000 lives and over 3 million medication errors could be avoided annually (The Leapfrog Group, 2012).

Two of these leaps are relevant for this study. The first suggests that by using a CPOE system, prescribing errors in hospitals could be reduced by more than 50% (The Leapfrog Group, 2012). As a tool for improving the quality and safety of patient care, CPOE allows providers to enter clear and specific orders for medication, diagnostic tests, and procedures that can enhance decision support and speed up communication (Maslove et al., 2011). ICU and tele-ICU staff in this study used a shared CPOE system for placing patient orders. This CPOE system was the source for determining the number of patient orders initiated by tele-ICU staff in order to determine the level of tele-ICU adoption at each facility.

The second relevant leap issued by The Leapfrog Group (2011) was the ICU Physician Staffing (IPS) standard. It included a recommendation to staff ICUs with board-certified intensivists based on evidence suggesting they improved quality of care and helped lower mortality rates. The exact verbiage of the IPS Leapfrog standard can be found in Appendix B.

**Open versus Closed ICU Staffing**

The IPS recommendation distinguishes between open versus closed ICUs. Open ICUs, referred to as low intensity, are staffed with physicians who also have responsibilities outside the ICU, and intensivists are either not available or may be available on a consulting basis. Closed

ICUs are referred to as high intensity, and physician staffing is done exclusively with intensivists. A detailed description of these staffing models adapted from Gajic and Afessa (2009) can be found in Appendix C.

Closed ICUs are associated with a 30% reduction in hospital mortality and a 40% reduction in ICU mortality (The Leapfrog Group, 2011). Meeting the IPS standard can be costly, so evidence of both the quality and financial benefits should be confirmed prior to implementation (Parikh, Huang, Murthy et al., 2012). According to a study done in 2006, about 73% of U.S. hospitals have low intensity or no intensivist coverage and are still unable to meet the IPS standard (Angus, Shorr, White et al., 2006). ICUs are closed and staffed exclusively with intensivists 24/7 in most other countries outside the U.S. (Angus et al., 2006; Gajic & Afessa, 2009).

**Optimizing ICU Staffing: Challenges and Questions**

Gajic and Afessa (2009) suggested that the presence of an intensivist in the ICU does not guarantee improved patient outcomes and that many studies have not included pertinent information about the ICU organizational systems that dictate how care is delivered. Wide variations in organizational characteristics can exist even amongst ICUs meeting the Leapfrog IPS standard. For example, a study in 2001-2002 that surveyed 29 hospitals regarding organizational characteristics of intensivist staffing found that only 25% of the hospitals that reported they met the IPS standard gave the intensivists the authority to write orders on all patients. This finding suggested that although a hospital may technically meet the IPS standards, the intensivists placed on staff may not always be empowered to oversee patient care or place patient orders, may lack admission and discharge authority, or may not care for all patient types.

This can have an impact on the intended quality improvement outcomes of staffing with intensivists (Pronovost, Thompson, Holzmueller et al., 2007).

According to Ward, Afessa, Kleinpell et al. (2013), tele-ICU can be seen as a way to extend or supplement the intensivist staffing and extend the efficiency of the current ICU workforce. To do so successfully depends on the existing staffing model, the intensivist needs of the hospital, and whether tele-ICU acts as a workforce extender or a substitute that can extend the reach but not the capability. Confirmation of the benefits of using tele-ICU for these purposes requires additional research that evaluates tele-ICU as well as other staffing alternatives for improving quality (Ward et al., 2013).

To add to the difficulty of meeting the Leapfrog IPS recommendations, a 2007 collaborative report between the U.S. Health Resources and Services Administration and the American College of Chest Physicians projected there would be a shortfall of 1500 intensivists in the U.S. by the year 2020 (U.S. Department of Health & Human Services, 2007). Despite the fact that the IPS standard only requires the intensivist to be onsite during daytime hours, many hospitals have opted to hire more intensivists to support bedside coverage 24/7

A recent study by Wallace et al. (2012) of 49 ICUs where nighttime intensivist coverage was added to low-intensity daytime staffing showed reduced mortality, but did not show any reduction in mortality when added to high-intensity daytime staffing. The results reconciled two previous studies. One confirmed the benefits of adding nighttime staffing where there was low intensity daytime staffing. The other also indicated no reduction in mortality following the addition of nighttime staffing to high-intensity daytime staffing. The results of all of these studies suggested that a blanket endorsement of 24/7 intensivist coverage is premature (Wallace et al., 2012). Note that only three of the 49 ICUs in the Wallace et al. (2012) study had tele-ICU, so it was not a factor in the analysis. Another reason the benefits of nighttime intensivist staffing should be confirmed is the unintended consequence of drawing intensivists away from regions where they are already in short supply and desperately needed (Kerlin & Halpern, 2012).

The need for intensivist coverage, coupled with a worsening intensivist shortage and a high rate of job burnout (Garland & Gershengorn, 2013) makes the case for supplemental intensivist staffing using tele-ICU more compelling. The expansion of tele-ICU can help mitigate issues arising from the current and future expected shortages of intensivists since each tele-ICU intensivist can monitor up to 150-200 patients, including patients in rural or underserved populations (Goran, 2012). Tele-ICU can also help alleviate the burden of large ICU caseloads (Ward et al., 2013).

Other challenges faced by hospitals in meeting the IPS standard include the unwillingness of non-intensivist physicians to relinquish care of their patients, the inability to hire due to intensivist shortages, and small units lacking the economies of scale to support full time intensivists. Consolidation of ICU care into larger hospitals and the implementation of tele-ICU are two ways to solve these issues (The Leapfrog Group, 2012).

## Tele-ICU

There have been two primary reasons why most hospitals implement tele-ICU (Goran, 2012). The first is to address the shortage of critical care providers, particularly intensivist physicians (Jarrah & Van der Kloot, 2010), and the second is to help improve quality and patient safety and facilitate early recognition of physiological deterioration (Kahn et al., 2014; Rufo, 2011). Tele-ICU becomes especially useful during night shifts when intensivists are not as readily available and the majority of patient care is monitored by nurses (Goran, 2012).

As of 2010, the total number of U.S. hospitals using tele-ICU was approximately 213, covering about 5800 ICU beds, mainly in larger hospitals in urban areas (Kahn et al., 2014). As of 2009, over one million patients in the U.S. had received care through a tele-ICU system (Lilly & Thomas, 2010).

According to a report issued by the New England Healthcare Institute in 2010 (Fifer, Everett, Adams et al., 2010), tele-ICU technology was first introduced as a commercially packaged system in 2000 when a command center covering two hospitals was opened in Virginia. Tele-ICU clinicians are able to monitor many patients simultaneously, or see a single patient using a bedside camera and 2-way audio to facilitate real time communication between tele-ICU and the bedside. Tele-ICU has access to systems available at the bedside, such as EMR and bedside monitoring systems, in addition to systems provided by the tele-ICU vendor which monitor patient trends and create alerts when certain predetermined thresholds have been met (Venditti, Ronk, Kopenhaver et al., 2012).

A 2007 report issued by the New England Healthcare Institute (NEHI, 2007) suggested that early adopters of tele-ICU have tended to be more financially stable hospitals that already use intensivists while the hospitals that would benefit the most by adding tele-ICU are unlikely to be able to afford it. Payers and providers need to find ways to lower the barriers to broader tele-ICU coverage and expand it’s use, especially with the growth in the aging population (NEHI, 2007).

**The Mechanics of Tele-ICU**

Although the operational model of tele-ICU may differ depending on the type of technology and services offered, times of coverage, and levels of delegation of authority given to tele-ICU, generally the responsibilities of tele-ICU encompass five main areas. First, they continually monitor patient progress. Second, they attempt to proactively identify emerging issues and initiate countermeasures to address them. Third, they issue treatments to help achieve patient care plan objectives. Fourth, they facilitate communications among the critical care team. And finally, they are responsible for ensuring best practice compliance and adherence. One ultimate goal of tele-ICU is to provide 24/7 seamless oversight of all ICU patients to ensure the highest level of care possible (Breslow, 2007).

Depending on the preferences of the ICU where tele-ICU is implemented, physicians may be empowered to dictate the level of care the tele-ICU team can provide. Although these can vary, one example (Breslow, 2007) of different levels of care is as follows:

1. Category 1: Tele-ICU team only allowed to intervene in emergencies.
2. Category 2: Tele-ICU team executes daily care plan (set by on-site team) and implements all best practices.
3. Category 3: Tele-ICU team provides all ICU services when there is not physician in the ICU and communicates with the attending physician for major issues.

The model of tele-ICU care delivery, as suggested by Celi et al. (2001) and shown in Figure 2.3, provides tools that support care process (technology) with preemptive care, timely interventions to prevent complications, and standardization of care with a focus on best practices and performance improvement (values). The tele-ICU team helps ensure continuous proactive care and prompt interventions when onsite care is not available (multidisciplinary care team) to support best practice adherence and continuity of care (Celi et al., 2001).

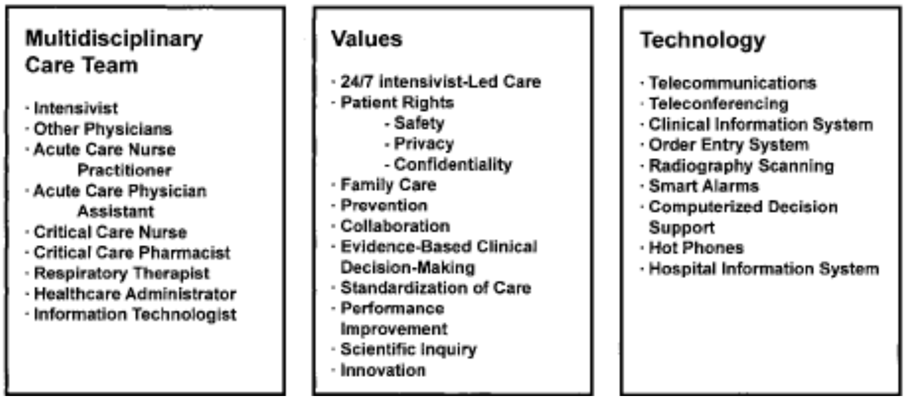


Figure 2.3: Core components of tele-ICU model of care delivery (from Celi et al. (2001)).

The tele-ICU program is typically staffed in a manner that resembles the traditional model of care in the ICU. As shown in Figure 2.4, this includes intensivists, critical care nurses, and computer intelligence such as smart alerts and/or clerical staff. This team working in conjunction with the interdisciplinary critical care team can collaborate on patient care and help ensure best practice adherence and improved outcomes (Ruesch, Mossakowski, Forrest et al., 2012).

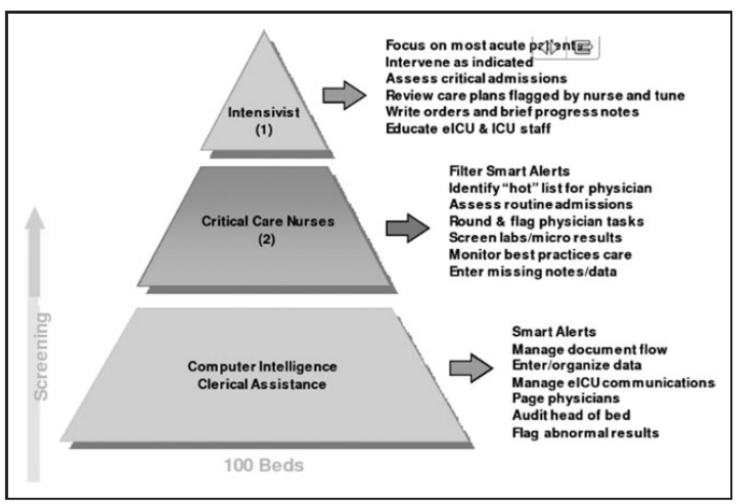


Figure 2.4: Tele-ICU care team workflow
adopted from Celi et al. (2001); Ruesch et al. (2012).

Tele-ICU operational protocols (proactive, reactive, or mixed), whether formalized or discretionary, can influence the level of tele-ICU interaction with the bedside team. The proactive model allows autonomy of the remote tele-ICU site to direct patient care if the bedside team is unavailable to respond to patient alerts or alarms, while in a reactive model, the bedside team will contact the remote tele-ICU site for assistance. A mixed model combines both (Kumar, G., Falk, et al., 2013).

**Tele-ICU Effectiveness**

Despite a 4% increase in hospitals adopting it between 2002-2010 (Kahn et al., 2014), tele-ICU effectiveness and the impact it has on patient outcomes remains somewhat unclear. Since it's introduction into the first U.S. hospital in 2000, most studies have measured patient outcomes, such as mortality and length of stay, before-and-after tele-ICU implementation. Non-trivial differences between studies, such as dissimilar levels of bedside intensivist staffing prior to tele-ICU implementation, the lack of a shared electronic medical record system, and variations in delegation of authority to tele-ICU, have likely impacted patient outcomes suggesting the need for more rigorous studies that control for these variations (Thomas et al., 2009; Willmitch et al., 2012; Young, Chan, Lu, et al., 2011).

A meta-analysis by Young, Chan, Lu, et al. (2011) of 13 before-and-after studies involving 35 ICUs indicated that tele-ICU coverage was associated with lower ICU mortality and ICU length of stay for ICU, but not for in hospital mortality and hospital LOS. Possible reasons cited included the lack of similar upgrades to technology outside the ICU, better adherence to best practices in the ICU, and changes in decision making processes about which patients should be admitted to the ICU, suggesting that the overall benefits of tele-ICU could be eroded once patients are transferred out of the ICU. One explanation for shorter ICU LOS is that

ICU throughput is more efficient with tele-ICU coverage since ICU admissions and discharges/transfers can be done 24/7 (Young, Chan, Lu, et al., 2011). More studies are needed to confirm the quality improvement benefits of tele-ICU for patients during their entire hospital stay inclusive of their time in and outside of the ICU (Kumar, G., Falk, et al., 2013).

Several studies in recent years have evaluated a variety of quality and patient outcome measures before-and-after the implementation of tele-ICU to determine whether or not these measures improved post-implementation (Goran, 2012; Kohl et al., 2012; Lilly et al., 2011; Sadaka, Palagiri, Trottier et al., 2013; Thomas et al., 2009; Willmitch et al., 2012; Young, Chan, Lu, et al., 2011). A quantitative study by Lilly et al. (2011) was conducted at a 834-bed academic medical center between 2005 and 2007. The study found that a tele-ICU intervention was associated with reduced adjusted odds of mortality (13.6% during the pre-intervention period compared with 11.8% during the tele-ICU intervention period), reduced hospital and ICU length of stay, higher rates of clinical care best practice adherence, and lower rates of preventable complications. The results suggested that tele-ICU interventions offered benefits beyond what was provided with traditional ICU approaches to quality improvement, such as process changes, and standard, daytime intensivist staffing in the ICU (Lilly et al., 2011).

**Organizational Impact of Tele-ICU**

In a pre and post tele-ICU study conducted at three hospitals in the Gulf region of the U.S., Chu-Weininger et al. (2010) surveyed ICU physicians and nurses using the Teamwork Climate Scale (TWS), a Safely Climate Score (SCS), and other survey questions. The researchers surmised that following the tele-ICU implementation, the safety climate, including the domains of acceptance, communication, trust, and level of engagement, would improve due to the additional around-the-clock assistance from the remote intensivists and nurses. In contrast, they thought the teamwork climate would worsen due to the difficulty associated with incorporating the remote personnel into bedside routines. The results indicated that especially among nurses, there were improvements in *both* safety climate and teamwork climate in some ICU's, while the overall hospital level safety climate scores remained unchanged. In addition, the researchers suggested that the improved collaboration between the remote and bedside ICU personnel enhanced quality and best practice adherence (Chu-Weininger et al., 2010).

According to a study by Romig et al. (2012), nursing staff perceived tele-ICU as a benefit which led to improved staff satisfaction and communication in a highly staffed ICU. Rufo (2011) suggested that the application of a tele-ICU technological model can help accelerate clinical decision-making and problem solving, both of which were identified as organizational factors that can help improve patient outcomes. The deployment of tele-ICU is not the same as deployment of a new device or procedure, and introduces a complex, new culture for managing patients, and studies showing improved patient outcomes have also indicated more proactive participation by tele-ICU (Willmitch et al., 2012).

In a review published by Goran (2012), a number of before-and-after tele-ICU studies were categorized based on clinical outcomes (i.e. severity-adjusted mortality and length of stay), cost savings, and customer satisfaction. The results indicated that tele-ICU, in collaboration with a bedside ICU team, can help enhance the quality goals of the ICU although the ability to achieve cost savings is complex and unclear. The author suggested that attention should be paid to the relationship between models of tele-ICU operation and job satisfaction. The importance of building strong team relationships was mentioned, along with indications that tele-ICU command center teams often work well as a team due to their confined space and natural engagement and interaction, which may be different from the experiences at the bedside (Goran, 2012).

**Tele-ICU Adoption**

Tele-ICU interventions are not always accepted by the bedside staff in the ICU. Physician resistance to change in patient management and sharing control over patient care with tele-ICU has been cited as a reason why some tele-ICU command centers have been deactivated (Fifer et al., 2010). If bedside staff are empowered to delegate authority to tele-ICU staff but choose not to do so, the ability to derive the full intended benefits from tele-ICU can be limited.

In a before-and-after study of six ICUs by Thomas et al. (2009) that did not show improvements in mortality, two thirds of the physicians in the study chose minimal delegation to tele-ICU, meaning that tele-ICU could only intervene in life threatening situations. In another before-and-after study of four ICUs by Morrison et al. (2010) that also did not yield improvements in patient outcomes, the majority of the physicians chose minimal delegation to tele-ICU, which did not allow them to provide proactive, early interventions, and required them to contact the physician before issuing treatments (Venditti et al., 2012). When providing feedback for a qualitative study by Khunlertkit and Carayon (2012), a tele-ICU nurse explained an unfortunate situation where tele-ICU cleary had little authority, stating:

> "A physician was trying very hard to intervene, the patient has no pulse on the monitor, ICU nurses need to start CPR but they were very resistant to listening to the tele-ICU physician until their own attending came in and said you need to start CPR and, you know, those kinds of things are unfortunate." (Khunlertkit & Carayon, 2012)

Other studies have indicated that bedside staff believe tele-ICU cannot improve upon the current high levels of performance, and resent what they see as 'policing,' the loss of autonomy, and the loss of their ability to control the care of their patients (Celi et al., 2001; Willmitch et al., 2012; Young, Chan, & Cram, 2011). Some concerns have been raised that tele-ICU is there to report care gaps without providing proactive solutions to address them (Venditti et al., 2012).

There are many possible reasons why physicians might not delegate to tele-ICU staff, and future research is needed to investigate factors that might influence adoption, including the domains of organizational climate, teamwork, communication, trust, and level of engagement (Kahn et al., 2011).

Factors such as improved work practices and increased coverage have contributed to increased staff acceptance of tele-ICU. Studies have indicated high acceptance of tele-ICU as a result of increases in attitudes regarding safety post tele-ICU implementation (Thomas et al., 2009). Hospitals wanting to implement tele-ICU should focus on change readiness and clearly articulate the purpose, goals, and benefits of tele-ICU in order to maximize adoption and utilization (Venditti et al., 2012). Appropriate change management, proper implementation of best-practice protocols, and quality assurance measures can enhance the value of tele-ICU as well as enable it to extend to other microsystems such as the ER (Kumar, S., Merchant, et al., 2013).

## Organizational Effectiveness in the ICU

In a 1999 study focused on patient outcomes following abdominal aortic surgery, ICU organizational characteristics in the domains of physician staffing, nurse staffing and ICU care processes were found to be associated with increased risk of in-hospital mortality, ICU days, and hospital LOS. The study also found that daily rounds by an ICU physician were associated with a reduction in in-hospital mortality and medical complications (Pronovost, Jenckes, Dorman et al., 1999).

A literature review by Shortell, Rousseau, Gillies et al. (1991) indicated that the most important organizational functions in healthcare are organizational culture, leadership, communication, coordination, and problem solving. Specifically, the authors concluded:

> "Intensive care units place great demands on care givers and support staff to effectively work together. A team-oriented, achievement-oriented culture and leaders who set high standards and provide necessary support are hypothesized to provide more open, accurate, and timely communication, effective coordination with other units, and more open collaborative problem-solving approaches. These, in turn, produce greater cohesiveness among team members resulting in the delivery of more effective patient care" (Shortell, et al, 1991, p. 710).

Figure 2.5 shows the relationships of the organizational constructs that impact ICU performance including caregiver interaction (leadership, culture, coordination, communication, conflict management and problem-solving), technological availability, nurse staffing, and task diversity (Shortell, Zimmerman, Rousseau et al., 1994).

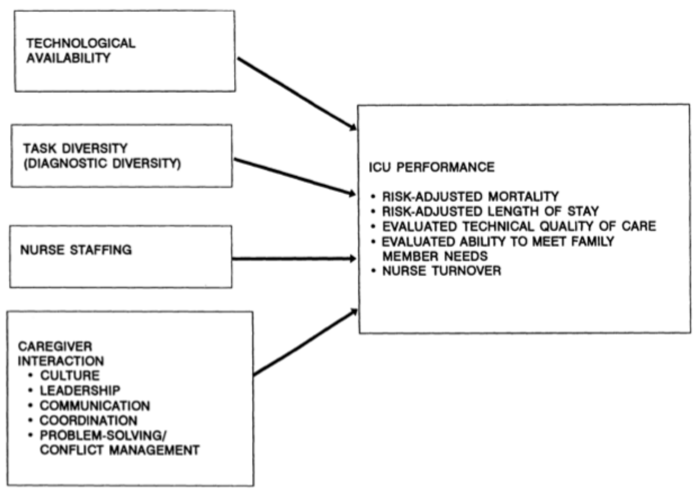


Figure 2.5: Analytic model for studying ICU performance (Shortell et al., 1994).

**Organizational Culture in the ICU**

According to Schein (1990), although one cannot "see" culture, it has a strong influence on all that takes place within an organization, because it defines the norms, shared values, beliefs, expectations, and assumptions shared by members of an organization that operate unconsciously and define an organization's view of itself and its environment. As such, culture can be difficult to understand and measure, and even more difficult to change (Schein, 1990).

Culture has become increasingly important in the critical care arena, especially since the Joint Commission cited culture and communication related shortcomings as main contributing factors to sentinel events. In the ICU, a safety culture would include an outcome measure for how often patients are harmed, a process measure for how often evidence-based interventions are used, and a structural measure for how clinicians know when they have learned from mistakes (Pronovost et al., 2009).

When reviewing the structure of surgical intensive care units, Barie, Bacchetta, and Eachempati (2000) noted characteristics of several ICU unit culture types. A team-oriented culture emphasizes communication, cooperation, staff development, and achievement. A people/security-oriented culture emphasizes adherence to procedure, approval, avoidance of conflict, and dependence. Finally a task-oriented culture emphasizes authoritarianism, competition, opposition, and perfectionism (Barie et al., 2000).

Shortell et al. (1991) conducted a study of 42 ICUs using the 48-item Organizational Culture Inventory (OCI) to measure (on a 1-5 Likert scale) factors associated with these three ICU unit culture types. The results indicated that a team-satisfaction oriented culture, strong leadership, open and timely communication, effective coordination, and open collaborative problem solving were associated with higher performing ICUs that had lower lengths of stay and a higher technical quality of care. Best practices, such as a strong commitment to customer service and employee support, were also identified. Shortell et al. (1991) developed a model, shown in Figure 2.6, that integrates a comprehensive set of these managerial and organizational process variables. When used together, these have been known to facilitate improvements in patient outcomes in the ICU.

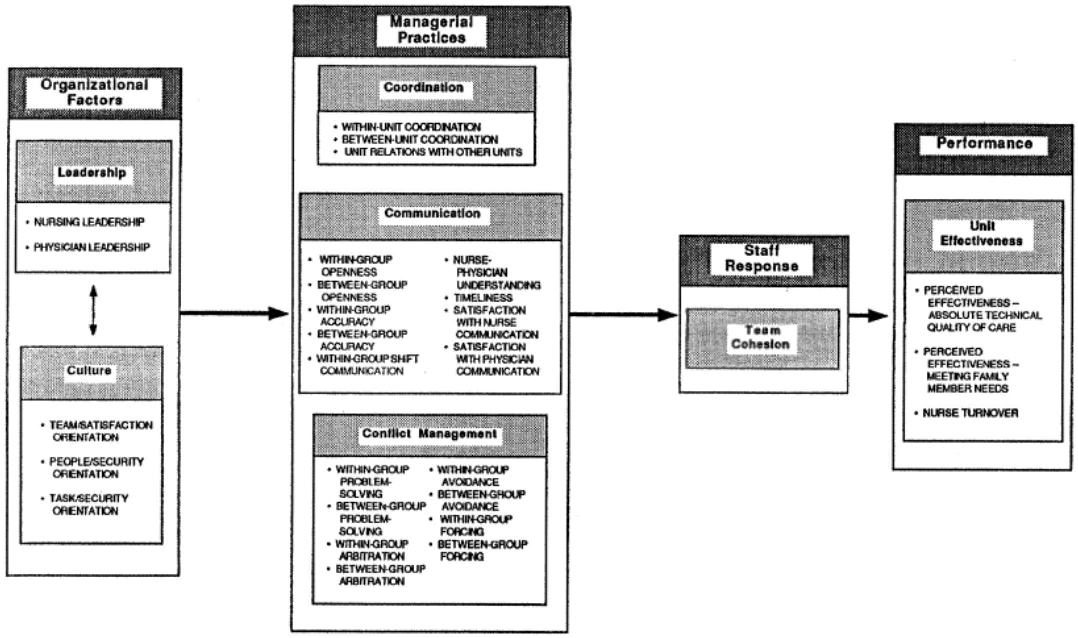


Figure 2.6: Managerial and organizational factors affecting ICU performance (Shortell et al., 1991).

Kutsogiannis et al. (2001) suggested that ICU organizational culture and climate are characterized by how physicians and other clinicians communicate and work together towards the goal of high quality care of patients, and how they work together to collaborate and resolve conflicts. The effectiveness of such interactions can be objectively measured using patient mortality, ICU occupancy rate and length of stay, and patient and family satisfaction (Kutsogiannis et al., 2001).

**Leadership in the ICU**

Another important construct related to optimal ICU performance is leadership, which is defined as "the capacity of individuals to influence others toward the accomplishment of organizationally relevant goals and objectives" (Shortell et al., 1991, p. 711). Results from the study noted above of 42 ICUs showed this involved not only physician leadership, but also nursing leadership, where leaders emphasized standards of excellence, clearly communicated goals and expectations, responded to changing situations, and were in touch with the needs of others (Shortell et al., 1991).

In a study of 51 ICU nurses from U.S. hospitals, results indicated the need for participatory and competent supervisors leading the unit, but when leaders were perceived as absent or incompetent, employees reported lower productivity and morale. In addition, active supervisor participation using communications, mentoring, and planning strongly correlated with organizational outcomes (Rouse, 2009).

With tele-ICU, the leadership of the intensivists or critical care nurses in the tele-ICU command center becomes especially important when bedside physician intensivists are not available or on-site. The ability for the tele-ICU intensivist to intervene can be minimized when the bedside intensivist has not delegated that authority or tele-ICU has not been fully adopted by the bedside staff (Goran, 2012).

**Communications and team processes in the ICU**

According to Shortell et al. (1994), when assessing the performance of ICUs, many aspects of communication are important including openness, accuracy, timeliness and understanding. The nature of the operation of an ICU requires complex information to be communicated in a short time period or between staff members on different shifts or monitoring via tele-ICU, especially when patient's conditions are unstable and need immediate attention. Studies of ICU staff nurses have indicated positive communication was associated with supportive management and shared decision-making (Hart & Moore, 1989).

Team leadership in the ICU supports the coordination of safe patient care and provides vital guidance for team interaction and collaboration within the ICU. These behaviors are important for ensuring safety and quality patient outcomes (Reader, Flin, & Cuthbertson, 2011).

Figure 2.7 provides an explanation of the input-process-output model that explains team performance in the ICU. This model for ICU team processes reiterates the importance of the other constructs of communication, leadership, coordination, and decision-making in the ICU mentioned previously.

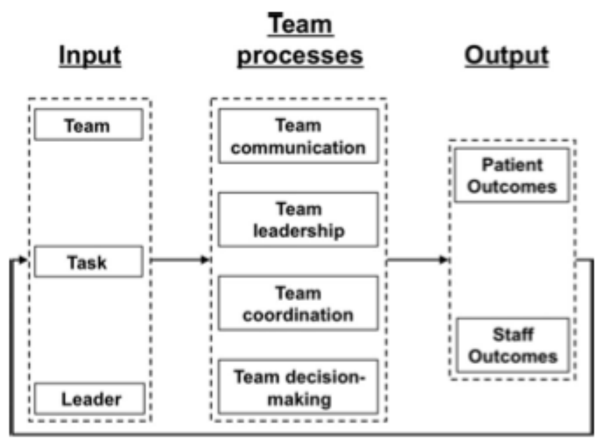


Figure 2.7: Input-process-output model to explain team performance in the ICU (Reader et al., 2011).

**Effects of Engagement at Work**

Schaufeli and Bakker (2010) described engagement as a positive, fulfilling, affective-motivational state of work related well being that is characterized by high levels of energy and involvement in work. It includes dimensions of vigor, dedication, and absorption, and is likely to occur when employee needs are met with events such as fostering learning, social support, and the need to belong. Engagement has implications for performance at an organizational level if the organization shares values with employees, inspires allegiance, and responds to employees in ways that show appreciation for their contributions (Leiter & Bakker, 2010). The Schaufeli and Bakker (2010) model in Figure 2.8 suggested the psychological state of work engagement could lead to performance outcomes.

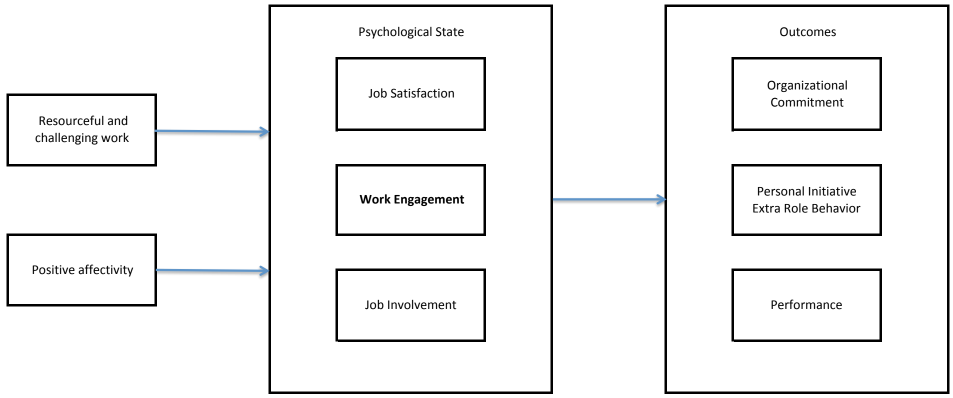


Figure 2.8: An integrative model of work motivation and engagement. This model illustrates employee motivation with work engagement mediates the impact of job and personal resources on organizational outcomes (Schaufeli & Bakker, 2010).

The performance-engagement link demonstrated in this model confirmed that employee engagement in their work contributes to the success of an organization. If necessary, targeted interventions can help employees become more engaged (Mastrangelo, 2009). Leiter and Maslach (2010) suggested that engagement interventions at the situational and organizational level are more impactful than individual ones. Engagement interventions can facilitate the creation of positive working conditions, new learning opportunities, and resources to support achievement of goals (Leiter & Maslach, 2010).

The subject of this study conducted an all employee survey that measured employee engagement using questions that were based on the Gallup Q12 instrument. Gallup defined employee engagement in terms of resourceful work, and measures job resources as antecedents to unit performance and job satisfaction. The instrument does not measure engagement at work in terms of an employee's involvement, satisfaction, and enthusiasm about their job. It measures elements of the work situation or engagement conditions that are actionable issues that management can directly address (Harter, Schmidt, Killham et al., 2009).

The Gallup Q12, which has been tested by over 152 organizations representing 955,905 employees, measures the relationship between engagement and the nine performance measures of customer loyalty/engagement, profitability, productivity, turnover, safety incidents, shrinkage, absenteeism, patient safety incidents, and quality defects. Patient safety was added specifically for the healthcare industry (Harter et al., 2009; Schaufeli & Bakker, 2010).

The graphic shown in Figure 2.9 demonstrates the relationship between the Q12 questions and patient satisfaction.

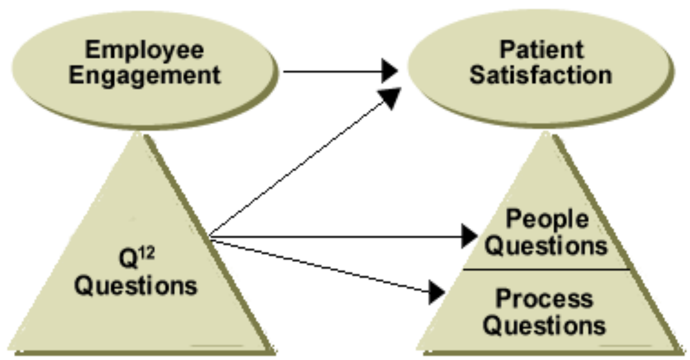


Figure 2.9: Model showing how Q12 employee engagement items impact controllable patient satisfaction measures (Blizzard, 2003).

The model in Figure 2.9 suggests that the processes of care along with the people who provide care are both foundational elements that must be managed in order to achieve high levels of patient satisfaction and loyalty. Employees who are committed to quality tend to communicate well with their patients and each other. Also, if an engaged employee believes an inefficient process is negatively affecting a patient, the employee will most likely take action to improve that process, thereby improving the patient experience (Blizzard, 2003).

While all of employee engagement items in the Q12 impact patient satisfaction, two questions have the most significant impact. For this study, the actual survey questions relating to these two were "The necessary materials and equipment are available when I need to perform my job" and "Employees of this organization show an attitude of genuinely caring about the patient." High employee scores on these two items are most likely to promote high-quality care (Blizzard, 2003).

## Summary

This literature review provided background, relevant information, and research results relating to healthcare and ICU quality in general, ICU staffing, telemedicine, tele-ICU, and tele-ICU adoption. Organizational factors related to ICU staff and processes, such as leadership, engagement, and culture, were also reviewed since they are linked to quality of care and patient outcomes. The remaining chapters will focus on the research methodology and results for this study, along with the significance of the findings and the implications for future research and practice.

# CHAPTER 3: METHODOLOGY

## Research Design and Rationale

This study was a retrospective, comparative, quantitative analysis using archived patient stay data from 2012. The study site involved eight adult medical/surgical ICUs from eight different hospitals that were part of a single health system in the United States. ICU staffing patterns, the level of tele-ICU adoption, and patient predicted and actual outcomes for mortality and length of stay were collected and/or processed using ETL (Extract-Transform-Load), then analyzed using version 21 of the IBM SPSS® statistical software. Various data sets were compared to determine if significant differences existed, or if certain variables acted as predictors of patient outcomes. Where preliminary findings indicated significant differences, additional analysis was done based on the condition of the patient using the predicted hospital mortality risk.

In cases where the data were normally distributed, *t*-tests, analysis of variance (ANOVA), or hierarchical linear modeling (HLM) tests were performed to determine where patient outcomes or employee survey responses differed significantly based on ICU staffing patterns and/or the levels of tele-ICU adoption. For datasets that were skewed, or where the assumptions for a *t*-test or ANOVA were otherwise violated, nonparametric statistics including Kruskal-Wallis and Mann Whitney *U* were performed. Associational statistics such as the Pearson product moment correlation, or Spearman rho for nonparametric tests, were used to determine if staffing patterns and tele-ICU adoption levels acted as predictors of ICU length of stay or hospital mortality. Effect-size estimates, which are values that characterize the strength of a relationship or magnitude of difference between independent and dependent variables (Gliner, Morgan, & Leech, 2009), were also calculated.

## Study Site

The study site consisted of eight ICUs that were part of an integrated delivery network (IDN) of hospitals in the U.S. in 2012. Tele-ICU was fully deployed in all eight of the ICUs prior to January 2011, so it had been in place at least one year prior to the start of the analysis, but in some cases for several years. The decision to invest in tele-ICU came following interviews with ICU nurses and staff who raised concerns over quality.

Two members of the health system executive management team provided the information contained in this section via interviews and by providing documentation. Both were board-certified intensivist physicians who had experience working in ICUs in the health system at the bedside as well as in tele-ICU. References related to the study site were intentionally not cited to maintain confidentiality.

In 2012, health system operations were based on a franchise model. Clinical staff at all hospital facilities were expected to adopt and adhere to standard operating procedures and a shared baseline of evidence-based protocols that were developed by multidisciplinary teams representing the different operating units. The goal of the hospital system was to create a team-oriented culture that emphasized open communication, cooperation, staff development, and achievement. The same HIT systems (EMR, CPOE, etc.) were deployed and used system wide. No major procedural, technological, or other differentiating interventions took place in any of the eight ICUs in this study during 2012.

The ICUs in the health system had similar staffing including a centralized team lead by a Medical Director of Critical Care and an ICU Services Director. The staffing model in the eight ICUs was considered closed staffing, with intensivists on site, however the model was not always high intensity, since the on-site intensivists were not always able to see every patient in the ICU. The eight ICUs were staffed with intensivists at the bedside either 12/7, 24/7, or a combination of the two. Where 24/7 was used, the intensivists were required to stay on-site through the nighttime hours. The ratio of total critical care beds relative to the number of intensivists available at the bedside varied from a low of approximately 1:12 to a high of 1:29. The maximum ratio that an intensivist would be expected to adequately cover was 1:22.

All tele-ICU intensivist physicians were board-certified in critical care. The 2012 scope of services for tele-ICU stated the role of the tele-ICU clinician was not to replace bedside caregivers, but to remotely assist them with ICU patient care twenty four hours a day, seven days a week. Several tele-ICU command centers were established in multiple remote locations including one at a facility owned by the health system. Each command center was staffed with a combination of board-certified intensivist physicians, acute care nurse practitioners, experienced critical care or medical-surgical nurses, and various other support staff.

The key objectives of tele-ICU included:

1. Responding to requests for help from the bedside care team;
2. Monitoring for adverse trends and interrupting before adverse trends became adverse outcomes;
3. Monitoring, supporting, and increasing “best practice” compliance;
4. Measuring and reporting performance across the system to help drive performance improvements.

In addition, responsibilities of intensivist physicians included:

1. Responding to code arrests;
2. Functioning as primary contact for high-risk patient issues;
3. Intervening as appropriate for high-risk patients or issues;
4. Overseeing the support physician functions;
5. Communicating with bedside managing physicians.

Multiple internal quality indicators were in place to measure performance in 2012 with the goal of improving patient outcomes. Both ICU and hospital length of stay and mortality were captured and compared in the same manner across all eight ICUs using the APACHE IV methodology (Manganaro, 2010). The overall focus of tele-ICU was to increase quality rather than achieve a return on the investment, but the health system did report cost savings as a result of lower overall lengths of stay after the initial deployment of tele-ICU. Hospital system management performed quarterly reviews to compare patient outcomes, assess trends, and audit overall unit performance across all hospital ICUs.

An established vendor installed the system wide tele-ICU technology (hardware and software) using a closed architecture network and a hub and spoke model as shown in Figure 3.1. Tele-ICU physicians and practitioners worked in one of a few centralized command centers supported by dedicated high-speed communication lines for connectivity (Reynolds, Rogove, Bander et al., 2011).

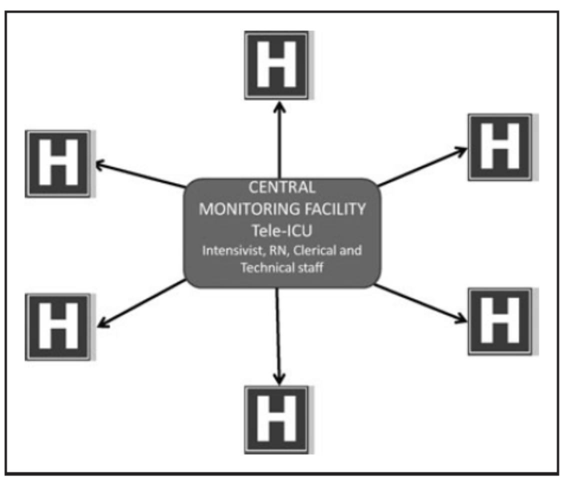


Figure 3.1: Depiction of a centralized tele-ICU
hub and spoke model (Reynolds et al., 2011).

Timing of monitoring was continuous as opposed to scheduled (virtual visits at defined times) or reactive (unscheduled, in response to an issue). Monitoring by tele-ICU was truly 24/7, with intensivist availability round-the-clock. The role of tele-ICU allowed for the co-management of patients as opposed to general consult. The protocol used was mixed, meaning it was up to the discretion of the bedside ICU staff whether to use a proactive or reactive protocol. A proactive protocol allows for autonomy of the remote tele-ICU site to direct patient care if the bedside team is unavailable to respond to patient alerts or alarms, whereas the bedside team will contact the remote tele-ICU site for assistance when using a reactive protocol (Reynolds et al., 2011).

According to hospital management, since it was left up to their discretion, ICU bedside staff may have based their level of delegation to tele-ICU on many factors, such as the attending ICU physician's preference, word of mouth, experience, subtle hints by other staff members, etc. As a result, it was hypothesized that the eight ICUs in this study had varying levels of adoption of tele-ICU, and that the full benefits of tele-ICU were not being realized in facilities where results indicated the level of adoption was very low.

## Research Questions

The first research question was as follows:

1. Is there a difference between the eight ICUs in the ratio of patient orders initiated by tele-ICU physicians to total patient unit stays?

*NOTE:* If there is a difference, it is assumed that sites that have higher levels of tele-ICU initiated orders also have a higher level of adoption of tele-ICU personnel as an essential member of the bedside critical care team.

To address the first research question, the ratio of tele-ICU physician orders to total patient unit stays was calculated for each ICU and quarter in 2012. For cases where a physician worked within tele-ICU and at the bedside for a given ICU, orders placed by that physician were not counted due to the difficulty of distinguishing which role that physician was performing when orders were placed.

Means of the tele-ICU order to patient stay ratios by facility were compared to determine if significant differences existed. Each ICU was put in rank order then classified with a level of adoption (i.e. high, medium, or low). For example, less than one tele-ICU physician order per patient unit stay might classify an ICU into the low adoption category, whereas more than ten orders might classify an ICU into the high adoption category.

The second research question was as follows:

2. Is there a difference in APACHE IV risk adjusted patient outcome measures for mortality and length of stay between the ICUs based on the level of tele-ICU adoption?

Mean scores of the risk-adjusted APACHE IV patient outcome measures were compared based on tele-ICU adoption level (see Figure 3.2) to determine if significant differences existed.

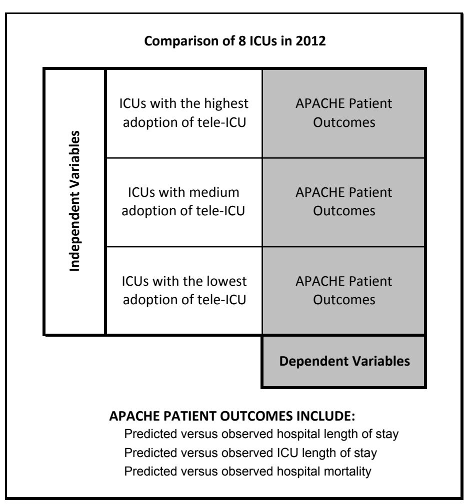


Figure 3.2: Independent and dependent variables for comparing APACHE outcomes based on high versus low levels of bedside adoption of tele-ICU.

The third research question was as follows:

3. Is there a difference in APACHE IV risk adjusted patient outcome measures between the ICUs based on different intensivist staffing patterns (24/7 versus 12/7)?

The mean scores of the risk-adjusted APACHE IV patient outcome measures were compared based on ICU staffing patterns (24/7 versus 12/7, as shown in Figure 3.3), to determine if significant differences existed. Note that one of the eight ICU's employed a hybrid of these staffing models and was eliminated from this part of the study.

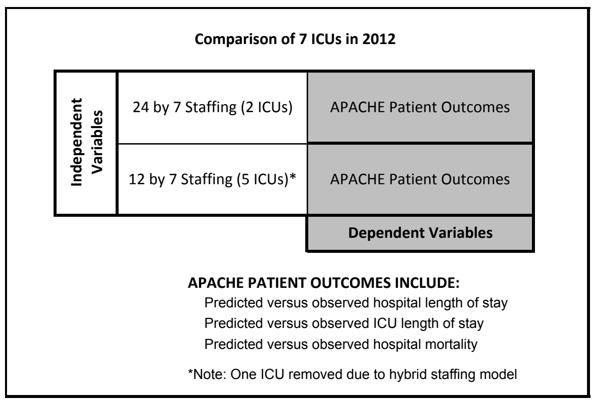


Figure 3.3: Independent and dependent variables for comparing APACHE patient outcomes based on ICU staffing pattern.

The fourth research question was as follows:

4. Is there an association between ICU intensivist staffing patterns (24/7 versus 12/7) and the level of tele-ICU adoption in predicting APACHE IV risk adjusted patient outcome measures?

Assuming significant differences existed in patient outcomes for tele-ICU adoption and staffing pattern, both variables were evaluated to determine if they acted as predictors of patient outcomes. For example, higher levels of tele-ICU adoption might be negatively correlated to lower (i.e. improved) risk-adjusted ICU lengths of stay (see Figure 3.4).

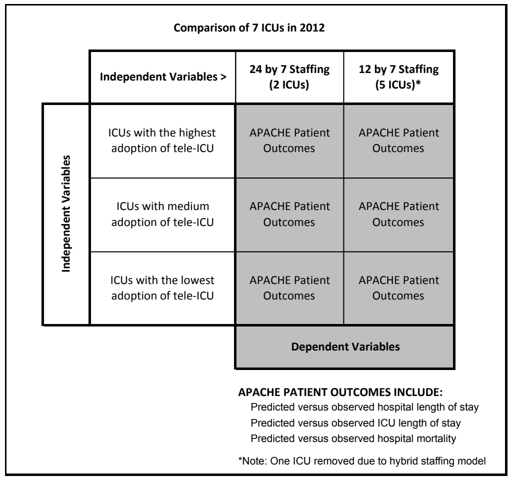


Figure 3.4: Independent and dependent variables for comparing APACHE outcomes based on staffing pattern and level of adoption of tele-ICU.

The fifth and final research question was:

5. Is there a difference between the ICUs with high versus low levels of tele-ICU adoption and the average scores of ICU employees for engagement and leadership effectiveness as measured by the annual all employee survey in Q3 of 2012?

Means for the two constructs measured by the 2012 all employee survey were compared based on level of tele-ICU adoption (see Figure 3.5), to determine if differences were significant.

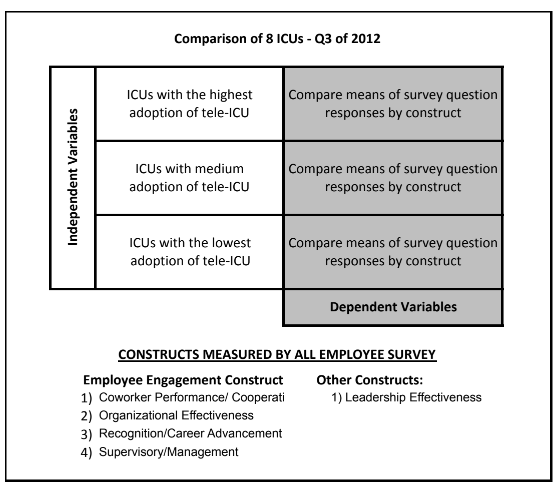


Figure 3.5: Independent and dependent variables for comparing all employee survey results based on high versus low levels of adoption of tele-ICU.

## Population and Sample

Since this study involved a single healthcare system with a unique operating model, the ability to generalize the results were limited, but could include similar U.S. medical/surgical adult care ICUs that use a closed, onsite intensivist staffing model and have or plan to implement tele-ICU. The sample was purposive based on the availability of patient stay data that included APACHE IV risk adjusted predictions, patient outcomes, and valid patient identifiers. The sample was gathered using a multiple step process that is described below.

First the ICUs that were going to be included in the study had to be determined. The health system had over 20 hospitals with a variety of ICU types in 2012. Only medical/surgical ICUs were included in the study, so ICUs specializing in cardiac, trauma, pediatric, neuro, and neonatal patients were eliminated. Only ten of the remaining ICUs had closed, onsite intensivist staffing. One was eliminated due to lack of data for two quarters in 2012.

Sample size was another consideration. According to the APACHE Foundations User Guide, actual versus expected outcome ratios based on samples of less than 200 patients are not reliable, and samples between 200 and 400 patients are potentially unreliable, so samples above 400 patients are preferred (Manganaro, 2010). One ICU was eliminated due to low numbers of patient stays for each quarter (< 100).

A total of eight ICUs met the final criteria for the study. One of the eight hospitals was considered both an academic and community hospital, while all the remaining hospitals were community hospitals. Figure 3.6 shows the final list which includes the staffing pattern and the number of licensed medical beds in 2012 per ICU. Licensed beds are defined as the maximum number of beds that a hospital holds a license to operate. Many hospitals do not operate all of the beds for which they are licensed (HHS, 2005).

| Hospital # | Intensivist Staffing Model | Licensed Medical ICU Beds in study |
|---|---|---|
| 1 | Closed: 12 by 7 | 26 |
| 2 | Closed: 24 by 7 | 24 |
| 3 | Closed: 12 by 7 | 24 |
| 4 | Closed: 12 by 7 | 24 |
| 5 | Closed: 12 by 7 | 12 |
| 6 | Closed: 24 by 7 | 32 |
| 7 | Closed: 12 by 7 | 20 |
| 8 | Closed: 12 by 7 | 16 |
| | Total | 178 |

Figure 3.6: Eight ICUs with staffing pattern and number of licensed ICU beds.

The second step in the process was to gather patient level data for patient unit stays during 2012 at the eight ICUs. Patient unit stays were defined as each stay in the ICU for a given patient, no matter if that patient was admitted and discharged from the ICU multiple times during their entire stay at that hospital. The sample was obtained from existing 2012 quarterly Master Patient Detail reports for each of the eight ICUs. These reports included all patient unit stays with a valid hospital discharge date in the reporting period (January 1, 2012, 12:01 am through December 31, 2012, 11:59 pm) since the patient's final mortality status was captured at the time they were discharged from the hospital. Hospital mortality can be a more appropriate patient outcome when compared to ICU mortality because it takes into account the status of the patient after they leave the ICU (i.e. patients who leave the ICU with a do not resuscitate order) (Willmitch et al., 2012). Even though the predicted and actual ICU mortality outcome measures were available, they were not used in this study because the more meaningful outcome was whether or not the patient died during their entire hospital stay, not just during their time in the ICU.

Hospital and ICU admission and discharge dates and times were captured for all patient stays. Patient stays with an admission type of Admit, Readmit, Stepdown/Other, or Transfer were included. All patients that met the criteria were included whether or not the patient was monitored by tele-ICU.

All patients in the report had APACHE predictions. Although not part of the final dataset, data required to calculate APACHE predictions included the patient's date of birth, gender, APACHE admission diagnosis, admission sources, mean blood pressure, heart rate, respiratory rate, and Glasgow Coma Scale. One patient was removed due to an invalid identifier, and all patients that had documented APACHE errors were removed. The final sample had a total of 14,362 patient unit stays.

The sample for the survey results included all employees at the eight ICU units who successfully completed the 2012 all employee survey in August of 2012. Descriptive data such as the ICU employee's role, tenure, status, etc. were also included in the final dataset.

## Survey Administration

No new survey was administered for this study. Employees who listed one of the eight study ICUs as the unit where they were employed ($n$ = 546) were extracted from the results of the annual all employee survey conducted from August 8 – August 22, 2012. Employees with non-responses to any question were removed, bringing the total to 491 respondents. Physicians were given a separate survey, but only eight physicians from one of the facilities responded to that survey, so those results were not included.

## Survey Reliability and Validity

Leadership effectiveness and employee engagement, two of the main constructs measured by the all employee survey, were analyzed in this study. Engagement was divided into the four sub-dimensions of Coworker Performance/Cooperation (two questions), Organizational Effectiveness (four questions), Recognition/Career Advancement (four questions) and Supervisory/Management (four questions). There was one outcome variable for engagement for Overall Satisfaction that was not evaluated. Leadership Effectiveness was measured with 13 questions. A listing of all questions categorized by dimension can be found in Appendix D.

Using the actual survey results ($n$ = 491), Cronbach's alphas were computed to assess interitem reliability of the two main constructs (engagement and leadership effectiveness) and each of the four sub-dimensions related to engagement. All of the dimensions showed acceptable to strong internal consistency with Cronbach's alpha coefficient values ranging from .69 to .97. This indicated that the mean correlation of each item was consistent within each dimension. The results by sub-dimension can be found in Table 3.1.

Table 3.1

*Cronbach's Alpha and Number of Items for Engagement and Leadership Dimensions*

| Variable | *Number of items* | α |
|---|---|---|
| Engagement Dimensions | | |
| Coworker Performance/Cooperation | 2 | 0.69 |
| Organizational Effectiveness | 4 | 0.75 |
| Recognition/Career Advancement | 4 | 0.83 |
| Supervisory/Management | 4 | 0.84 |
| Leadership Effectiveness Dimension | 13 | 0.97 |

The value for Coworker Performance/Cooperation (α = .69) fell slightly below the acceptable threshold of .7 indicating support for internal consistency reliability, but still within an acceptable range for a two item scale (Gliner et al., 2009). Since the Spearman-Brown statistic is considered the most appropriate for a two item scale, and on average is less biased than the Cronbach's alpha, (Eisinga, Grotenhuis, & Pelzer, 2012), it was also calculated for Coworker Performance/Cooperation and the resulting coefficient was also $\rho = .69$.

Exploratory factor analysis (EFA) using principal component analysis was performed to determine how well the factors loaded for each of the main constructs of employee engagement and leadership effectiveness, and for the four sub-dimensions of engagement. The adequacy of the sample size ($n = 491$) was confirmed using a principal component analysis when communalities after extraction exceeded .414 for all factors using Likert scale responses.

The EFA results indicated a one-factor structure for both engagement and leadership effectiveness. The engagement items loaded into one single category ranging from the lowest score of 0.549 to the highest score of 0.818. The leadership effectiveness items loaded into one single category ranging from the lowest score of 0.732 to the highest score of 0.912. These results indicated that the survey items are a good measure of both of the main constructs. When using a varimax rotation to load the survey items associated with each of the 4 sub-dimensions of engagement, none of the sub-dimensions were loading as expected, indicating that many of the questions are likely measuring more than one construct.

## External Validity

The study sample was representative of similar ICUs in medium to large health systems in the U.S. that have closed intensivist staffing models and tele-ICU. The sample included patient stays for a wide variety of adult patients types from eight different ICUs in different states and different geographical areas with distinctly different climates. Results from a full calendar year took into account seasonality of illnesses. The study used recent data from 2012, so the results should remain relevant for several years. Other published studies have also indicated variability in the levels of tele-ICU adoption (Morrison et al., 2010; Thomas et al., 2009; Willmitch et al., 2012), but in several cases the results were not generalizable due to heterogeneity across study settings.

## Data Collection and Analysis

Archived ICU patient stay data were collected for patients that were discharged from each of the eight facilities between 12:01 am on 1/1/2012 through 11:59 pm on 12/31/2012. An overview of the types of data collected is shown in Figure 3.7.

| Data Type | Data | Used for | Notes |
|---|---|---|---|
| **Computerized physician initiated ICU patient order data including:**<br>Unique patient ID<br>Ordering physician ID<br>Order date/time/type<br>ICU Unit | Total physician initiated orders for that patient stay, number of orders per patient initiated by tele-ICU physician, total patient stays per ICU | Used to determine level of adoption of tele-ICU per facility in each quarter based on the ratio of tele-ICU physician initiated orders to patient stays | All patient identifiers removed |
| **APACHE IV Patient Outcome measures (risk adjusted), including:**<br>Predicted versus actual hospital length of stay<br>Predicted versus actual ICU length of stay<br>Predicted versus observed mortality | Scores for all patient stays with predictions for 2012 by quarter, by ICU unit | Used to determine if significant differences or associations exist in patient outcomes across ICU units that are grouped based on unit staffing patterns and level of tele-ICU adoption | All patient identifiers removed |
| **Results of 2012 all employee survey for ICU employees in the 8 ICUs.** Categories are:<br>**a) Engagement constructs:**<br>Coworker Performance/Cooperation<br>Organizational Effectiveness<br>Recognition/Career Advancement<br>Supervisory/Management<br>**b) Leadership Effectiveness** | Based on survey scale:<br><br>(i.e. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree) | Used to determine if there are significant differences in responses between ICU units that are grouped based on level of tele-ICU adoption | Questions grouped by construct |
| **ICU Intensivist Staffing Patterns** | Closed: 24/7 or 12/7 | Grouping of ICUs for analysis | 1 type per ICU |

Figure 3.7: Description of data collected for the study including how the data were used.

### Data Collection and Preparation Procedures

In order to determine the ranking of the ICUs with the highest versus lowest levels of tele-ICU adoption amongst the eight hospitals in the study, a multiple step ETL (extract-transform-load) process was conducted. An enterprise data warehouse was used to integrate patient stay data from one source with order data for the same patients from another source.

A data warehouse is a system that extracts, cleans, conforms, and delivers source data into a dimensional data store and then implements querying and analysis for the purpose of decision-making. 'Extract, Transform, Load' (ETL) is a technology specializing in extracting data from one or more sources, transforming the data (e.g. cleansing, reformatting, standardization, aggregation, or the application of any number of business rules), then loading the resulting data set into specified target systems or file formats (Kimball & Caserta, 2006). Reports can then be created using the cleansed, consolidated data.

The health system uses the APACHE IV severity-adjusted methodology to predict outcomes for critically ill adult patients. A total of 27 variables, including age, vital signs, lab values, and the patient's history were used to calculate predictions for each patient for mortality and length of stay. These predictions were compared to actual patient outcomes to determine quality and improve performance in the ICU (Manganaro, 2010). Although the 27 variables noted above were used to calculate the APACHE predictions for each patient stay, they were not part of the datasets used in this study.

The health system captured APACHE outcomes for ICU patient stays using the 2012 quarterly Master Patient Detail reports. These reports provided the basis for the study sample of patient stays for all eight facilities, and contained a unique patient stay identifier for each patient. The reports were in spreadsheet format, and included hospital admit and discharge dates, ICU admit and discharge dates, ICU unit, admitting diagnosis, the APACHE score, actual and predicted mortality for the hospital and ICU, actual and predicted length of stay for the hospital and ICU, actual and predicted ventilator days, and error descriptions (if applicable). All patient unit stays with errors were removed. One other patient unit stay was removed due to an invalid identifier. The final study sample contained 14,362 patient unit stays.

The pre-assigned unique identifier for each of the 14,362 patient unit stays, along with the facility code and the ICU admit and discharge dates, were used to identify and extract the ICU orders written for each patient unit stay from a secondary data source, the CPOE system. Frequency orders, which are repeat orders that are scheduled for the same treatment, were removed. System generated orders were also not extracted. This resulted in 2,280,013 total orders for the 14,362 patient unit stays. The patient data was then de-identified, and all unique references, including any unique patient identifiers, were removed from the dataset.

At this point, a count of the subset of orders initiated by tele-ICU physicians was obtained based on extracting orders where the physician ID matched a listing of tele-ICU physician IDs. Orders were not counted if the same physician worked in the tele-ICU and the bedside for the same ICU.

Three reports were generated as a result of the ETL process. The first was an order report that included order and patient detail for all 2.28 million orders including the order type, order date, patient identifier, and ordering physician identifier. The second was a summary report that included the total number of physician initiated orders, the total tele-ICU physician initiated orders, ratio of tele-ICU orders to patient unit stays, and the ratio of tele-ICU orders to total orders (shown in Appendix E). The third was a physician rollup report that showed the total number of orders initiated by each physician by facility and quarter.

**New Variables**

Predicted and actual patient outcome data extracted from the 2012 Master Patient Detail report were used to create risk adjusted ratios in SPSS in order to compare actual outcomes to predicted outcomes for each patient stay. Assuming LOS predictions were captured, the actual length of stay (in days up to 2 decimals) was divided by the predicted length of stay to create the risk-adjusted length of stay ratio for that patient stay. The resulting variables were named ICU LOS Ratio (*n* = 14220) and Hospital LOS Ratio (*n* = 13265).

For hospital mortality, new patient level variables were created to measure and assess the mortality outcomes so they could be compared across groups (tele-ICU adoption level or staffing pattern). To capture whether a patient lived or died during their hospital stay, a new numeric variable called the Actual Hospital Mortality Number was created. A zero represented a living patient when the patient was discharged from the hospital, and a one represented a patient who died during their hospital stay. The APACHE IV mortality prediction was subtracted from the Actual Hospital Mortality Number for each patient stay to create a second variable, the Risk Adjusted Hospital Mortality Assessment. The APACHE IV mortality predication value had already taken into account the patient's age, chronic health, physiology, disease, and lead time bias (Manganaro, 2010).

The resulting values for the second variable were within the range of -1 to +1. This factor provided a probability variation along a range of -1 to +1 that was based on expected versus unexpected mortality compared to a patient's assessed risk upon ICU admission. Values closer to -1 represented patients who had a high mortality risk but did not die during their hospital stay. Values close to +1 represented patients who did not have a high mortality risk but did die during their hospital stay. For example, if the predicted mortality for a patient was very low at 5% but they died, the resulting .95 would be considered undesirable (close to +1). In contrast, if the predicted mortality for a patient was very high at 95% but they lived, the resulting -.95 would be considered desirable (close to -1). This calculation has similarities to a risk-adjusted cumulative sum procedure (CUSUM), which is used to identify substantial increases or decreases in risk-adjusted mortality through continuous monitoring, except CUSUM applies various weightings based on the direction of the change (Cook, Steiner, Cook et al., 2003).

For the all employee survey, new variables were created to calculate the mean values of each of the 5 constructs being measured for each employee. New variables were also created in all datasets that transformed the facility code where the patient stayed into the corresponding level of adoption (i.e. high, medium, low) and staffing pattern (12/7, 24/7).

# CHAPTER 4:  RESULTS

## Descriptive Statistics

Descriptive statistics are provided for order summary, patient outcome, and employee survey data. The order summary data were used to respond to the first research question. Patient outcome data, in conjunction with the results of research question one, were used to respond to questions two through four. Employee survey results were used to respond to the final research question.

### Orders by Physician type

The order summary data, subtotaled by ICU and quarter, can be viewed in Appendix E. ICU patient unit stays ranged from 206 to 687 patient unit stays per quarter, with a mean of 449 and standard deviation of 144. Total orders ranged from 31,585 to 131,368 per ICU per quarter, with a mean of 71,250 and a standard deviation of 27,354.

Total tele-ICU physician initiated orders ranged from 87 to 6017 per ICU per quarter, with a mean of 2,156 and a standard deviation of 1,660. The ratio of tele-ICU orders to patient unit stays ranged from .137 to 13.7 per ICU per quarter, with a mean of 5.38 an a standard deviation of 3.87. All of the data were normally distributed with skewness ranging from -.4 to .8.

### Patient Outcomes

The second data set contained the predicted and actual patient outcome data for mortality and length of stay along with several newly created variables. Both the ICU LOS ratio (16.96) and the Hospital LOS ratio (11.6) were positively skewed, while Risk-Adjusted Hospital Mortality Assessment was normally distributed. Note the reason why some *n* values were less than the total *N* of 14,362 was because no APACHE prediction was provided. These results are displayed in Table 4.1.

Table 4.1

*Means, Standard Deviations, Range of Values and Skewness for Patient Outcome Data*

| Variable | *n* | Lowest value | Highest value | *M* | *SD* | Skewness |
|---|---|---|---|---|---|---|
| Length of Stay - ICU | | | | | | |
| Predicted ICU LOS | 14220 | 0.01 | 11.25 | 3.76 | 2.03 | 0.50 |
| Actual ICU LOS | 14362 | 0.17 | 30 | 2.35 | 3.08 | 3.9 |
| ICU LOS Ratio | 14220 | 0.02 | 52 | 0.69 | 0.97 | 16.96 |
| Length of Stay - Hospital | | | | | | |
| Predicted Hospital LOS | 13265 | 0.1 | 49.47 | 10.14 | 4.77 | 1.4 |
| Actual Hospital LOS | 14362 | 0.13 | 50 | 8 | 7.7 | 2.4 |
| Hospital LOS Ratio | 13265 | 0.01 | 29.69 | 0.74 | 0.76 | 11.6 |
| Mortality | | | | | | |
| Predicted Hospital Mortality | 13265 | 0.001 | 0.99 | 0.151 | 0.2 | 2.09 |
| Actual Hospital Mortality* | 14362 | 0 | 1 | 0.08 | 0.27 | 3.06 |
| Risk Adj. Hospital Mortality Assessment | 13265 | -.980 | 0.99 | -.074 | .252 | .994 |

*Only using hospital mortality. A value of one indicates patient died during hospital stay.

**Survey Data**

The third dataset contained results from the all employee survey. There were 526 total respondents from the eight ICUs in the study, which was reduced to 491 after result sets that contained blank responses were removed. Questions measuring employee engagement and leadership effectiveness were of interest to this study. The four sub-dimensions that measured employee engagement were organizational effectiveness, recognition/career advancement, supervisory/management, and coworker performance/cooperation. The survey questions grouped by category are shown in Appendix D.

Respondents included 373 female employees (76%) and 118 male employees (24%). The largest job classification of respondents was Registered Nurses, who accounted for 152 out of the 491 respondents or 31%. Next were Specialists (*n* = 131, 27%) followed by HIMS (*n* = 28, 5.7%), Nursing Assistants (*n* = 23, 4.7%), Supervisors (*n* = 20, 3.8%), Technicians (*n* = 19, 3.6%), and Radiologists (*n* = 18, 3.4%). The remaining 24 categories each accounted for less than 3% of the survey respondents. Physicians were administered a separate survey which was not used in this study. The majority of the respondents (*n* = 468, 95.3%) were full time employees. Tables 4.2 and 4.3 are frequency distributions showing age range and length of service of survey respondents.

Table 4.2

*Survey Respondents – Age Range*

| Age Range in years | *n* | % |
|---|---|---|
| Under 20 | 1 | 0.2 |
| 20 – 29 | 73 | 14.9 |
| 30 – 39 | 124 | 25.3 |
| 40 – 49 | 122 | 24.8 |
| 50 – 59 | 115 | 23.4 |
| 60 and above | 56 | 11.4 |
| Total | 491 | 100 |

Table 4.3

*Survey Respondents - Length of Service*

| Length of Service | *n* | % |
|---|---|---|
| Less than 6 months | 15 | 3.1 |
| 6 months to 1 year | 20 | 4.1 |
| 1 – 2 years | 51 | 10.4 |
| 2 – 5 years | 97 | 19.8 |
| 5 – 10 years | 144 | 29.3 |
| 10 – 20 years | 117 | 21.4 |
| More than 20 years | 64 | 12 |
| Total | 491 | 100 |

Frequency distributions of survey respondents based on the two main independent variables, ICU staffing pattern and level of tele-ICU adoption, can be found in Tables 4.4 and 4.5.

Table 4.4

*Frequency of Responses by Facility Type*

| Response rates – 12/7 vs. 24/7 facilities* | *n* | % |
|---|---|---|
| ICU intensivist staffing pattern | | |
| 12/7 | 269 | 65.1 |
| 24/7 | 144 | 34.9 |
| Total | 413 | 100 |

*NOTE: One facility removed due to a staffing model that was a hybrid of 12/7 and 24/7

Table 4.5

*Frequency of Responses by Tele-ICU Adoption Level*

| Response rates – Tele-ICU adoption level | *n* | % |
|---|---|---|
| High adoption | 111 | 22.6 |
| Medium adoption | 236 | 48.1 |
| Low adoption | 144 | 29.3 |
| Total | 491 | 100 |

**Results: Research Question 1**

1. Is there a difference between the eight ICUs in the ratio of patient orders initiated by tele-ICU physicians to total patient unit stays?

*NOTE:* If there is a difference, it is assumed that sites that have higher levels of tele-ICU initiated orders also have a higher level of adoption of tele-ICU personnel as an essential member of the bedside critical care team.

Data captured during the Extract-Transform-Load process described in the previous section were used to respond to this research question. All orders initiated for each patient unit stay were extracted. Frequency orders and system-generated orders were then removed. Orders initiated by ICU physicians that worked in both tele-ICU and at the bedside ICU were removed. The orders initiated by tele-ICU physicians were separated into a different category. The ratio of tele-ICU physician orders to patient unit stays was calculated for each facility for each quarter ($n$ = 32). The ratio of tele-ICU orders to total orders was also calculated. A recap of this data is provided in Appendix E.

The data were loaded into SPSS and a one-way ANOVA was performed. Statistically significant differences were found between groups of facilities in the ratio of tele-ICU physician orders to patient stays, $F$ (7, 24) = 70.28, $p < .001$. The Eta effect size of $\eta^2 = .95$ was much larger than typical indicating that 95% of the variance between the facilities was due to the level of tele-ICU adoption. The Levene test was significant ($p = .004$) indicating the assumption of equal variances was violated, so a Games Howell post hoc test was conducted. A listing of the means and standard deviations in facility rank order (low to high) is shown in Table 4.6.

Table 4.6

*Means, Standard Deviations: Ratio of Tele-ICU Orders to Patient Stays*

| Facility (rank order*) | *M* | *SD* |
|---|---|---|
| 6 | 0.251 | 0.175 |
| 2 | 0.649 | 0.361 |
| 4 | 4.212 | 1.123 |
| 8 | 4.382 | 1.215 |
| 3 | 5.198 | 0.36 |
| 7 | 7.148 | 1.157 |
| 5 | 9.646 | 0.154 |
| 1 | 11.569 | 1.676 |
| Total | 5.382 | 3.871 |

*Facilities ranked from lowest to highest levels of adoption

The Games Howell post hoc test reported significant differences ($p < .05$) between all eight facilities. Facilities 2 and 6 had the lowest level of adoption with mean values of less than one order per patient stay, and were significantly different from all other facilities (facility 2: $M$ = .251, and facility 6: $M$ = .649). Facilities 3, 4, and 8 were significantly different from both the low and high adoption groups with a range of 4.2 to 5.2 orders per patient stay, indicating a medium level of adoption. Facility 7, which had a ratio of 7.1 orders per patient stay, was not significantly different from any facility in the high or medium adoption groups, but it was significantly different when compared to the low adoption group, so it was placed in the medium group. The final group clearly had the highest level of tele-ICU adoption with 9.6 (facility 5) and 11.6 (facility 1) orders per patient unit stay. The means plot in Figure 4.1 shows the thresholds where significant differences existed for the high, medium, and low groupings of tele-ICU adoption.

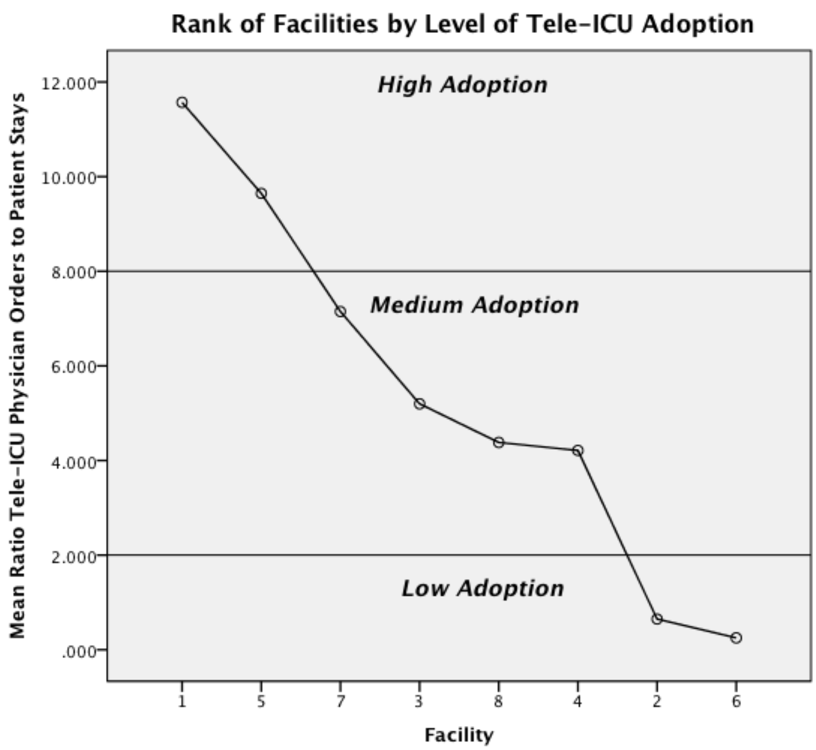


Figure 4.1: Means plot showing mean number of tele-ICU physician initiated orders to patient stays by facility in 2012, ordered from highest to lowest level of adoption

The two facilities that were classified as low adopters were the only two ICUs with a 24/7 staffing pattern. The remaining facilities with 12/7 staffing were in either the medium or high adoption groups. The facility that was classified as having a hybrid-staffing model was also in the medium adoption group.

In order to apply the level of tele-ICU adoption to the patient outcome data, a new variable was created for each patient stay that transformed the facility ID to the appropriate level of tele-ICU adoption (1 = low, 2 = medium, and 3 = high). Descriptive statistics showing the number of patient stays for the three categories of tele-ICU adoption are shown in Table 4.7.

Table 4.7

*Number of Patient Stays for Each Level of Tele-ICU Adoption*

| Level of Adoption for entire sample | *n* | % |
|---|---|---|
| Patient unit stays | | |
| Low adoption of tele-ICU | 4715 | 32.8 |
| Medium adoption of tele-ICU | 6881 | 47.9 |
| High adoption of tele-ICU | 2766 | 19.3 |
| Total | 14,362 | 100 |

**Results: Research Question 2**

2. Is there a difference in APACHE IV risk adjusted patient outcome measures for mortality and length of stay between the ICUs based on the level of tele-ICU adoption?

The length of stay ratios were not normally distributed so nonparametric tests were used. The ICU LOS ratio had skewness of 16.891 and the hospital LOS had skewness of 11.607. Risk adjusted mortality assessment was normally distributed with a skewness value of .994. Mean, standard deviation, and mean rank values for both hospital and ICU LOS ratios for all categories of adoption can be found in Table 4.8.

Table 4.8

*Means, Mean Ranks, and Standard Deviations: Actual to predicted LOS ratios by adoption level*

| Tele-ICU adoption level | *n* | *M* | *SD* | *Mean Rank* |
|---|---|---|---|---|
| Hospital Length of Stay ratio | | | | |
| Low adoption | 4297 | 0.83 | 0.995 | 7055 |
| Medium adoption | 6421 | 0.704 | 0.601 | 6495 |
| High adoption | 2547 | 0.676 | 0.617 | 6269 |
| Total | 13265 | 0.74 | 0.756 | |
| ICU Length of Stay ratio | | | | |
| Low adoption | 4677 | 0.817 | 1.351 | 7636 |
| Medium adoption | 6865 | 0.643 | 0.746 | 7007 |
| High adoption | 2678 | 0.582 | 0.599 | 6457 |
| Total | 14220 | 0.689 | 0.972 | |

A Kruskal-Wallis nonparametric test was conducted to determine if there were significant differences in risk adjusted patient lengths of stay between ICUs with high, medium, and low levels of tele-ICU adoption. Both ICU and hospital length of stay were tested.

The test for hospital length of stay indicated that the three levels adoption of tele-ICU differed significantly $x^2$ (2, $n$ = 13265) = 83.68, $p$ <.001. The test for ICU length of stay also indicated that the three levels adoption of tele-ICU differed significantly $x^2$ (2, $n$ =14220) = 148.46, $p$ < .001. A chart showing these results can be found in Figure 4.2. Note that the lower the mean length of stay ratio, the shorter the actual length of stay when compared to predicted.

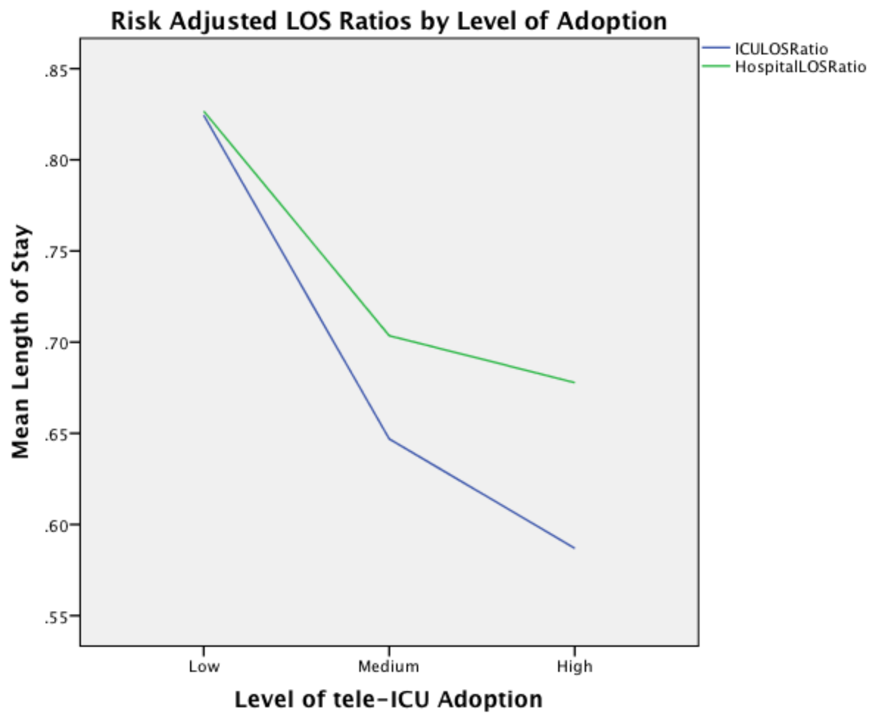


*Figure 4.2: Mean length of stay ratios for hospital and ICU by level of tele-ICU adoption. Note: The lower the mean LOS ratio, the shorter the LOS when compared to expected.*

Post hoc Mann-Whitney *U* tests compared all possible combinations of the three levels of tele-ICU adoption (high, medium, low) for both hospital and ICU length of stay ratio using a Bonferonni corrected *p* value of .017 to indicate statistical significance. All combinations were significant with values ranging from $p < .001$ to $p = .010$.

For the ICU length of stay post hoc tests, the mean rank for the high adoption group (3297) was significantly lower than the mean rank for the low adoption group (3896), $U = 5{,}241{,}107$, $p < .001$, $r = -0.136$, with a smaller than typical effect size. The mean rank for the medium adoption group (5562) was significantly lower than the low adoption group (6078), $U = 14{,}618{,}387$, $p < .001$, $r = -0.076$ with a smaller than typical effect size. Finally, the mean rank for the high adoption (4502) was significantly lower than the mean rank for the medium adoption group (4877), $U = 8{,}468{,}187$, $p < .001$, $r = -0.016$ also with a smaller than typical effect size.

For the hospital length of stay post hoc tests, the mean rank for the high adoption group (3170) was significantly lower than the mean rank for the low adoption group (3572), $U$ = 4,829,950, $p < .001$, $r = -0.098$, with a smaller than typical effect size. The mean rank for the medium adoption group (5177) was significantly lower than the low adoption group (5632), $U$ = 12,622,553, $p < .001$, $r = -0.072$, with a smaller than typical effect size. Finally, the mean rank for the high adoption (4373) was significantly lower than the mean rank for the medium (4529), $U$ = 7,892,284, $p = .010$, $r = -0.027$, with a smaller than typical effect size.

To ensure variations between groups were not due to the patient's condition (i.e. that certain ICUs treated a higher volume of sicker patients), Kruskal-Wallace tests were run to determine if significant differences existed based on the patient's predicted mortality. Three classifications were identified based on the APACHE methodology. High-risk patients had a predicted mortality of >50%, low-risk patients had a predicted mortality of <10%, and patients with predicted mortality values between 10% and 50% were considered medium-risk.

Tests showed significant differences still existed for ICU length of stay ratios for patients who had a predicted mortality of >50%, $x^2$ (2, $n$ = 1065) = 19.25, $p < .001$. Mann Whitney $U$ post hoc tests were run and significant differences existed between the high (mean rank = 289) versus low (mean rank = 327) adoption group on the >50% predicted mortality subgroup, $U$ = 40,432, $p = .010$, $r = -.103$ indicating a smaller than typical effect size. The only combination that did not show significant differences for the >50% predicted mortality subgroup was between the medium (mean rank = 334) and high (mean rank = 354) adoption groups $U$ = 49,876, $p = .215$, $r = -.047$ indicating a smaller than typical effect size.

For the low risk subgroup with less than a 10% risk of mortality, Kruskal-Wallace tests indicated significant differences existed between all three levels of adoption on ICU length of stay ratio, $x^2$ (2, $n$ = 7902) = 79.21, $p < .001$. There were similar results for the medium risk group where the predicted hospital mortality ranged from 10% to 50%, $x^2$ (2, $n$ = 4167) = 40.845, $p < .001$. Post hoc test for all levels of adoption combinations (high, medium, and low) indicated significant differences ($p$ values ranging from <.001 to .003) for both the low risk subgroup (<10% risk of mortality) and the medium risk subgroup (10% to 50%).

To calculate the differences in the mortality assessment across the ICUs with high, medium, and low tele-ICU adoption, means of the variable Risk Adjusted Hospital Mortality Assessment were compared using a one-way ANOVA. The new variable was calculated by subtracting the predicted mortality from zero if the patient lived, or from one if the patient died. Mean and standard deviation values for all three levels of adoption are shown in table 4.9.

Table 4.9

*Means, Standard Deviations for Risk Adjusted Mortality Assessment*

| Variable | *n* | *M* | *SD* |
|---|---|---|---|
| Risk Adjusted Hospital Mortality | | | |
| Low adoption | 4297 | -0.0677 | 0.262 |
| Medium adoption | 6421 | -0.0749 | 0.228 |
| High adoption | 2547 | -0.0848 | 0.288 |
| Total | 13265 | -0.0745 | 0.252 |

A statistically significant difference was found among the three levels of tele-ICU adoption for risk adjusted hospital mortality, $F$ (2, 13262) = 3.684, $p = .025$. Tukey post hoc tests indicated that only the high and low adoption groups were significantly different ($p = .019$, $\eta^2 = .0006$) with a much smaller than typical effect size.

To address the potential violation of the ANOVA assumption for independence of observations due to the hierarchical structure of the data (i.e. patient level, unit level, adoption group level), hierarchical linear modeling (HLM) was also conducted. HLM was used to statistically analyze the data structure where patients from multiple ICUs were nested within the high, medium, and low adoption groups (Woltman, Feldstain, MacKay et al., 2012). The estimated marginal means were the same as those shown in Table 4.9. The intercept was allowed to vary by ICU. The mean intercept estimate for the risk adjusted hospital mortality assessment was statistically significant ($\Upsilon_{00} = -.0826$, $t = -9.447$, $p < .001$). None of the estimates of fixed effects for the high, medium and low categories of the hospital mortality were significant, with *p* values ranging from .267 to .597. Figure 4.3 displays the mean values for the hospital mortality assessment ratio.

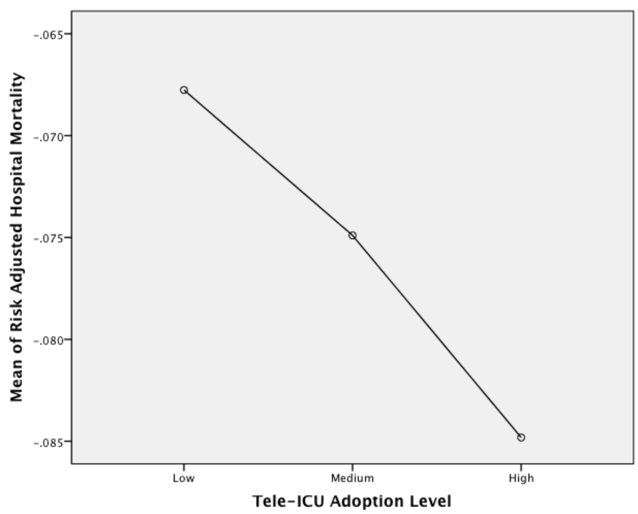


Figure 4.3: Mean risk adjusted hospital mortality outcome assessment based on level of tele-ICU adoption.

**Results: Research Question 3**

3. Is there a difference in APACHE IV risk adjusted patient outcome measures between the ICUs based on different intensivist staffing patterns (24/7 versus 12/7)?

Since the data were not normally distributed and there were significant differences in variances between the groups, nonparametric Mann-Whitney *U* test were performed to compare 12/7 and 24/7 ICU staffing groups. For ICU LOS ratio, the mean rank of the 24/7 group (7104) was significantly higher than the mean rank of the 12/7 group (6414), $U$ =18,100,089, $p < .001$, $r$ =.086. The mean rank for hospital LOS ratio was also significantly higher for 24/7 (6574) when compared to 12/7 (5995), $U$ = 15,762,208, $p < .001$, $r$ = -.077. Both sets of results had a smaller than typical effect size.

A one-way ANOVA was conducted for the risk adjusted mortality assessment since the data were normally distributed. The results did not indicate a significant difference in risk-adjusted mortality between the 12/7 and 24/7 unit staffing patterns for a 95% confidence interval ($p$ = .09).

**Results: Research Question 4**

4. Is there an association between ICU intensivist staffing patterns (24/7 versus 12/7) and the level of tele-ICU adoption in predicting APACHE IV risk adjusted patient outcome measures?

The results of question 2 indicated that the two ICUs with the lowest levels of adoption were also the two hospitals that had 24/7 intensivist staffing, and the five ICUs with medium and high adoption were those with 12/7 intensivist staffing. One facility was removed from the original eight ICUs because it employed a 'hybrid' staffing model. A Pearson correlation indicated a high correlation between tele-ICU adoption and unit staffing pattern variables (-.859) confirming the likelihood of multicollinearity, thus violating an assumption for the use of multiple regression.

Correlations were conducted to determine if statistically significant associations existed between ICU staffing, tele-ICU adoption, and patient outcomes. Both ICU LOS (16.96) and hospital LOS (11.6) were positively skewed which violated the assumption of normality, so a Spearman rho statistic was used.

ICU LOS ratio was significantly correlated with unit staffing pattern, $r_s$ (13310) = .09, $p$ < .001, and tele-ICU adoption level, $r_s$ (14218) = -.10, $p$ < .001. Hospital LOS ratio was significantly correlated with unit staffing pattern, $r_s$ (12388) = .08, $p$ < .001, and tele-ICU adoption level, $r_s$ (13263) = -.08, $p$ < .001. In all cases, because the $r_s$ were less than .19, the effect size was considered very weak.

For both hospital and ICU LOS, the direction of the correlation was positive for unit staffing pattern, meaning the higher staffing pattern (24/7) had higher length of stay ratios. Therefore the mean of the length of stay ratio was longer and closer to the predicted length of stay for the 24/7 ICUs, whereas for 12/7 ICUs the lengths of stay were shorter and not as close to the predicted LOS.

For both hospital and ICU LOS, the direction of the correlation was negative for the level of tele-ICU adoption, meaning that the lower the level of adoption, the higher the length of stay ratio. In both cases, the effect size was much smaller than typical. ICU LOS had an $r_s^2$ = .007 for unit staffing pattern and an $r_s^2$ = .01 for tele-ICU adoption level. Hospital LOS had an $r_s^2$ = .006 for unit staffing pattern and an $r_s^2$ = .006 for tele-ICU adoption level.

A Pearson correlation was calculated for the risk adjusted hospital mortality assessment since this ratio was normally distributed. Although the results were not significant for ICU unit staffing pattern ($p$ = .09), the results did show significance at the .01 level for a 2-tailed test for tele-ICU adoption level $r$ (13263) = -.023, $p$ = .007. As indicated in the response to research question 2, however, when HLM was used to further analyze the data structure where patients from multiple ICUs were nested within the high, medium, and low adoption groups, the results were not statistically significant.

## Results: Research Question 5

5. Is there a difference between the ICUs with high versus low levels of tele-ICU adoption and the average scores of ICU employees for engagement and leadership effectiveness as measured by the annual all employee survey in Q3 of 2012?

A one-way ANOVA with a Tukey HSD post hoc test was conducted. The mean scores for the three levels of adoption for each of the constructs can be found in Table 4.10.

Table 4.10

*Mean Employee Survey Responses of ICU Employees by Level of Tele-ICU Adoption*

| Constructs and sub-dimensions | *High Adoption* | *Medium Adoption* | *Low Adoption* | *Overall p value* |
|---|---|---|---|---|
| Engagement | | | | |
| Recognition/Career Advancement | 4.00 | 4.01 | 4.10 | 0.572 |
| Organizational Effectiveness | 3.61* | 3.66 | 3.76* | 0.039* |
| Supervisory/Management | 3.93 | 3.85 | 4.00 | 0.259 |
| Co-worker Performance/Cooperation | 4.39 | 4.30 | 4.24 | 0.290 |
| Leadership Effectiveness | 4.17 | 4.09 | 4.19 | 0.524 |

* Only pair of mean scores where significant differences exist at the .05 level

As indicated in Table 4.10, the only construct where a statistically significant difference was found was for engagement, for the sub-dimension of organizational effectiveness, $F$ (2, 488) = 3.254, $p = .039$. Post hoc Tukey HSD tests showed that only the low and high tele-ICU adoption groups differed significantly ($p = .035$, $d = .31$) indicating a small effect size. The mean for the low adoption group (*M* = 3.7569) was higher than the mean for the high adoption group (*M* = 3.6059). The specific survey questions that measured organizational effectiveness were as follows:

1. I know what is expected of me in my job.
2. The necessary materials and equipment are available when I need to perform my job.
3. I have [not] thought of resigning in the last six months (reverse scored item).
4. My employer makes it possible for employees to directly contribute to its success.

Similar results were found when comparing the 24/7 staffed units with the 12/7 staffed units, which was expected due to the high correlation between these two independent variables. Since the ICU that was removed from this dataset would have fallen into the medium ICU adoption group, the mean scores for 24/7 (*M* = 3.7569) were very similar to those reported above for the low adoption group and the 12/7 (*M* = 3.6097) were very similar to high adoption group. Because the overall N was reduced from 491 to 413, the *p* value for organizational effectiveness went down ($p$ = .004, $d$ = .31) and the effect size remained much smaller than typical.

# CHAPTER 5: DISCUSSION, CONCLUSIONS, and RECOMMENDATIONS

## Discussion of Findings

This study had several key findings. First, a method for determining the level of tele-ICU adoption using the ratio of tele-ICU initiated orders to patient stays was proposed and tested. Since placement of routine orders, changing treatment plans, and intervening in life threatening situations is indicative of full delegation to tele-ICU (Thomas et al., 2009), in this study it was hypothesized that this ratio would be quite small where adoption was low, and much larger where adoption was high.

Based on the analysis of a dataset containing more than 2.2 million orders, significant differences were found among the eight ICUs. These differences ranged from less than one tele-ICU order per patient stay at the lowest level to nearly 12 orders per patient stay at the highest level. With this method, the study confirmed the hypothesis that significantly different levels of adoption of tele-ICU existed across ICUs in the same health system.

More importantly, this study found that ICUs with high levels of adoption of tele-ICU had better patient outcomes. The ICUs with high adoption had significantly lower risk-adjusted lengths of stay when compared with low adopters. In addition, the direction of the correlation indicated that as the level of adoption went down, the lengths of stay went up. Significant differences still existed for length of stay between the high and low adoption groups after testing based on the patient's condition, suggesting the differences should not be attributed to certain ICUs treating higher volumes of sicker patients.

The risk-adjusted hospital mortality assessment variable had scores ranging from -1 to +1 based on the expected versus unexpected mortality compared to the patient's assessed mortality risk upon ICU admission. When comparing groups of patients based on the level of tele-ICU adoption, significant differences were found using an ANOVA test, but significance was not confirmed after further testing using HLM to address the hierarchical nature of the data. The mean mortality assessment score for the high tele-ICU adoption group was lower than the mean for the low adoption group which mirrored the trend for the length of stay results, suggesting there may be practical significance in these results.

Another interesting outcome of this study was the correlation between the ICU staffing pattern and tele-ICU adoption. The two ICUs with 24/7 intensivist staffing had the lowest levels of tele-ICU adoption, which was less than one order per patient stay on average. According to the IPS standard, co-management of patients means tele-ICU is authorized to diagnose, treat, and write orders for a patient on their own authority (NEHI, 2007; The Leapfrog Group, 2011). The low number of tele-ICU orders indicated that the bedside staff at the 24/7 facilities were not allowing tele-ICU to co-manage patients or were assigning low levels of delegation to tele-ICU, possibly because intensivists were onsite and available 24/7. Hospital policy allowed delegation to tele-ICU to be at the discretion of the bedside ICU staff.

When comparing ICU employee responses to an all employee survey in Q3 of 2012, mean scores ranged from 3.61 to 4.39, which was consistently higher than the midpoint of the 5-point Likert scale. This indicated there were likely no major issues with the overall levels of engagement and leadership effectiveness at the time of the study that might be attributable to lack of tele-ICU adoption.

The only significant differences in responses were between the high and low adoption groups for the questions relating to organizational effectiveness. The low adoption group mean score ($M = 3.76$) was significantly higher than the high adoption group ($M = 3.61$). The question

"The necessary materials and equipment are available when I need to perform my job" was part of the organizational effectiveness category. The Gallup organization stated that this question has a high impact on patient satisfaction (Blizzard, 2003). Because the high adoption group scored lower on this and similar questions, it may have been an indication that the ICUs that were high adopters of tele-ICU may not have had the same level of resources that lower adopters had.

**Limitations of Findings**

There were several limitations of the study findings. All of the tests that had patient outcomes as the dependent variable also had results with very small effect sizes, despite large sample sizes and significant *p* values. There appears to be clear clinical and practical significance in these results, however, indicating that further analysis would be appropriate.

Because this was a retrospective study, specific factors beyond patient outcomes that can be indicative of tele-ICU performance or contributions, such as best practice adherence, were not analyzed. Although the results established the existence of varying levels of performance between ICUs, the root cause of those variations was not directly identified. Also, since the only two 24/7 ICUs were both low adopters, the study was unable to compare patient outcomes across ICUs with high and low levels of tele-ICU adoption where nighttime onsite intensivist staff were present.

The removal of physicians who worked in both tele-ICU and at the bedside may have had an impact on the results. For the ICU with the highest adoption this was not an issue because there were no physicians that worked in both locations. Six of the remaining seven ICUs had only one or two physicians that worked in both locations. However, one ICU that was considered a low adopter had six physicians who worked at both the bedside and tele-ICU, and orders for these six physicians were not included in the final dataset. In addition, lack of physician responses to the all employee survey was also considered a limitation that may have impacted those results.

## Relationship of Findings to Previous Research

Young, Chan, and Cram (2011) conducted a systematic review of 23 existing studies on staff acceptance of tele-ICU. Their definition of "acceptance" included any objective or subjective evaluation, which was admittedly very broad. For this study the term "adoption" of tele-ICU was chosen with the suggested definition as "The decision of ICU staff to make full use of tele-ICU resources as the best course of action available. This includes allowing tele-ICU to proactively co-manage patient care and ensure best practice adherence" (Rogers, 2003; Zanaboni & Wootton, 2012).

The Young, Chan, and Cram (2011) review had several findings that relate to this study. One was the need for additional studies, a suggestion that nearly all tele-ICU studies concurred with. Another was the belief that context matters. The review found that many ICU staff members perceived tele-ICU was only worthwhile in ICUs with quality issues or poor baseline performance (Young, Chan, & Cram, 2011). This could be a reason why the 24/7 staffed ICUs in this study resisted adopting tele-ICU, but it does not explain why patient outcomes were not as good as the 12/7 ICUs with high tele-ICU adoption. The results of this study indicated that resistance to adoption of tele-ICU might be unwarranted even when quality is perceived to be very high.

The results of this study supported findings in other studies that suggested tele-ICU may not positively impact patient outcomes such as risk-adjusted mortality and length of stay when not fully adopted by the majority of bedside staff (Morrison et al., 2010; Thomas et al., 2009). Future tele-ICU studies that test the impact of tele-ICU on patient outcomes should take the level of tele-ICU adoption into account. Likewise, other performances measures, such as best practice adherence, should be evaluated based on the level of tele-ICU adoption.

Previous research has indicated that despite the Leapfrog Group IPS standard, the optimum intensivist-staffing models are still unclear, and blanket application of 24-hour ICU intensivist coverage is premature especially considering the shortage of intensivists in the U.S. (Gajic & Afessa, 2009; Garland & Gershengorn, 2013; Wallace et al., 2012). In this study it has been suggested that future studies that investigate intensivist staffing models should also consider tele-ICU if available as an alternative to onsite, particularly when investigating the benefits of nighttime onsite intensivist staffing. More importantly, when measuring the impact of intensivist staffing on patient outcomes, the level of delegation of authority to the intensivist (i.e. adoption), whether working at the bedside or tele-ICU, should also be taken into account. According to Pronovost et al. (2007), even though some hospitals employ intensivists to help meet the IPS standard, they may not be empowering them to co-manage all patients, which in turn can prevent them from realizing the intended benefit of the IPS standard. In this study it has been confirmed this can also be the case with tele-ICU intensivists.

## Implications for Future Practice

This study identified a difference in patient outcomes based on low versus high levels of adoption of tele-ICU across ICUs within a hospital system. Although it did not identify the root cause for the varying levels of adoption in this case, many studies have suggested ways to address low tele-ICU adoption based on some of the more common root causes. A few of these will be outlined here.

In the study by Willmitch et al. (2012) that showed improvements in patient outcomes following the deployment of tele-ICU, the authors noted that tele-ICU is a complex process with hundreds of discrete elements, which when encompassed together can create a new culture for the management of ICU patients. This new culture takes time and effort to establish, and requires the creation of a collaborative extended care team that is based on trust. Tele-ICU should be encouraged to be as proactive as possible, and bedside staff should be assured that tele-ICU will not alter current bedside consulting patterns, but instead will facilitate broader application of evidence-based best practices (Willmitch et al., 2012). Romig et al. (2012) likewise noted that staff perceptions of tele-ICU may be an underappreciated variable impacting its success, especially since perceptions and culture are tightly tied to adoption. Cultural assessments and concerted efforts to address cultural barriers may be appropriate tactics to help promote tele-ICU adoption. Direct measurement of other organizational performance constructs that impact both the bedside and tele-ICU staff such as teamwork, climate, communications, and collaboration to determine areas needing improvement, and develop plans to directly address these areas, may also be appropriate.

Because it is a complex, multi-faceted intervention, tele-ICU should establish clear, unambiguous expectations including clinical decision pathways and evidence-based protocols that help avoid role confusion or the duplication of work or patient care gaps. Shared governance councils and work groups can not only help build relationships across the extended critical care team, but they can also help establish shared expectations (Venditti et al., 2012).

Since physicians can be resistors to tele-ICU, especially if they believe things are already “running smoothly,” showing results of studies that provide evidence supporting the benefits of tele-ICU can help break down barriers to adoption (Celi et al., 2001). To address the concerns that “big brother” is watching, education, knowledge sharing, open dialogue, and the use of two way video communications if available can also help overcome resistance. On-site visitations of tele-ICU staff at the bedside, or bedside staff at the tele-ICU command center, can allow staff to ask questions, observe, and understand each other's workflow and work environment. Such visits help build trust and facilitate open communications (Venditti et al., 2012).

In the article by Young, Chan, and Cram (2011) outlining a systematic review of staff acceptance of tele-ICU, one suggested strategy to facilitate adoption of tele-ICU was to focus on change readiness and allow ICU clinicians to participate early on with the design and implementation of tele-ICU. There should be a concerted effort to build support with ICU staff prior to rollout if possible. There are multiple activities that can contribute to effective change management, such as overcoming resistance to change, constructing the envisioned future, influencing stakeholders, providing resources for change and a support system for change agents, reinforcing new behaviors, and staying the course (Cummings & Worley, 2008). These activities can be incorporated into an initial tele-ICU deployment, or introduced post deployment.

Demonstrating the benefits achieved through improved best practice compliance can help address resistance to tele-ICU adoption. Examples of improved best practice compliance with tele-ICU include VAP bundle, sepsis protocols, peptic ulcer prevention, and venous thrombosis preventions based on routine medical chart reviews. Hospitals in both Seattle and Chicago observed 95% and 99% compliance with VAP bundle adherence and significant reductions in VAP cases based on tele-ICU best practice compliance. Tele-ICU is also being used to initiate automated screening to detect sepsis and deploy sepsis intervention protocols (Venditti et al., 2012).

## Implications for Future Research

Future tele-ICU studies that intend to understand the impact tele-ICU has on patient outcomes need to take into account and measure bedside staff perceptions and adoption levels of tele-ICU. The intended benefits of tele-ICU cannot be realized if the services provided by tele-ICU are intentionally not fully utilized. There are many factors that can contribute to high or low levels of adoption, so future research should attempt to identify and measure these factors.

The cost associated with tele-ICU is also an area that has had minimal research to date. Research should determine if the benefits of a fully adopted tele-ICU outweigh the costs, in addition to understanding the cost implications of lack of adoption. Finally, research is needed to further understand the value of tele-ICU when fully adopted as an alternative or supplement to bedside intensivist staffing especially during nighttime hours.

Some studies, including this one, have noted that even though they have found improved patient outcomes with tele-ICU, they have not been able to confirm with certainty which components of tele-ICU are essential for success (Wilcox & Adhikari, 2012). These components need to be identified and included in future tele-ICU studies.

## Conclusion

This study has provided support for the idea that tele-ICU can have a positive effect on patient outcomes, but only when fully adopted by ICU bedside staff. Detrimental effects of lack of adoption, including the impacts on patient outcomes and cost, need to be better understood in order to assess the true value of tele-ICU, break down the barriers to adoption, and attain the intended benefits.

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## APPENDIX A: LEAPFROG IPS STANDARD for Tele-ICU INTENSIVISTS

The Leapfrog Group requirements for meeting the standard for ICU intensivist physician staffing (IPS) using telemedicine intensivists, a hospital must affirm that its telemonitoring intensivist presence fulfills the following ten key features (NEHI, 2007):

a. An intensivist who is physically present in the ICU (on-site intensivist) performs a comprehensive review of each ICU patient each day and establishes and/or revises the care plan. The tele-intensivist has immediate access to information regarding the on-site intensivist's care plan at the time monitoring responsibility is transferred to him or her by the onsite intensivist. When care is transferred back to the on-site intensivist, the tele-intensivist communicates with the on-site intensivist to review the patient's progress and set direction.

b. When an intensivist is not on-site in the ICU managing or co-managing all ICU patients, a tele-intensivist is monitoring and able to manage all ICU patients for the remaining 24 hours per day, 7 days per week. "Monitoring" means the tele-intensivist has no other concurrent responsibilities, is immediately available to communicate with the ICU staff, and is in the physical presence of the Tele-ICU's patient monitoring and communications equipment. "Manage" means authorized to diagnose, treat, and write orders for a patient in the CU on his/her own authority.

c. A tele-intensivist has immediate access to key patient data, including:

1. Physiologic bedside monitor data (in real time);
2. Laboratory orders and results;
3. Medications ordered and administered; and,
4. Notes, radiographs, ECGs, etc. on demand.

d. Data links between the ICU and the tele-intensivist are reliable (more than 98 percent of the time) and secure (HIPAA compliant).

e. Via A-V support, tele-intensivists are able to visualize patients with sufficient clarity to assess breathing patterns, and communicate with on-site personnel at the bedside in real time.

f. Written standards for remote care are established and include, at a minimum:

1. Tele-intensivists are certified by a national medical specialty board in critical care medicine;
2. Tele-intensivists are licensed to practice in the legal jurisdiction in which the ICU is located;
3. Tele-intensivists are credentialed in each hospital to which he/she provides remote care (can be special telemedicine credentialing);
4. Activities of the tele-intensivist are reviewed within the hospital's quality

assurance committee structure;
5. There are explicit policies regarding roles and responsibilities of both the on-site intensivist and the Tele-intensivist; and,
6. There is a process for educating staff regarding the function, roles, and responsibilities of the tele-intensivist.

g. Tele-ICU care is proactive, with routine review of all patients at the frequency appropriate to their severity of illness.

h. A Tele-intensivist's patient workload ordinarily permits him or her to complete a comprehensive assessment of any patient within 5 minutes of the request for assistance being initiated by hospital staff.

i. There is an established written process to ensure effective communication between the on-site care team and the tele-intensivist.

j. The tele-intensivist documents patient care activities and this documentation is incorporated into the patient record.

(NEHI, 2007)

## APPENDIX B: LEAPFROG CRITERIA FOR IPS STANDARD

Criteria for meeting the Leapfrog standard for intensivist physician staffing (IPS) (The Leapfrog Group, 2011):

> Hospitals fulfilling the IPS Standard will operate adult or pediatric general medical and/or surgical ICUs and neuro ICUs that are managed or co-managed by intensivists who:
>
> 1. Are present during daytime hours and provide clinical care exclusively in the ICU and,
>
> 2. When not present on site or via telemedicine, returns pages at least 95% of the time,
>     (i) within five minutes and
>     (ii) arranges for a FCCS-certified physician or physician extender to reach ICU patients within five minutes.
>
> These requirements are rooted in evidence. Dr. Pronovost interviewed the lead authors from the studies in his systematic review that demonstrated reduced mortality with IPS. During the high intensity staffing phase of the interventions studied, all interventions met the pager response and most met the hour requirements for an intensivists presence. (The Leapfrog Group, 2011)

## APPENDIX C: INTENSIVIST STAFFING MODELS

Description of types of intensivist staffing models (Gajic & Afessa, 2009):

1. Closed vs open ICU[37]
   a. Closed ICU: the intensivist is responsible for day-to-day management of the patients, including all admissions and discharges, orders, and clinical management
   b. Open ICU: day-to-day management decisions are taken by the primary physicians. Although there are policies for ICU admission and discharge, the patients' primary attending physicians determine the need. There may be no full-time intensivist or intensivists may be involved in the patients' care at the discretion of the primary physicians
2. High-intensity vs low-intensity ICU[14]
   a. High intensity:
      i. The intensivist is responsible for all patient care in a closed ICU
      ii. Mandatory intensivist consultation: the ICU is open but it is mandatory to consult the intensivist to manage the critical care of the patient
   b. Low intensity:
      i. Elective intensivist consultation: the ICU is open and consulting the intensivist to manage the critically ill is not mandatory
      ii. No intensivist available: no patient is managed by a full-time consulting intensivist
3. High-intensity vs intermediate-intensity vs no intensivist ICU[11]
   a. High intensity: $\geq$ 80% of patients managed by intensivist
   b. Intermediate intensity: $>$ 0 but $<$ 80% of patients managed by intensivist
   c. No intensivist: no patient managed by intensivist
4. Choice vs no-choice ICU[21]
   a. Choice: it is an open ICU, and consulting the intensivist is at the discretion of the primary attending physician
   b. No choice:
      i. Closed ICU or mandatory intensivist consult
      ii. No intensivist available
5. Categorization by Levy et al[21]
   a. $\geq$ 95% of patients receiving care by an intensivist for entire ICU stay
   b. 5 to 95% of patients receiving care by an intensivist for entire ICU stay
   c. $\leq$ 5% of patients receiving care by an intensivist for entire ICU stay

## APPENDIX D: SURVEY QUESTIONS

Excerpt of all employee survey questions, grouped by construct and sub-dimension.

| |
|---|
| **1. Engagement: Outcome Variable** |
| 16. All in all, I am satisfied with my job. |
| **2. Engagement: Organizational Effectiveness** |
| 2. I know what is expected of me in my job. |
| 3. The necessary materials and equipment are available when I need to perform my job. |
| 9. I have [not] thought of resigning in the last six months. |
| 12. My employer makes it possible for employees to directly contribute to its success. |
| **3. Engagement: Recognition/Career Advancement** |
| 1. My employer provides me the opportunity to improve my professional knowledge and job skills. |
| 4. My job gives me the opportunity to do the things I do best. |
| 6. Employees here receive recognition for a job well done. |
| 8. My immediate leader encourages my career growth. |
| **4. Engagement: Supervisory/Management** |
| 5. My immediate leader lets employees know when they have done a good job. |
| 7. The top leadership team of my facility/entity is concerned about the employees. |
| 11. I have the opportunity to participate in decisions made by my immediate leader that affect my work environment. |
| 15. My immediate leader regularly gives me feedback on my work performance. |
| **5. Engagement: Coworker Performance/Cooperation** |
| 13. Employees of this organization show an attitude of genuinely caring about the patient. |
| 14. My coworkers are friendly and helpful. |
| **6. Leadership Effectiveness** |
| 5. My immediate leader lets employees know when they have done a good job. |
| 8. My immediate leader encourages my career growth. |
| 11. I have the opportunity to participate in decisions made by my immediate leader that affect my work environment. |
| 15. My immediate leader regularly gives me feedback on my work performance. |
| 21. My immediate leader shows an attitude of genuinely caring about the customer. |
| 22. I would proudly recommend my immediate leader to a friend or relative as an effective leader. |
| 23. My immediate leader is committed to collaborating with other departments. |
| 25. My leader takes accountability for his/her actions. |
| 26. I am satisfied with the communication I receive throughout the year from my immediate leader about my performance (i.e. before my performance evaluation). |
| 27. My immediate leader is committed to continuous quality improvement. |
| 28. My immediate leader keeps me informed about matters affecting me. |
| 29. My immediate leader actively engages others in our goal of achieving Industry Leadership. |
| 30. I trust my immediate leader. |
| 31. My immediate leader is appropriately concerned with accomplishing the organization's goals and objectives. |
| 33. My immediate leader makes me feel valued and part of the team. |

## APPENDIX E: TELE-ICU INITIATED ORDERS BY FACILITY BY QUARTER

Tele-ICU orders, patient stays, and ratio of tele-ICU orders to patient unit stays by facility and quarter (2012) in rank order (lowest to highest adoption ratio).

| 2012 Quarter | Facility code | Total ICU Patient Stays | Total Physician Initiated Orders | Total tele-ICU Physician Orders | Ratio tele-ICU orders to patient stays |
|---|---|---|---|---|---|
| 1 | 6 | 647 | 131268 | 129 | 0.199 |
| 2 | 6 | 670 | 127991 | 105 | 0.157 |
| 3 | 6 | 636 | 131206 | 87 | 0.137 |
| 4 | 6 | 687 | 124181 | 351 | 0.511 |
| **SUBTOTAL** | | **2640** | **514646** | **672** | **0.251** |
| 1 | 2 | 522 | 78882 | 116 | 0.222 |
| 2 | 2 | 526 | 84717 | 252 | 0.479 |
| 3 | 2 | 475 | 75302 | 455 | 0.958 |
| 4 | 2 | 552 | 84118 | 518 | 0.938 |
| **SUBTOTAL** | | **2075** | **323019** | **1341** | **0.649** |
| 1 | 8 | 260 | 42615 | 1208 | 4.646 |
| 2 | 8 | 231 | 37917 | 734 | 3.177 |
| 3 | 8 | 206 | 31585 | 771 | 3.743 |
| 4 | 8 | 211 | 31703 | 1258 | 5.962 |
| **SUBTOTAL** | | **908** | **143820** | **3971** | **4.382** |
| 1 | 4 | 562 | 73950 | 3034 | 5.399 |
| 2 | 4 | 547 | 71857 | 2695 | 4.927 |
| 3 | 4 | 524 | 64133 | 1797 | 3.429 |
| 4 | 4 | 502 | 58855 | 1553 | 3.094 |
| **SUBTOTAL** | | **2135** | **268795** | **9079** | **4.212** |
| 1 | 3 | 535 | 85915 | 3043 | 5.688 |
| 2 | 3 | 450 | 69499 | 2329 | 5.176 |
| 3 | 3 | 409 | 59788 | 2087 | 5.103 |
| 4 | 3 | 454 | 73588 | 2190 | 4.824 |
| **SUBTOTAL** | | **1848** | **288790** | **9649** | **5.197** |
| 1 | 7 | 539 | 80737 | 3956 | 7.34 |
| 2 | 7 | 481 | 76745 | 4184 | 8.699 |
| 3 | 7 | 470 | 69853 | 2871 | 6.109 |
| 4 | 7 | 500 | 81077 | 3222 | 6.444 |
| **SUBTOTAL** | | **1990** | **308412** | **14233** | **7.148** |
| 1 | 5 | 284 | 50132 | 2718 | 9.57 |
| 2 | 5 | 224 | 41091 | 2182 | 9.741 |
| 3 | 5 | 224 | 41212 | 2121 | 9.469 |
| 4 | 5 | 215 | 37325 | 2108 | 9.805 |
| **SUBTOTAL** | | **947** | **169760** | **9129** | **9.646** |
| 1 | 1 | 528 | 75551 | 5159 | 9.771 |
| 2 | 1 | 439 | 67441 | 6017 | 13.706 |
| 3 | 1 | 412 | 58839 | 4476 | 10.864 |
| 4 | 1 | 440 | 60940 | 5252 | 11.936 |
| **SUBTOTAL** | | **1819** | **262771** | **20904** | **11.569** |
| | | | | | |
| | | **14,362** | **2,280,013** | **68,978** | |

# APPENDIX F: IRB APPROVAL LETTER

Research Integrity & Compliance Review Office
Office of Vice President for Research
Fort Collins, CO 80523-2011
(970) 491-1553
FAX (970) 491-2293

Date: October 15, 2012

To: Gene Gloeckner, Education
Helen Hawkins, Education

[redacted]

From: Janell Barker, IRB Coordinator

Re: Understanding Patient Outcomes Related to Varying Levels of Employee Engagement and Adoption of Tele-ICU at Multiple ICU Units within a Single, Large Hospital System

**IRB ID:** 117-13H **Review Date:** October 15, 2012

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The Institutional Review Board (IRB) Coordinator has reviewed this project and has declared the study exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b)(2): Research involving the use of educational tests,….survey procedures, interview procedures or observation of public behavior, unless: a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects.

The IRB determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as proposed in the Exempt application**, including obtaining and documenting (signed) informed consent if stated in your application.
- **Any modification of this research should be submitted to the IRB Coordinator through an email prior to implementing any changes**, to determine if the project still meets the Federal criteria for exemption. If it is determined that exemption is no longer warranted, then an IRB protocol will need to be submitted and approved before proceeding with data collection.
- **Please notify the IRB Coordinator if any problems or complaints of the research occur.**

Please note that you must submit all research involving human participants for review by the IRB. **Only the IRB may make the determination of exemption**, even if you conduct a similar study in the future.