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Characteristics of Adult ICU Patients with Device Associated Nosocomial Infections

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2016

Abstract

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by

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MS, Texas Woman's University, 1994

BS, University of Texas at Arlington, 1985

Dissertation Submitted in Partial Fulfillment

Of the Requirements for the Degree of

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Public Health Epidemiology

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Abstract

Nosocomial infections are a cause of concern for hospital patients and the incidence rates of these infections are greater in intensive care units (ICUs) due to the invasive nature of treatments, additional risk factors and comorbidities, and therapies used. Invasive devices, such as vascular central lines, Foley catheters, and mechanical ventilators pose a risk for critically ill patients in the ICUs to develop device-related, healthcare-associated infections (HAI). The purpose of this study was to describe the epidemiological characteristics of patients who developed device-related HAIs within 3 ICU units (medical-surgical, cardiovascular, and neurosurgical) of an academic medical facility. The ecosocial theory of disease distribution provided the theoretical framework for the study to describe how ecological and social determinants interact and affect health variances. Secondary data were analyzed using analysis of variance (ANOVA), Pearson correlations, and chi-square statistical tests. A total of 4,213 patients admitted to the 3 ICUs from 2010-2014 were identified. According to the chi-square analysis, there was significant association between race/ethnicity and type of device-associated infection; between gender and types of infection; and between risk factors (diabetes, obesity, smoking habits) and kinds of infection, all of which the statistical significance had varied for each individual ICU. Bacterial differences were noted between device-associated infections. The potential positive social change from this study could be insight on possible new processes and interventions to reduce nosocomial infections and improve adult ICU patient outcomes such as decreased HAIs, decreased length of stay, comorbidities, and cost for both the patient and the hospital.

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Table of Contents

List of Tables v

List of Figures vi

Chapter 1: Introduction to the Study 1

Introduction 1

Background 2

Problem Statement 3

Purpose of the Study 6

Theoretical Framework 7

Research Questions and Hypothesis 8

Nature of the Study 9

Definitions 11

Assumptions 15

Scope and Delimitations 17

Limitations 19

Significance 21

Summary 22

Chapter 2: Literature Review 24

Introduction 24

Literature Search Strategy 24

Theoretical Framework 25

Surveillance and Prevention Guidelines 31

Incidence and Complications 32

Risk Factors 33

Microbial Transmission 34

Research Studies of Nosocomial Infections in the Intensive Care Units 37
Cost of HAIs 39
Control and Prevention 39
Summary 41
Chapter 3: Methodology 43
Introduction 43
Research Design and Rationale 44
Reason for Selection of Design 44
Strengths and Key Points of the Research Design 44
Methodology 45
Study Variables and Measures 45
Study Population 47
Data Collection 48
Data Analysis 51
Threats to Validity 57
Ethical Procedures 57
Summary 58
Chapter 4: Results 59
Introduction 59
Data Collection 59
Results 60
Research Question 1 and Hypothesis 65
Research Question 2 and Hypothesis 72
Research Question 3 and Hypothesis 91
Research Question 4 and Hypothesis 100
Summary 104
Chapter 5: Discussion 107

Introduction 107
Interpretation of Findings 108
Research Question 1 108
Research Question 2 109
Research Question 3 110
Research Question 4 112
Limitations of the Study 115
Recommendations for Future Research 116
Implications for Social Change 117
Conclusion 118
References 120
Appendix A 132
Appendix B 137
Appendix C 140
Appendix D 143
Appendix E 144
Appendix F 146

List of Tables

Table 1. Description of Variables Corresponding to Research Questions and Database Source . 50

Table 2. Calculation of Device-related Healthcare Associated Infection Rates 54

Table 3. Demographics and Clinical Characteristics of Patients across Three Adult Intensive Care Units, 2010-2014 63

Table 4. Incidence Rates of Device-related Nosocomial Infections in the Three ICUs, 2010 – 2014.....68

Table 5. Standardized Infection Ratio (SIR) of Device-related Nosocomial Infections in the Three ICUs, 2010 – 2014.....68

Table 6. Correlation between Device Utilization and Device Infection Rate across the ICUs, 2010 – 2014.....72

Table 7. Comparison of Mean APACHE II Scores Between HAI and Non-HAI Patients Within and Across Three ICU Units, 2010-2014 74

Table 8. Severity of Illness of ICU Patients within the Three ICUs which were Measured by the Acute Physiology and Chronic Health Evaluation II (APACHE II) Score in 2010 – 2014 75

Table 9. Severity of Illness as Measured by APACHE II across the ICUs, 2010-2014 by Demographics (without Risk Factors) 778

Table 10. Severity of Illness as Measured by APACHE II across the ICUs, 2010-2014 by Demographics (Patients with only Diabetes).....80

Table 11. Severity of Illness as Measured by APACHE II across the ICUs, 2010-2014 by Demographics (Only Patients with Smoking Habits).....82

Table 12. Severity of Illness as Measured by APACHE II across the ICUs, 2010-2014 by Demographics (Patients with only Obesity) 84

Table 13. Severity of Illness as Measured by APACHE II by ICU Type, 2010-2014 by Demographics (Patients with both Smoking Habits and Diabetes) 86
Table 14. Severity of Illness as Measured by APACHE II by ICU Type, 2010-2014 by Demographics (Patients with both Obesity and Diabetes) 88
Table 15. Severity of Illness as Measured by APACHE II by ICU Type, 2010-2014 by Demographics (Patients with both Obesity and Smoking Habits) 90
Table 16. Demographic and Risk Factors of Patients with No HAI and with HAI in Three Adult ICUs 93
Table 17. Associations between Age and HAI Type 94
Table 18. Associations between Sex and HAI Type 95
Table 19. Associations between Ethnicity/Race and HAI Type 96
Table 20. Associations between Risk Factors and HAI Types 98
Table 21. Risk Factors of Patients Admitted to Each ICU 99
Table 22. Risk-Factors of Patients with Device-Associated Infections and Patients with No Infections 100
Table 23. Distribution of Microorganisms and Device-Associated Infections 101
Table 24. Distribution of Device-Related Bacterial Infections Across the Three Adult ICUs ... 102
Table 25. ICU-specific Gender Breakdown of Various Microbes 102
Table 26. Microorganisms Contributing to CLABSI 103
Table 27. Microorganisms Contributing to CAUTI 103

List of Figures

Figure 1. Ecosocial conceptual model. 27

Figure 2**.** Central-line associated bloodstream infection (CLABSI) rate over a period of 5 years in three intensive care units. 69

Figure 3. Cather-associated urinary tract infection (CAUTI) rate over a period of 5 years in three ICUs. 70

Figure 4. Ventilator-associated pneumonia (VAP) rate over a period of 5 years in three ICUs. ..70

Figure 5. Comparison of device associated infection rates per 1000 device line days in the three ICUs from 2010-2014 71

Figure 6. Device utilization rates in the three ICUs from 2010-2014 compared to NHSN national utilization rates pooled mean 71

Figure 7. Multidrug resistant organisms compared to susceptible organisms. 104

Chapter 1: Introduction to the Study

Introduction

Nosocomial infections pose a threat to intensive care unit (ICU) patients and are a cause of increased morbidity, mortality, length of stay, and cost of care (Marschall et al., 2014). According to Septimus et al. (2014), healthcare-associated infections are the fifth leading cause of death in acute care hospitals with a 15% development of infection while in the hospital. Despite ICU populations being relatively small, compared to nonintensive care units, the incidence rate of hospital-acquired infections is greater in intensive care units. This is primarily due to the invasive nature of the treatments and multiple therapies used in ICUs, such as mechanical ventilation, central venous catheters, pulmonary artery, and urinary catheterization (DePalo et al., 2010). In addition to invasive therapies and treatments, ICU patients typically have additional risk factors and comorbidities associated with developing nosocomial infection. Invasive devices such as vascular central lines, Foley catheters, and ventilators pose a threat to the critically ill and often immunocompromised ICU patient population, resulting in a greater risk of developing device-associated nosocomial infections (Marschall et al., 2014). Healthcare-associated infections (HAIs) are problematic in the United States causing a burden to hospitals, patients, family members, and society in general (Scott, 2009; Umscheid et al., 2011). A historical, quantitative study was designed to identify and describe the epidemiological characteristics of ICU patients who developed device associated infections in three different ICU settings in a large acute care teaching hospital. The findings from this study may offer an opportunity for healthcare systems to promote positive social change by supporting preventive techniques related to patient care that may contribute to the elimination of HAIs and improve patient outcomes. The study may help provide a better understanding of the pathogenesis of

HAIs by developing strategies or interventions that may aid in the prevention processes to prevent nosocomial infections.

Background

Obtaining and maintaining reliable vascular access has become one of the most essential features of medical care. However, during hospitalization, any patient who is admitted to an intensive care unit and has a central venous catheterization placed will have a higher chance of acquiring a primary bloodstream infection, which increases the chances of morbidity and mortality (Blot, Bergs, Vogelaers, Blot, & Vandijck, 2014; Olaechea et al., 2013). According to the Centers for Disease Control and Prevention (CDC, 2016), there has been progress in reducing HAIs; however, there is still further action needed at every level of public health to eliminate infections that are potential threats to each patient admitted into an acute care facility (CDC, 2016).

It was estimated that nearly 40% of all healthcare associated bacteremias are derived from vascular access (Crnich & Maki, 2009). It was also estimated that more than 250,000 intravascular, device-associated bloodstream infections occur in the United States each year (Crnich & Maki, 2009). These infections are associated with increased length of hospital stay, excess healthcare costs, and increased chances of morbidity and mortality (CDC, 2016; Olaechea et al., 2013; Zimlichman et al., 2013). In a meta-analysis study of costs and financial impact of HAIs, inflated to 2012 U.S. dollars, it was estimated that the annual costs for major infections (CLABSI, CAUTI, VAP, MRSA, *Clostridium difficile*) in adult care facilities were between $8.3 to $11.5 billion (Zimlichman et al., 2013). Furthermore, scholars who included all hospital acquired infections and pediatrics population estimated that the cost of HAIs in the U.S. healthcare system range from $28 billion to $45 billion per year (Scott, 2009). There are several

sources of intravascular, device-associated bloodstream infections that play a role in producing infections. Two contributors include colonization of the intravascular device and contamination of the fluid that is being administered through the device (Marschall et al., 2014). It is important that best practices such as aseptic techniques and infection prevention practices take place during any hospital stay. Factors associated with increased risks of central line-associated bloodstream infections include prolonged hospitalization; severity of the illness; and clinical states such as HIV, neutropenic patients, and any similar condition or illness (Lukenbill et al., 2013). Additional factors that contribute to the increase of central line bloodstream infections include insertion and maintenance of the lines (O'Grady et al., 2011). Even though, there are currently guidelines/bundles for HAI prevention, optimizing quality improvement processes and standardization of care provide potential benefits to the well-being of ICU patients (Perez-Granda, Guembe, Rincón, Muñoz, & Bouza, 2015). The findings from this research may provide knowledge for clinicians to improve existing preventive guidelines (The Joint Commission, 2013), such as an educational initiative in addition to the bloodstream bundle set that could be used to help improve central venous catheter insertion and reduce the rate of primary bloodstream infections.

Problem Statement

Critically ill patients have a significant risk of acquiring infections related to healthcare. Nosocomial infections that are device-related are considered a standard threat to a patient's wellbeing in the intensive care unit and are considered to be a cause of patient morbidity and mortality (Chen, Wang, Liu, & Chou, 2009). The use of invasive devices is a danger to the safety of each patient and a potential health risk for patients because it increases the possibility of these patients acquiring a HAI (Lukenbill et al., 2013). These types of infections can be linked with

extended hospital stays, sustained costs, and correlated with higher number of comorbidities (Chen et al., 2009). Patients with multiple risk factors have a higher incidence rate of developing a central-line bloodstream infection (CLABSI), catheter-associated urinary tract infections (CAUTI), and ventilator associated pneumonias (VAP), (Chen et. al., 2009; Elpern et al., 2009; Ong et al., 2011; Clarke et al., 2013). According to Barnett, Graves, Rosenthal, and Salomao (2010), vascular access causes risks for a patient to develop a central line bloodstream infection. It was estimated that approximately 60% of all types of HAI bloodstream infections derive from vascular access (Barnett et al., 2010). Any patient who develops a central line bloodstream infection while in the ICU is inclined to stay longer in the ICU. The length of stay for an ICU patient with a bacteremia is estimated to be 3 to 48.5 days (Barnett et al., 2010). Despite multiple interventions and increased attention directed to identification and prevention of CLABSIs, CAUTI, and VAPs, there continues to be ongoing occurrences of these healthcare device-related infections that patients can succumb to during their hospitalization.

According to the literature, there is a gap in clinical practices between interventions and attention focused on minimizing these infections and actual success at completely eliminating them (Cardo et al., 2010; Saint et al., 2008). Additional gaps in practice include determining differences in the types of microorganisms and understanding these pathogens in order to optimize diagnosis, prevention, and treatment of HAIs. It was the intent of this research study to address these identified gaps in the literature. By identifying the types of microorganisms most likely to be involved with device associated healthcare infections, the knowledge base for future prevention and treatment of these infections in the adult ICU populations may increase. Additionally, even though scholars (Callister, Limchaiyawat, Eells, & Miller, 2015) have proven care bundles to reduce CLABSI, device-associated infections are still prevalent in U.S. hospitals.

Therefore, looking at risk factors such as the ones in this study can provide additional information that may be beneficial for developing other preventive tools in the future. The answers to the research questions may provide a broader base of information to address the gaps in future research. The existence and continuing evolution of multidrug resistant organisms may necessitate adaptations to current approaches in order to help prevent HAIs. Further components for clinical practices and interventions include understanding human factors that may play a role in implementing appropriate interventions to minimize device-related infections.

Due to there are diverse risk factors including comorbidities associated with different ICU patient populations (Table 1), historical analysis and comparison of three varied ICU patient populations and the nosocomial infections encountered may provide insight to more comprehensive interventions and more accommodations required to minimize CLABSIs, CAUTIs, and VAPs in an explicit ICU type. The teaching institution at which this study was conducted had implemented various interventions to help reduce the number of HAIs, but has unsuccessfully been able to accomplish this goal. Patients in each intensive care unit may have different risk factors; therefore, each unit may have to accommodate particular interventions and surveillance in order to improve patient outcomes. Determining if there was a causal relationship between device use and risk factors can provide additional information pertaining to incidence of infections. Addressing the device-related nosocomial infection gaps in the literature could contribute to creating comprehensive interventions suited for each intensive care unit population. There have been no recent identified scholars who have taken into account device-related HAIs by patient outcomes, risk factors, and microorganism epidemiological characteristics such as Gram-stain; biological classification (genus and species); and antibiotic susceptibility patterns for each CAUTI, CLABSI, and VAP. In addition, I looked at the association between age,

gender, and race within the three ICUs to determine if any of these factors played a role in contributing to device-related nosocomial infections. The data were derived from the patient line listing that included the microorganisms identified as contributing to the infection.

Purpose of the Study

The purpose of this study was to evaluate epidemiologic characteristics of device-associated infections (CLABSI, CAUTI, and VAP) within three ICUs in a large teaching academic medical center, which consists of two hospitals with an infection control program. This research aided in the understanding of the types of device associated infections by knowing the distribution patterns of each ICU and determinants such as persons affected and the correlation of the location with the ICU type.

In this study, I compared the incidence rates of HAIs in a medical-surgical ICU, cardiovascular ICU, and a neurosurgical ICU in a large, acute care teaching hospital setting. The aim of this study was to evaluate characteristics, such as organism types, infection patterns, and patient demographics, and risk of developing nosocomial infections within three ICUs in a large medical teaching facility. The goal was to compare and contrast ICU patient outcomes, risk factors, and the microorganism epidemiological characteristics such as Gram-stain, biological classification, antibiotic sensitivity, and resistance of each pathogen identified as causing the HAI within the ICU population. Attention was focused on incidence rates of device-related nosocomial infections, association between severity of illness and types of device-related nosocomial infection, demographics and acquiring device-related nosocomial infections, and the differences between types of microorganisms associated with device-related nosocomial infections in three adult ICUs. The results from this study could lead to positive social change by delivering insight that could lead to the development of additional future studies related to

nosocomial infections. This could then lead to the development of new processes and interventions to help minimize nosocomial infections with the ultimate goal of improving patient health outcomes. Ideally, improvements in critically ill patients could be beneficial with regard to the incidence of HAIs, decreased length of stay, comorbidities, and cost for both the patient and hospital. The information from this study could aid public health by focusing on ways to prevent and control the risk of contracting HAIs and lead to development of future studies.

Theoretical Framework

The ecosocial theory of disease distribution was the guiding framework for this research. Descriptive theory employs an empirical method to describe and classify events by summarizing the commonalities found in the research observations (Krieger, 2009). This research encompassed the identified device-related HAIs and investigated factors associated with the different intensive care units. The ecosocial theory of disease distribution and the ecosocial model provided the framework used to develop a multilevel approach that could account for the possible pathways for interaction between determinants, as well as the simultaneous effects of ecosocial levels on disparities (Krieger, 2014). This approach should also result in new understanding of how the levels and inequalities in social advantage (i.e., age, race and ethnicity, and gender) interact to produce disparities. The ecosocial model was used to understand how biological factors (age, gender, race, and ethnicity), processes (central-line, Foley catheter, and ventilator usage), and environment (three different ICUs) interact and contribute to HAIs. Following the guiding principles of the framework allows for the systematic approach to identify disease patterns and to develop an explanation of the disparities that exist in ICU populations.

Research Questions and Hypothesis

RQ#1: Is there a difference in the incidence rates of device-related nosocomial infections between the different types of ICUs?

$H_0$1: There is no difference in the incidence rates of device-related nosocomial infections between the different types of ICUs.

$H_1$1: There is a difference in the incidence rates of device-related nosocomial infections between the different types of ICUs.

RQ#2: What is the association between severity of illness, measured by the Acute Physiology and Chronic Health Evaluation II (APACHE II) score and CLABSI, CAUTI, and VAP?

$H_0$2: There is no association between severity of illness (APACHE score) and CLABSI, CAUTI, and VAP.

$H_1$2: There is an association between severity of illness (APACHE score) and CLABSI, CAUTI, and VAP.

RQ#3: What is the association between age, gender, race, and ethnicity from the device associated HAIs identified in the three different adult ICUs within an academic medical facility?

$H_0$3: There is no association between age, gender, race, and ethnicity from the device associated HAIs identified in the three different adult ICUs within an academic medical facility.

$H_1$3: There is an association between age, gender, race and ethnicity from the device associated HAIs identified in the three different adult ICUs within an academic medical facility.

RQ#4: Are there significant differences in the types of microorganisms (e.g., genus, species, and susceptibility according to the Clinical and Laboratory Standards Institute (Patel et

al., 2015) that are associated with device-related HAIs in three adult ICUs within an academic medical facility?

$H_0$4: There are no significant differences in the types of microorganisms (e.g., genus, species, and susceptibility) according to the Clinical and Laboratory Standards Institute (Patel et al., 2015) associated with device-related HAIs in three adult ICUs within an academic medical facility.

$H_1$4: There are significant differences in the types of microorganisms (e.g. genus, species, and susceptibility according to the Clinical and Laboratory Standards Institute (Patel et al., 2015) that are associated with device-related HAIs in three adult ICUs within an academic medical facility.

Nature of the Study

The approach was a nonexperimental, observational study that used a quantitative prospective methodology and incorporated a historical prospective study of secondary data. The data were collected from Epic, which is an electronic health record software used by the hospital to gather patient care information. Epic is a secure database that stores patient data including demographics, clinical synopsis, graphs of vitals, clinical events, risk scoring, and clinical documentation along with other vital information. This information was used to determine if there was an infection classified as an HAI. National Healthcare Safety Network (NSHN) guidelines are used by infection preventionist to determine if infections are device-associated and healthcare-related. Statistical data were used to compare incidence rates of infection on any patient with a central line, Foley catheter, and/or ventilator placement in an adult medical-surgical, neurosurgical, and cardiovascular ICUs. The data of patients with positive cultures were abstracted from Epic using TheraDoc, a data mining software, as the interface. The data were

collected according to guidelines established by the CDC's NHSN, which determines the presence of a device-associated infection. The denominator was defined as the number of patients in the ICUs between 2009-2014 with a central line, Foley catheter, and ventilator. The incidence rates of each device-related HAI (CLABSI, CAUTI, and VAP) were calculated and compared separately (Table 4 and Appendix D). I assessed recorded information about intensive care patients without manipulating the study environment and compared three subgroups of patients from a hospital database (medical-surgical ICU, cardiovascular ICU, and neurosurgical ICU) from 2009 through 2014. An electronic database called Theradoc was used to provide information such as the patient line listing, infection type and acquisition, infection documentation and classification, demographics, and linked microbiology results. The electronic TheraDoc database provided the specimen source, collected and resulted dates, organism results, and susceptibilities. The data were abstracted from TheraDoc, which also included the identification of the type of device-associated HAIs. Although there were three different ICU population types, the devices used were the same for all three populations. Multiple variables were studied for each ICU type, including age, gender, ethnicity, comorbidities (diabetes and obesity), and severity of illness at admission. The nature of the patients (such as differences in demographics and severity of illness) may confound interpretations of the results. Comparing the sex of the patient with respect to the HAI type reveals statistically significant differences for MSICU and when all three ICUs were aggregated (Table 3). Additionally, there were few demographic groups possessing statistically significant differences in the mean APACHE score between patients with and without HAI, both groups possessing smoking habits across racial groups and ethnicities (Table 11). In this study, I evaluated device-related HAIs, risk factors, and the relationship of microorganisms within three intensive care units. The definitions for the

device-related HAIs are based upon standardized definitions, and were predetermined by NHSN (See Appendix B).

This historical prospective study allowed comparison of different variables at the same time. This was a standardized method to capture the severity of illness upon admission. The data were analyzed using SPSS version 21.0 and Stata 12, performing statistical analyses such as *t*-tests, chi-squared tests, and ANOVA.

Definitions

The terminology used to describe and define HAIs in this study was well-defined to assist in the interpretation analysis. Some of the following definitions are standardized by the NHSN, a division of the CDC that tracks HAIs in the United States, for the classification of device-associated and HAIs (CDC, 2015a).

Adult patients: A patient who was admitted into a hospital setting that was 18 years of age or older.

Bacteremia: Bacteremia is an infection in the bloodstream caused by the presence of microorganisms. Bacteremia can be transient, continuous, or intermittent (CDC, 2015c).

Comorbidity: Disease(s) that exist(s) in a study participant in addition to the index condition that is the subject of study (Last, 2001, p. 36).

Confounder: A variable whose presence affects the outcome that is being studied. It is the unobserved exposure that might have an effect on the outcome of interest and can be correlated with both the dependent and independent variables (Pourhoseingholi, Baghestani, & Vahedi, 2012). A variable that can cause or prevent the outcome of interest (Last, 2001, p. 38).

Device associated infection: An infection in a patient with a device such as a central-line, Foley catheter, or ventilator that was used for greater than 2 calendar days before the onset of symptoms (CDC, 2015a).

Device infection rate: The number of device-associated infections (cases) divided by the total number of device days multiplied by 1,000. Device days are the number of days each device was used for all the patients during a specified period (central line, Foley catheter, or ventilator; CDC, 2015a).

Device utilization ratio: The number of device days divided by the number of census days for a particular unit. It provides a use ratio that can be compared to other units within a facility and/or with similar unit populations. The ratio can provide information on over usage (Dudeck et al., 2011).

Disease: A physiological/psychological dysfunction (Last, 2001, p. 52). Physiology changes related with damages to the body's organ system.

Healthcare-associated infection (HAI): Can also be referred as a nosocomial infection. A localized or systemic condition resulting from an adverse reaction to the presence of an infectious agent and/or the toxins produced by the microorganism causing the infection (see nosocomial infection definition; CDC, 2016).

Incidence: The number of instances of illness commencing, or of persons falling ill, during a given period in a specified population, or the number of new events (e.g., new cases of a disease in a defined population) within a specified period of time (Last, 2001, p. 91). For this research the study, incidence rate were analyzed quarterly and yearly for a period of 5 years, from 2010-2014.

Infection: Invasion of the body tissues of a host by an infectious agent, whether or not it causes disease (CDC, 2015a). The term infection was used when there was multiplication and invasion of microorganisms in tissue or any other body surfaces associated with tissue reaction. Infection involves the growth of microorganisms that result in damage to the host (Horan, Andrus, & Dudeck, 2008; Tao, Hu, Rosenthal, Gao, & He, 2011). The severity of the infection and damage depend on many factors. Some of the factors include the organism's ability to cause disease, the body site of the infection, and the general health of the individual.

Mean Standardized Infection Ratio (SIR): An average of SIR numbers. For this study, a calculated central value from yearly SIR averages ranging from 2010-2014. Each years SIR was added and then divided by how many numbers were averaged (CDC, 2016).

National Healthcare Safety Network (NHSN): CDC's NHSN is the nation's tracking system for HAIs. NHSN provides the nation with the data needed to identify problem areas. The network helps facilities measure progress of prevention to provide reduction or elimination of HAIs (CDC, 2016).

Nosocomial Infection: Nosocomial infections, also known as HAIs, are localized or systemic conditions that result from an adverse reaction to the presence of infectious agents or toxins (CDC, 2015a). The CDC (2015a) defined these infections as hospital-acquired if they developed after admission with no evidence that the infection was present or incubating during admission. HAIs can be caused by endogenous sources such as skin, nose, mouth and gastrointestinal tract or exogenous sources such as personnel, visitors, medical devices and healthcare environment (CDC, 2015a).

Present on admission (POA): This term refers to infections that occur during admission or within the first 2 days after admission into the hospital setting. The infection began prior to

admission and was not caused during hospitalization. POAs are not reported as HAIs (CDC, 2015a).

Septicemia or sepsis: Septicemia or sepsis is a condition where bacteria and/or their toxins are in the bloodstream and they are causing infection along with systematic inflammatory response to an individual. During sepsis the clinical manifestation can reveal fever with temperature >38º C or hypothermia with temperature < 36º C; chills, white blood cells >12,000, or hypotension (CDC, 2015c).

Smoking: Tobacco encased in cigarettes, pipes, and cigars that contain nicotine that is inhaled into the lungs and is dispersed into the rest of the body. I classified smokers as any person smoking on a daily basis.

Standardized Infection Ratio (SIR): A summary statistic that is used to compare the actual number of HAIs with the predicted number based on a baseline of the U.S. standard population. It is used to measure relative difference in HAI occurrence during a period of time (CDC, 2015a; CDC, 2016).

Urinary tract infections: The urinary tract anatomy includes the kidneys, ureters, bladder, and urethra, and infections to this area are characterized as either upper or lower infections. Urinary tract infections are defined as bacteriuria also known as bacteria in the urine. Quantitative cultures are used to determine if the UTI is diagnostic by determining if the urine culture was a contaminant, colonization, or infection (CDC, 2015b; CDC, 2016).

Ventilator associated pneumonia: Pneumonia caused in the lower respiratory tract due to mechanical ventilation. Ventilator-associated pneumonias are defined as a pneumonia that is caused when a patient was on a mechanical ventilator for greater than 2 calendar days, with day of ventilator placement being Day 1 (CDC, 2015d; CDC, 2016).

Assumptions

This study included several assumptions. There are defined policies and procedures to standardize care to ensure optimal treatment for all patients. Varying immune status, condition of the patient, and the potential variation of prophylactic antibiotics could result in varying incidence rates between the three units. Due to patients' varying conditions upon admission and given the different types of ICU, the severity of illnesses was quantified using the APACHE score system, which addresses the degree of acute illness and chronic health status of ICU patients (Knaus, Draper, Wagner, & Zimmerman, 1985; Vincent & Moreno, 2010). Thus, I looked to see if there were statistical differences between device-associated infections and severity of illness of patients in the three ICUs using APACHE scores.

APACHE II scores were used as an additional tool for analysis. The APACHE II scores were collected by one of the infection preventionists and the informatics analyst. It was assumed that the collection of the APACHE II scores were reliable because only those two individuals developed the data and were trained to use the same computerized worksheet format. The abstraction of the APACHE II score data used standardized definitions, computerized calculation methods, and strict adherence to the guidelines. It was assumed that the data represented the first 24 hours after the ICU admission. The elements used to calculate the APACHE II scores and determine the severity of illness can be found in Table 1. The APACHE II score was an additional analytical tool that provided a snapshot of the patient's severity of illness. According to Donahoe (2009), the APACHE II is one of the most widely used methods to describe the severity of illness in patients. In Donahoe's study, the APACHE II score was found to provide a highly reliable severity of illness scoring system especially when the scoring was limited to individuals who have been trained to collect the data.

Another assumption in this study was that the care given to the patients was uniform in quality because patients are critically ill. The experience and education levels of the physicians and nurses placing and maintaining invasive devices should be similar if comparisons are to be made between units, as lower experience levels among physicians and nurses placing devices are associated with increased risk of infection and complication (Cardo et al., 2010; Yokoe et al., 2008). I expected that hospital staff was following the infection prevention and control policies and procedures that were in place to prevent infections from occurring. For example, standardization care can be measured and validated by usage device-associated care bundles. Care bundles include central line, Foley catheter, and ventilator checklist of best practices as measured by hospital quality and performance improvement committees. A care bundle is a set of evidence-based interventions for a defined patient population. However, it was important to note that even implementing care bundles, which include avoiding femoral sites, strict hand-hygiene, full barrier precautions, the use of chlorhexidine skin preps, and removal of unnecessary catheters, it was found that device-associated infections still remain prevalent in U.S. hospitals (Callister et al., 2015).

The final assumption was that the infection control team, nurses, and physicians in the hospital were uniformly adept at identifying the various nosocomial infections within each of the three units. Validation of these nosocomial infection identifications are processed and confirmed by the infection prevention department by use of the standardized NHSN/CDC definitions for HAIs. When verifying device-associated HAIs, data such as age, gender, race and ethnicity, and severity of illness are not used for further comparative analysis within the infection prevention department. Although the infection prevention department identifies nosocomial infections, the gap in knowledge was the analysis of the statistical differences (if any) of incidence rates

between ICU types, microorganism population type, demographics, and risk factors associated with these types of nosocomial infections.

With respect to the statistical tests used in the analyses, there are a number of assumptions. For the chi-squared tests, the dataset should be a large, simple random sample and the patients should not be dependent on each other (i.e., independent observations); which has been fulfilled, as number of observations in the data set exceeded 4,000 and the individual answers in the survey from each patient were independent of others. For ANOVA there must exist constant variance for the groups, the relationships between variables requires linearity. Because demographic characteristics do not change over time (except age, which increases linearly) and due to the inherent traits of the APACHE II scores that have been previously discussed, variance was constant and relationships were linear.

Scope and Delimitations

The aim and scope of this research was to evaluate the causative elements of device associated infections in the medical surgical, neurosurgical and cardiovascular ICUs. Critically ill patients in the ICUs are more likely to acquire a device-associated infection (Tao et al., 2011). Hence, APACHE scores were included for analysis. Thus, the research may assist in the understanding of the nosocomial infections as well as how to plan and implement preventive measures in an acute care environment. This research provides information on ways to reduce HAIs and improve patient safety and outcomes in the acute care setting. Examining confounders such as gender, age, obesity, diabetes, and smoking could make the study findings more precise and facilitate a comparative analyses. Additionally, this research may potentially provide a guide in developing future interventions and incorporate different quality improvement strategies to reduce device-related nosocomial infections if further prospective studies are established.

This study was limited to the adult population, both male and female, in the medical surgical, neurosurgical, and cardiovascular ICUs of an academic medical center, which consisted of two hospitals, from 2010 to 2014. The neonatal intensive care unit (NICU) was not included in the study because their criteria to identify HAIs are different from adult ICUs in that birth weight was used. Furthermore, Foley catheters were not used in the neonatal population in this acute care teaching facility. Insurance was used as an indicator to determine the socioeconomic status of the population in the study. Although I focused on device-related HAIs in the ICUs, the constraints included examining each of the 21 components within three categories (age, physiological component, and chronic health) that make up the APACHE II score and their potential role in acquiring device-associated infections. The three categories used in the APACHE II system included information on age, physiological components, and chronic health, which were recorded for each ICU in the electronic patient chart in order to determine severity of illness (APACHE II score). The use of computerized clinical information calculated each of the APACHE II scores reliably. Other unforeseen factors that may influence the research outcomes include complications of surgical procedures, adverse reactions, debilitating conditions, and inadequate documentations related to lines and devices. However, because I aimed to evaluate factors contributing to nosocomial infections in three ICUs, the results from the findings may assist in developing new interventions and new processes in patient safety specific to the teaching facility. However, though the factors such as age, gender, and severity of illness were the contributing factors being analyzed, these factors could be confounding by indication as most patients admitted to ICUs tend to be older and already in poor health, thus predisposing them to other infections. To control for confounding variables, mean APACHE II scores were compared

between patients with and without HAI for each category of age, gender, and race/ethnicity under various combinations of risk factors (i.e., obesity, diabetes, and smoking habits).

Limitations

A major limitation of this study was that the majority of the patients in the hospital were referred from other facilities such as long term acute care (LTAC) and were admitted with lines/devices in place, thus making these patients predisposed to developing infections. It was assumed that patients admitted to the ICU had higher risks of developing infections due to their higher level of acuity upon admission. The majority of these ICU patients were referred from other facilities for higher level of care than the transferring facility can provide. An additional limitation was that the study findings were not applicable to every ICU population at a national level. ICUs in different geographic areas may have diverse environmental, economic, and population demographics that may predispose patients to an increased or decreased likelihood of developing a nosocomial infection. However, the population for the acute care facility was not limited to a geographic area, thus providing a more diverse demographics for the study. Furthermore, patients residing in non-teaching facilities may be exposed to different levels of care or available technologies, medications, and equipment. The varying types of ICUs, for example neurology, cardiology, and medical surgical, may affect the types of infections and organisms detected.

Limitations may exist due to the three different ICU patient populations, which may impact the interpretations of these results. Having three different ICUs with varying population may have had an impact on the analysis and the interpretation of the results. The outcomes of the study, which include understanding the demographic characteristics ICU patients, may highlight demographic limitations in future research studies of nosocomial infections. The demographic

findings may provide additional information about potential commonalities and patterns that may be involved in device-associated HAIs. Other concerning limitations included confounding factors such as gender, age, diabetes, obesity, and smoking. To control for these confounding factors, each subgroup of these factors were held constant when making comparisons across ICUs.

The final limitation of the study was that the competency of the infection control personnel and physicians could have affected the data collection methods. The study was dependent on microbiology testing being ordered and collected when a patient exhibits symptoms of infection. If testing were not performed, the data would be skewed to show falsely low rates of HAIs. Additionally, the data were dependent on competent infection control personnel using subjective and objective criterion to classify infections. Differences in practice and experience in infection control personnel could render varying data. To ensure data integrity and accuracy, the data mining software TheraDoc was utilized to validate training and competency of infection preventionists. Quality assurance was performed using parallel testing of data from microbiology culture reports and TheraDoc data abstraction. Educational testing modules were used to confirm and ascertain the appropriate training of infection prevention personnel. Ignoring a multilevel approach and focusing on a single determinant produces an incomplete understanding of how to reduce HAIs and was likely to limit the effect of an intervention. Although an attempt to control the confounding factors was made, a limitation of this approach would be that the lifestyles of the patients, such as specific dieting habits, were not recorded in the clinical data. The potential impact on the results may cause differences in the statistical significance in the chi-squared tests and thus possible estimation bias in the *p*-values.

Therefore, future research could include interventions that can systematically address the issue of HAIs in the intensive care unit at each ecosocial level.

Significance

The results to this study may lead to enhanced understanding of the elements involved in the transmission of infection. The purpose and significance of the study may also demonstrate outcomes and relationships that can possibly be helpful in understanding the relationships of the host, environment, and organisms involved in each device-associated HAI. It was important to understand the association between risk factors and infection in the different ICU settings in order to determine how these findings can be used to reduce infection risks for the three different ICU patient populations. Each of the patients were all 18 years of age or older, and each patient was admitted into one of the three ICUs during 2010-2014. Although there were three distinct ICU populations, they all were considered to be critically ill patients. However, the differences in population included neurosurgical ICU patients who are cared for and monitored for intracranial and hemodynamic monitoring such as brain injury or stroke, tracheostomy and nutritional support and who receive less sedation than other ICUs (Kurtz et al., 2011). As for cardiovascular ICU patients, that population is mainly treated for heart failure, and any other cardiovascular problems such as heart attacks, cardiac surgery, and cardiothoracic pathophysiology. In the medical-surgical ICU population, the focus is on patients who have acute exacerbation of chronic health problems (COPD, CHF, ESRD, etc.) with acute illness or any failure of major systems in the body following surgery or patients who have experienced trauma injuries and any immediate risk of complications. Despite these differences in ICU types, all three intensive care units require higher acuity and complexity of care.

The HAIs, specifically central line-associated bloodstream infections (CLABSI), represent a significant safety risk to critically ill patients. According to (Perencevich & Pittet, 2012), HAIs have a vast economic cost of $6.5 billion in excess expenditure annually and an estimated 100,000 deaths in the United States. Central-line bloodstream infections are one of the leading causes of HAIs (Perencevich & Pittet, 2012). According to scholars, 65% to 70% of CLABSI and CAUTI cases are preventable, and 55% of VAPs are also preventable if evidence-based practices and strategies were used (Umscheid et al., 2011). The HAIs are a primary cause of morbidity and mortality with an estimated 1.7 million HAI cases reported in the United States (Septimus et al., 2014). It was estimated that 20%-70% of HAIs are thought to be preventable (Nakamura, Fukushima, Hayakawa, Sekiya, & Matsumoto, 2015).

Summary

Patients in the intensive care units often require life-saving therapies that involve the use of invasive medical devices. Unfortunately, these invasive devices also carry the threat of nosocomial infection, which can increase patient morbidity, mortality, length of stay, and cost of care. According to O'Grady et al. (2011), it was estimated that in the United States alone, there were 15 million central vascular catheter days that occur in the intensive care units each year. It was estimated that 80,000 central line bloodstream infections occur in the ICUs each year (O'Grady et al., 2011). The total cost of nosocomial infections account for nearly a third for ICU in-patients (O'Grady et al., 2011). Given the severity of the threat device-associated HAIs pose to patients in intensive care units, it was necessary to examine the risk factors, comorbidities, and microbiology of different intensive care units, as well as the differences between them. In this historical prospective study, I examined these factors to identify any significant associations with device-associated HAI rates. The results of this study could result in novel approaches to address

device-associated nosocomial infections. The findings could help to focus on implementing prevention approaches and guidelines depending on the ICU patient population. The awareness and better understanding of healthcare associated infections (HAIs) related to devices is problematic and the healthcare industry should continue to promote quality improvements and prevention of HAIs. The following literature review on hospital-acquired infections builds the foundation for the research study to evaluate factors contributing to device-related infections in acute-care setting.

Chapter 2: Literature Review

Introduction

Device-associated HAIs are increasingly being recognized in the scientific literature as the preeminent threat to patient safety in the ICU, contributing to patient morbidity, mortality, and economic cost of care (Guanche-Garcell et al., 2011). The use of multiple therapies, invasive procedures, and devices including mechanical ventilators and central venous, pulmonary artery, and urinary catheters leaves the critically ill patient population at an increased risk of developing device-related healthcare associated infections DA-HAIs (Tao et al., 2011). Scholars have estimated that the number of HAIs in the United States was approximately 1.7 million with 99,000 annual deaths. It was estimated that the cost of HAIs each year was over $10 billion dollars (Septimus et al., 2014). It was also estimated that 48% of patients in the ICU have a central line catheter in place (Sacks et al., 2014). According to Sacks (2014), there are 80,000 catheter-associated bloodstream infections each year, which accounts for 24,000 deaths reported from CDC.

Literature Search Strategy

The majority of the published studies that were summarized and used for this investigation included scientific journals, government agency websites, and websites of professional organizations. A systematic literature search for comparative historical studies was performed on PubMed, MEDLINE, JAMA, and IDSA. Some scientific journals were searched by using Google search engine and PubMed library, limiting the time range from 1990 to 2014. The search was conducted by using keywords such as *social epidemiology*, *ecosocial theory, microbiological pathogens, infection control,* and *infectious diseases*. The use of relevant articles included peer-reviewed journals obtained from the Walden University Library and the UT

Southwestern Health Sciences Digital Library and Learning Center. The peer-reviewed journals used included *Morbidity and Mortality Weekly Report* (*MMWR*), *The New England Journal of Medicine*, *Critical Care Medicine*, *Infection Control & Hospital Epidemiology*, *Public Medicine Journal*, *Clinical Infectious Diseases*, *International Journal of Infectious Diseases,* and *American Journal of Infection Control (AJIC*) from 2005-2016.

Theoretical Framework

The ecosocial theory of disease distribution provided the theoretical framework to understand what and how determinants of health, both biological and social, interact and contribute to HAIs. Following the guiding principles of the framework allows for the systematic approach to identify disease patterns and to develop an explanation of the disparities that exist in ICU populations. This theory was developed by Krieger in 1994 to incorporate social and biological conditions in shaping the population's health overtime (Krieger, 2001). Different from other social epidemiology theories, that focus on aspects of social and biological conditions in shaping the population's health, the ecosocial theory of disease distribution (Krieger, 1994) is used to explain patterns of health in relation to different levels of biological, ecological, and social organization—from cell organization to society to the ecosystem (Krieger, 2001, 2014).

Recognizing how social and biological factors contribute to the epidemiology of diseases, the central question for ecosocial theory is "who and what is responsible for population patterns of health, disease, and wellbeing, as manifested in present, past, and changing social inequalities in health?" (Krieger, 2001, p. 668). The ecosocial constructs include embodiment; pathways of embodiment; cumulative interplay between exposure, susceptibility, and resistance; and accountability and agency. Embodiment refers to the relationship between the social and biological world and an individual's body (Krieger, 2001, 2014). Pathways to embodiment

describe the processes in which social, biological, and environmental factors interact with a person's body, including evolutionary history, ecological context, and individual histories (both biological and social development).

This, this theory includes spatial-time component. The cumulative interplay of exposure, susceptibility, and resistance explains how disease patterns are affected by people's biological and social histories and experiences at multiple levels over the life course. In accountability and agency, institutions (individual and households, government, business, and public sector) are responsible for monitoring, analyzing, and addressing patterns of diseases (Krieger, 2001, 2009, 2014). These ecosocial constructs may guide in the understanding of disease patterns and determinants of health of ICU populations, in relation to device-related infections. The ecosocial approach factors such as social determinants of health and biological determinants of health that led these populations to the ICU was analyzed. For this research, the ecosocial theory (Krieger, 2009) was adapted for this research as a conceptual framework to determine factors that influence the incidence rates of device-associated infections in an acute care setting. Figure 1 illustrates the ecosocial conceptual model that includes the pathways to embodiment adapted from Krieger (2001).

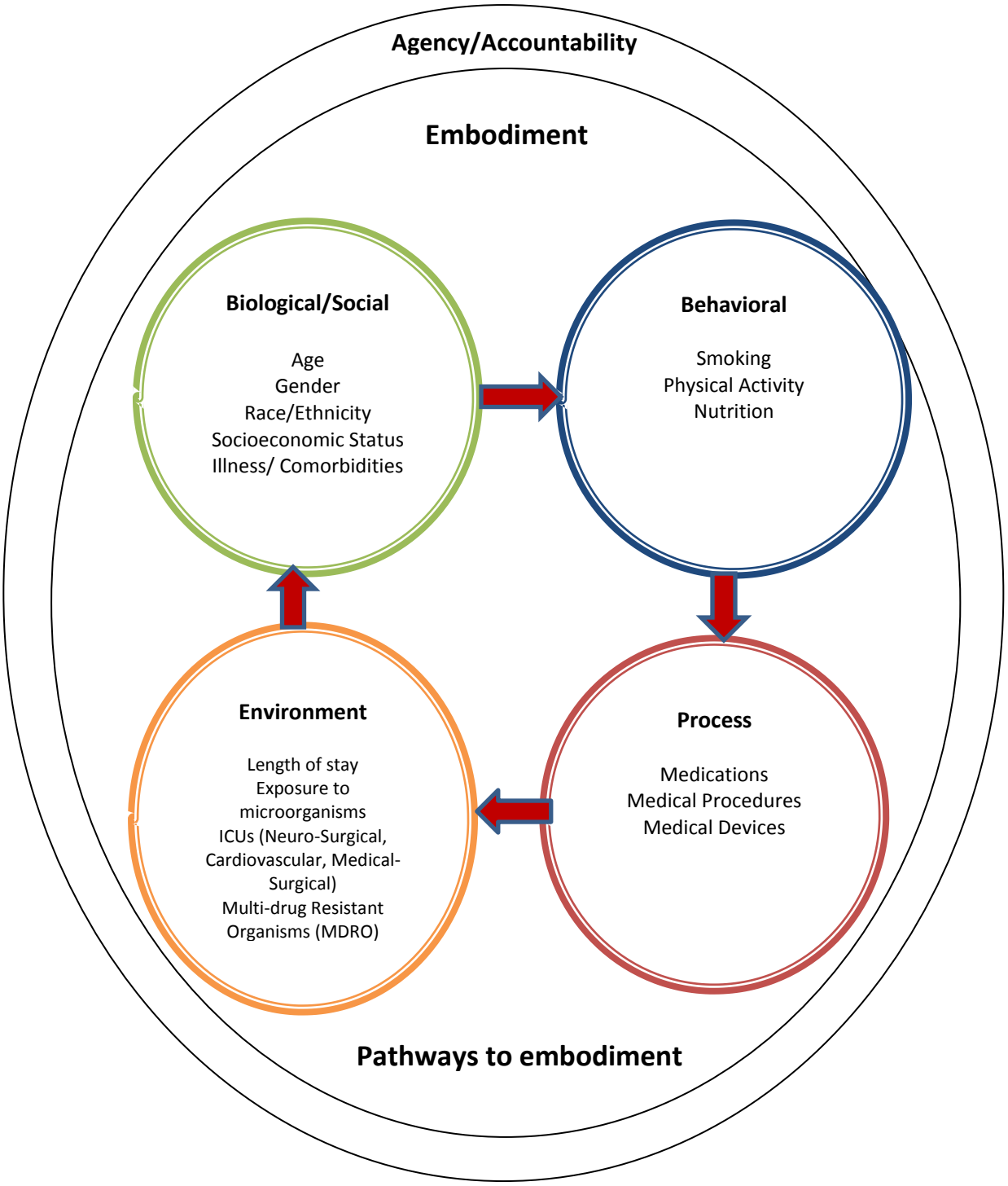


Figure 1. Ecosocial conceptual model.

Types of Device-Related Healthcare Associated Infections

Catheter-Associated Urinary Tract Infections

The introduction of medical devices, such as Foley catheters, into the urinary tract that remain in place for extended periods of time carries a risk of infection. Device associated urinary tract infections are tied with pneumonia as the second most common type of nosocomial infection (Horan et al., 2008). These types of device-associated infections account for more than 15% of infections in acute care facilities and are associated with more than 13,000 deaths each year (Horan et al., 2008). These infections can lead to further complications such as cystitis, pyelonephritis, prostatitis, bacteremia, epididymitis, and other complications (Horan et al., 2008). The CAUTIs are a complication of diabetes, renal disease, and structural abnormalities that interfere with urine flow. It was estimated that CAUTIs are the origin for about half of all nosocomial infections (Clarke et al., 2013). The CAUTIs are one of the most common HAIs in the United States and are preventable as well (Kennedy, Greene, & Saint, 2013).

The CDC (2015b) defined urinary tract infections as symptomatic urinary tract infections (SUTI) or asymptomatic bacteremic urinary tract infections (ABUTI) based on differentiating criteria (Horan et al., 2008). SUTIs are divided into four different classifications (SUTI 1-4) based on age and the number of colony forming units (CFU)/ml present in the urine culture (CDC 2015b). These four classifications are further divided into subtype A and B based on whether the infection was catheter-associated. Subtype A requires that an indwelling catheter was in place >2 calendar days and was removed the day of or the day before the infection, whereas subtype B requires that an indwelling catheter was not in place or was in place for <2 calendar days (CDC 2015b). SUTI 1 and 2 include any age, while SUTI 3 and 4 are limited to infants (CDC 2015b). Because the ICUs included in this study were exclusively from an adult

population, I only examined SUTI 1a, 2a, and ABUTI device associated infections. See Appendix A and B for CDC/NHSN criteria.

Central-line Bloodstream Infections

The CDC's National Healthcare Safety Network (NHSN) defines a central line as "an intravascular catheter that terminates at or close to the heart or in one of the great vessels that is used for infusion, withdrawal of blood, or hemodynamic monitoring" (CDC, 2015c p.2). Central venous catheters (CVC) are used on patients for multiple purposes to provide parenteral nutrition, drug and other fluid administration. It is estimated that more than 5 million central venous catheters are placed each year increasing the incidence of adverse events (McGee & Gould, 2003). One of the major problems associated with these devices is the risk of nosocomial infections (HAIs). According to literature review, these device-related infections are harmful to patients, typically increasing length of stay, cost of care, and risk of mortality (Perencevich & Pittet, 2012). NHSN defines a central line-associated bloodstream infection as a primary bloodstream infection in a patient who had a central line within the 48-hour period before the development of the bloodstream infection (Horan et al., 2008). These infections are of particular concern in intensive care units where, at any given time in the US, half of all patients have an indwelling CVC (Sacks, et al., 2014). Central-line bloodstream infections are a leading cause of HAIs with approximately 80,000 intensive care unit cases occurring annually and around 24,000 patient deaths (Perencevich & Pittet, 2012). In all, hospital associated infections are a common and potentially harmful patient safety issue in the U.S. and world-wide (Krein, Kowalski, Hofer, & Saint, 2012). Several mechanisms have been proposed for the occurrence of catheter-related infections: infection of the exit site followed by migration of the pathogen down the external surface of the catheter; contamination of the catheter hub, resulting in intraluminal catheter

colonization; and hematogenous seeding of the catheter (O'Grady et al., 2011). See Appendix B for CDC/NHSN criteria.

Ventilator Associated Pneumonia

Mechanical ventilators ease the work of breathing in those patients who are unable to breathe on their own, usually by connecting the patient to the ventilator via endotracheal intubation or tracheostomy. In addition to the life-saving benefits mechanical ventilation offers to those patients suffering from critical illness and respiratory failure, mechanical ventilation is also associated with significant risk for complications and poor outcomes. Negative outcomes associated with mechanical ventilation include death, ventilator-associated pneumonia (VAP), sepsis, acute respiratory distress syndrome (ARDS), pulmonary embolism, barotrauma, and pulmonary edema (Kalanuria, Zai & Mirski, 2014). These complications often result in increases in the duration of ventilation, length of stay in the ICU and hospital, cost of care, risk of disability, and risk of mortality.

It is estimated that more than 300,000 patients receive mechanical ventilation each year in the United States (Peyrani, 2009). Further, Magill et al. (2014), estimated that in 2011 there were 157,000 healthcare associated pneumonias identified in U.S. hospitals. Half of all VAP cases are responsible for hospital acquired pneumonia and it is estimated that 9-27% of all mechanically ventilated patients acquire a VAP during the patient's early course of hospitalization (Kalanuria et al., 2014). The National Healthcare Safety Network (NHSN) reported more than 3,957 ventilator associated pneumonias with an incidence range from 0.0-4.4 per 1,000 ventilator days for the year 2012 (CDC, 2015d). Pneumonia clinically causes inflammation of the lower respiratory tract which involves the lungs airways and supporting

structures. Pneumonia is a major cause of illness and death in hospital settings (Pogorzelska et al., 2011).

To be considered a VAP, the patient must be intubated and ventilated at the time of, or within 48 hours of the onset of the event (Peyrani, 2009). It was important to mention that the duration of ventilation was not relevant for identifying a VAP, i.e. there was no minimum time the ventilator must be in place to be considered a VAP. The diagnostic criteria for VAP for this research study was based on the old protocol prior to the ventilator associated events set forth by the CDC (Dudeck et al., 2013). The criteria used for identification separates pneumonia into three different classifications, PNU1, PNU2, and PNU3, based on differences in patient signs, symptoms, and laboratory results (Horan et al., 2008). It was important to note that a pneumonia diagnosis alone was not an acceptable criterion for VAP. Further, determining the presence of pneumonia can be complicated by other health conditions, including respiratory distress syndrome, pulmonary embolism, and other respiratory diseases (Kalanuria et al., 2014). Early onset pneumonia can also be mistaken for tracheal colonization or upper respiratory tract infections. Consequently, it was important that the specific site algorithms established by the CDC are followed in order to ensure accurate diagnosis, treatment, and reporting (Peyrani, 2009). All three classifications of pneumonia require the same radiology testing and results, requiring more than two chest x-rays that have cavitation, consolidation, and persistent infiltrates which may be new or progressive (Peyrani, 2009). See Appendix B for CDC/NHSN criteria.

Surveillance and Prevention Guidelines

In the United States, the CDC reports that surveillance plays a leading role in reducing DA-HAIs (Doshi, Patel, MacKay, & Wallach, 2009). Further, the Study of the Efficacy of Nosocomial Infection Control (SENIC) has suggested that approximately one third (32%) of

HAIs are preventable through programs of surveillance and infection control (Sydnor & Perl, 2011). Active infection control surveillance and the implementation of evidence based guidelines and practices can increase patient safety and reduce the incidence of HAIs. Reported findings showed a decrease in incidence of HAIs in ICU settings by incorporating an educational program focused on interventions directed at ICU clinical staff (Sacks et. al., 2014). Surveillance was crucial in recognizing outbreaks, trends, HAIs, and emerging infectious diseases in order to implement control measures to aid in controlling the spread of infections (Rosenthal et al., 2012).

Incidence and Complications

The use of Foley catheters in an intensive care unit are used routinely to monitor urine output, for convenience and necessity**.** Urinary tract infections are problematic particularly with patients in the intensive care units. These urinary tract infections account for 32% of health care associated infections (Elpern et al., 2009). According to Nicolle (2014), CAUTIs are one of the most common HAIs especially with patients who have indwelling urinary catheters in place. Complications include lower abdominal pain, burning urination, and frequency to urinate. Urinary tract infections are known to be associated with secondary bloodstream infections given the high frequency of indwelling catheter use especially in the critically ill patients (Nicolle, 2014). The CDC (2015b) states that urinary tract infections are the third most common healthcare associated infection which account for more than 93,000 infections in hospitals alone. The use of antibiotics can predispose an individual for acquiring other multidrug resistant organisms which in turn can increase the risk for potentially more severe conditions.

Central vascular catheters are used as a resource to provide nutrients, medicine, fluids and even take blood samples without having to use a needle to stick a patient. There can be serious complications with any central line bloodstream infection (Marschall et al., 2014). The

complications include prolonged length of stay, mortality and the increased cost of medical services. The clinical manifestations of a central line bloodstream infection can include fever, chills, and/or hypotension (Pronovost et al., 2006). Once the microorganisms are in the bloodstream they can be carried to other parts of the body and in turn can cause organ damage. Other complications include urosepsis which can progress to septic shock. Septic shock is a serious and life threatening complication which can lead to a drop in heart rate and blood pressure along with decrease in urine output and an altered mental status.

Risk Factors

The most prominent risk factor for developing a CAUTI was extended use of a urinary catheter (Clarke et al., 2013). However, other prominent risk factors include a disconnection of the catheter drainage system and a lower level of professional training and experience of the inserter (Clarke et al., 2013). Female sex, old age, impaired immunity, having a catheter placed outside of an operating room, incontinence, diabetes, meatal colonization, and renal dysfunction are also associated with an increased risk of developing a CAUTI or catheter-associated bacteriuria (Edwards, Peterson, & Andrus, 2007; Gould et al., 2009).

Nosocomial infections in ICU patients are especially at risk for adverse consequences due to their risk factors. Gastmeier, Sohr, Geffers, Behnke, & Rüden, (2007) performed research in a German-based hospital to determine risk factors for death among patients who acquired nosocomial infections. The researchers used surveillance data consistent with methods standardized by the CDC. Based on two primary nosocomial infections in their ICUs, pneumonia and primary BSI, the researchers investigated risk factors that contributed to death. Though they found that the types of ICUs and age to be important factors, causative pathogens particularly antimicrobial-resistance pathogens may influence the outcome of patients with nosocomial

infections. A limitation of the study, however, was their inability to adjust for severity of illness at hospital admission. Thus, further investigations of the role of the pathogens in different types of ICUs that contribute to nosocomial infections are warranted.

The importance of investigating antimicrobial resistance organisms in critically ill patients who acquired nosocomial infections were further demonstrated by Chen and colleagues (2012). In this study, prospective surveillance was conducted to determine device-associated infection rates and incidence of antimicrobial resistance in adult medical-surgical ICU in Taiwan from 2003-2005, though the surveillance was conducted according to the CDC procedures (Chen et al., 2012). The findings revealed that through their infection control practices and surveillance program, the rates of device-associated infections and three of the most common antimicrobial resistance pathogens causing VAP were decreased (Chen et al., 2012).

Microbial Transmission

Microorganisms in the bloodstream can be continuous, intermittent or transient depending on the circumstances. Transient bacteremia is incidental and is likely to occur when brushing teeth, post dental procedures, manipulation of infected tissue, certain surgeries, or instrumentation of contaminated mucosal surfaces to name a few. Intermittent bacteremia is usually organisms that make their way into the bloodstream because of other factors such as abscesses, wounds and other trauma conditions. Continuous bacteremia involves constant release of organisms into the bloodstream and usually causes septic shock, bacterial endocarditis and other vascular infections. Microorganisms in the bloodstream can be a threat to any organ in the human body and can have serious consequences. Some of the serious consequences include shock, multiple organ failure, disseminated intravascular coagulation and death (Seifert, 2009). Septicemia or sepsis occurs when the organisms in the bloodstream produce toxins which harm

the patient. Sepsis is recognized by a sudden increase in pulse rate, temperature and the onset of chills (Shah, Bosch, Thompson, & Hellinger, 2013). The pathogens can be bacteria, fungi, viruses or parasites. The organisms that are most commonly linked with bloodstream HAIs are gram-positive cocci such as coagulase negative staphylococcus, *Staphylococcus aureus* and *Enterococcus* species followed by aerobic gram-negative bacilli and then yeast. A large number of the gram negative bacilli causing bloodstream infections can be due to gram negative bacteria such as *Pseudomonas aeruginosa*. Studies conducted by Durojaiye Carbarns, Murray & Majumdar, (2011) have reported that *Pseudomonas aeruginosa* is a major opportunistic pathogen that is involved in many hospital infections. The study reported that *Pseudomonas aeruginosa* has been the cause of outbreaks in intensive care units. The organism's ability to survive in a wide range of physical conditions makes it more likely to cause infections especially since *Pseudomonas aeruginosa* is essentially resistant to several antibiotics (Durojaiye et al., 2011). Bloodstream infections can also be caused by organisms that colonize the skin, oropharyngeal and gastrointestinal tract of patients. Seifert (2009) noted a landmark study by Weinstein and colleagues (1997) which defined the portal of entry for primary bloodstream infections as intravascular catheter (19.1%), and secondary sources were genitourinary tract, respiratory tract, the abdomen, and the skin and skin structure (Seifert, 2009; Weinstein et al., 1997).

The urinary tract consists of the kidneys, ureters, bladder and urethra. Typically when an infection takes place it is either an upper or lower infection depending on the anatomic location of the infection. The lower urinary tract consists of the bladder and urethra while the upper urinary tract encompasses the ureters and kidneys. It was important to remember that the female gender have a relatively short urethra compared to males thus putting the female gender at a higher chance of acquiring a urinary tract infection. The reason females have a higher chance of

infection was because bacteria can reach the bladder in a quicker and easier manner. The urethra has resident flora that colonizes along the epithelium in the distal portion. The potential pathogens include gram negative bacilli such as the *Enterobacteriaceae*. Other pathogens include yeast and some gram positive cocci. The most common urinary tract pathogen was *Escherichia coli* but other frequent urinary tract infections can include bacteria such as *Klebsiella* species, and other *Enterobacteriaceae* (Pallet & Hand, 2010). For gram positive pathogens, *Staphylococcus saprophyticus* is a common pathogen in females that are sexually active. Recurrent urinary tract infections have a tendency to be caused by *Proteus*, *Pseudomonas*, *Klebsiella*, and *Enterobacter* (Pallet & Hand, 2010). The hospital environment plays an important role in determining the microorganisms involved in these types of infections. The hospitalized patients are inclined to develop a urinary tract infection with *Escherichia coli*, *Klebsiella* species, *Proteus mirabilis*, other *Enterobacteriaceae, Pseudomonas aeruginosa, Staphylococcus* and *Enterococcus* species (Pallet & Hand, 2010). The introduction of a foreign body such as a Foley catheter carries a substantial risk of infection (Clarke et al., 2013). In many hospitalized patients, urinary tract infections are introduced during urinary catheterization or other manipulations of the urinary tract. Urine is typically sterile and all areas of the urinary tract above the urethra are sterile in healthy individuals (Clarke et al., 2013).

The respiratory tract is divided into two separate section areas; one section consists of the upper area while the other section makes up the lower respiratory tract. Infections that are associated with mechanical ventilation are associated with organisms which can influence certain traits or certain products to promote colonization and subsequent infection in the host. Most of the organisms associated with respiratory infections have a propensity to gain foothold within the respiratory tract to grow to adequate numbers and produce symptoms. Most etiologic agents of

the respiratory tract disease adhere to the mucosa area of the respiratory tract. The bacteria that possess specific adherence factors include *Streptococcus pneumoniae,* and other *Strep* species, *Staphylococcus aureus, Haemophilus influenza,* and many gram negative bacilli. These types of pathogens cause disease by merely growing in host tissue which in turn causes interference with normal tissue function. Diseases of the lower respiratory tract include both bronchitis and pneumonia. There are four major routes of infection with regard to pneumonia causing organisms. There is upper airway colonization, aspiration of organisms, by inhalation of airborne droplets or by seeding of the lung via the bloodstream. Hospital acquired pneumonia can be related to contaminated inhalation therapy equipment. Any intubated patient has an increased risk of acquiring respiratory nosocomial pneumonia especially when reintubation occurs. The organisms associated with these types of infections can be hospital specific. However the most common pathogens related to lower respiratory infections are *Pseudomonas aeruginosa*, *Klebsiella* species, other *Enterobacteriaceae, Staphylococcus aureus*, *Streptococcus pneumonia* and a variety of other common organisms (Kalanuria et al., 2014). Aspiration pneumonia with infection caused by gram negative bacilli or *Staphylococcus* is a major type of hospital acquired pneumonia followed by pneumococcal disease.

Research Studies of Nosocomial Infections in the Intensive Care Units

HAIs are a major cause for concern as it relates to morbidity and mortality, patient safety, and cost of care (Leblebicioglu et al., 2007; Scott, 2009; O'Grady et al., 2011). There have been research studies done to demonstrate the efficacy of surveillance to prevent nosocomial infections. A study related to device associated healthcare infections which was conducted to determine the epidemiological characteristics of nosocomial infections in combined medical-surgical (MS) and trauma ICUs within the International Nosocomial Infection Control

Consortium (Guanche-Garcell et al., 2011). It was found that BSI, UTI, and respiratory tract infections were almost always associated with an invasive device, and device-associated infections in major teaching hospitals were higher than other hospitals with combined medical-surgical units. This study, however, only looked at two medical-surgical ICU populations from 2006 – 2009. An updated epidemiological study of nosocomial infections is warranted and this proposed research addresses that gap in knowledge.

In Turkey a prospective study of HAI surveillance was performed in 13 ICUs from 12 hospitals, which were all members of the International Nosocomial Infection Control Consortium (INICC) (Leblebicioglu et al., 2007). The objective of the study was to determine the incidence of device-associated infections in the ICUs of the Turkish hospitals to compare them with international infection control standards, and to plan infection control activities based on the data. The study looked at CAUTI rates, VAP, and central venous catheter-related BSI. It was found that device utilization in the ICUs used in the study was similar to that reported in the U.S. rates of device-association infections in the Turkish ICUs were higher than the CDC National Nosocomial Infections Surveillance System. The findings of the study were used to inform the researchers about hospital practices that contribute to nosocomial infections. According to their study, one of the limitations of this research study was not taking into account patients' severity of illness, which might skew the results of the study (Leblebicioglu et al., 2007).

Another study of device-associated nosocomial infections of critically ill patients was conducted in nine Colombian hospitals (Moreno et al., 2006). The study was conducted in respond to other published studies of nosocomial infections in the ICUs in developed countries using CDC standardized definitions. However, few surveillance studies have been performed in developing countries using standardized definitions (Moreno et al., 2006). The objective the

study was to perform a prospective study to measure the rate of device-associated infections, organisms causing the infections, the difference in mortality rates between patients with and without a device in adult ICU settings (Moreno et al., 2006). It was found that the device-associated infections were lower than other published studies in Latin America, but still higher than those reported in the US (Moreno et al., 2006). The study limitations included the use of data from only one population -type of ICU (medical-surgical) and the use of a less sophisticated severity of illness scoring system (Moreno et al., 2006).

Cost of HAIs

Many studies have been conducted to measure the cost of healthcare associated infections and each type of HAI has its own cost. A study on cost was conducted by Scott (2009), using results from medical and economic literature to provide a range of estimates for treating healthcare associated infections. Adjustments were made in the cost with regard to the use of infection prevention and control interventions. The cost for central line-associated bloodstream infections are estimated to range from $5,734 to $36,441. The cost for CLABSIs can be substantial with the possibility of morbidity and financial resources expended (O'Grady et al., 2011). The estimated cost for ventilator associated pneumonia infections ranged from $11,897 to $25,072. The estimated cost for catheter associated urinary tract infections ranges from &758 to $1,006. It was important to keep in mind that each HAI increases the length of stay and increases the possibilities of prolonged care and can contribute to negative outcomes.

Control and Prevention

Understanding certain factors related to device-related HAIs can provide guidelines and important solutions in the ICU. The Infection Prevention & Control Program includes surveillance, data abstraction and preventive measures. However, though surveillance is an

important aspect of Infection Prevention & Control programs, it can be labor intensive and time consuming; thus, limiting resources for quality improvement (Reilly, McCoubrey, Cole, Khan, & Cook, 2015). It is important to focus on prevention from the start rather than treatment after the fact. The novel approach to this research study was comparing three different ICUs within an academic medical center. Control and prevention should use measures for early detection and prompt intervention to control a healthcare problem and minimize the consequences related to device associated infections. Since policies and guidelines evolve constantly, the findings from this study may possibly aid in the development of a more comprehensive plan to prevent nosocomial infections within this facility. However, assessing interventions was not focus of this study. The use of comparison data with regard to disparities can possibly aid in the development of policies and procedures to reduce the possibility of device-associated infections and better treatment strategies in the future. The ability to recognize the differences between risk factors can contribute to prevention or reduction of HAIs.

The Healthcare Infection Control Practices Advisory Committee (HICPAC) has established prevention strategies and guidelines to reduce the incidence of CAUTIs. The core prevention strategies established by HICPAC are evidence based and have demonstrated feasibility. These strategies include the following: 1) insert catheters only when appropriate, minimizing use in all patients; 2) remove catheters as soon as they become unnecessary; 3) ensure that only trained and experienced persons insert and maintain catheters; 4) insert catheters using aseptic technique and sterile equipment, including performing hand hygiene pre and post insertion as well as wearing proper PPE; 5) maintain a closed drainage system; 6) maintain unobstructed urine flow, keeping the collecting bag below the level of the bladder at all times; 7) use hand hygiene and standard or isolation precautions; 8) implement quality improvement

programs to reduce the risk of CAUTI by decreasing inappropriate use of indwelling catheters (Gould et al., 2009).

Summary

Device associated healthcare related infections are associated with an increased length of hospital stay, an increased chance of additional complications and excessive healthcare costs. These infections impose significant economic consequences to the healthcare system. All intensive care unit patients are at increased risk of acquiring HAIs because of the many pre-existing comorbidities which may be present in ICU patients. Risk factors play a role in reducing the body's resistance to infections however it may be difficult to determine how each of these risk factors would contribute to HAIs. Physical environmental factors play a role in contributing to the development of HAIs. The goal must be to prevent these infections rather than identify and treat these infections. Promotion of best practices must be initiated to include maximal barrier protection, use of chlorhexidine for skin prior to insertion, avoiding femoral sites for central line placement, removal of devices when no longer needed. Educational modules should be used pertaining to the prevention of CLABSI, CAUTI, and VAP. A combination of heightened awareness with increased accountability, empowerment of frontline staff, and the opportunity for feedback provides important downward pressure on device associated healthcare infections. The ultimate goal of this research was to identify the types of device associated infections within each ICU, the significant risk factors associated with these infections and the microorganisms linked to these types of infections surrounding the healthcare setting. This research may provide information which may help guide strategic procedures and consideration of narrowing the spectrum of antibiotic usage, shortening the utilization of devices such as Foley catheters and central lines in order to prevent complications and reduce the risk of death. The research could

provide a positive social change which could benefit the hospitals by conveying an understanding on the types of problems related to infections due to vascular lines, Foley catheters and ventilators. Information regarding types of lines, microorganisms, and/or the environment plays a role in eliminating healthcare associated infection. In conclusion, determining the underlying relationships related to the microbial growth associated with these types of infections could help prevent unnecessary prolonged hospital stay, complications, and/or death.

Chapter 3: Methodology

Introduction

Nosocomial infections are a cause of concern and have been shown to increase morbidity, mortality, length of stay, and cost of care in hospitals (Marschall et al., 2014). Critically ill patients in ICUs are more at risk of acquiring infections due to the invasive nature of treatments and multiple therapies used, such as mechanical ventilation, central venous, pulmonary artery, and urinary catheterization (DePalo et al., 2010). Patients with multiple risk factors have higher incidence rates of developing CLABSI, CAUTI, and VAP (Barnett et al., 2010).

Despite multiple interventions and increased attention directed towards identification and prevention of CLABSIs, CAUTI, and VAPs, there continues to be ongoing occurrences of these healthcare device-related infections that patients succumb to during their hospitalization. After reviewing the literature, a gap in clinical practices was identified between interventions and attention focused on minimizing these infections, and actual success at completely eliminating those types of infections (Cardo et al., 2010). Although the focus of this research was not on assessing clinical practices, the findings of this study may provide suggestions for future researchers to develop interventions to minimize infections. Specifically, the research aimed to address the gap in knowledge in regards to the statistical difference analyses (if any) of incidence between ICU types and risk factors that include severity of illness. Additionally, I included types of microorganisms identified in each type of device-associated infection. I addressed the knowledge gap in the associations between the ICUs, device-associated infections, and microorganisms. The purpose of this historical prospective study was to analyze and compare the key pathogens, risk factors of ICU patients, and trends of nosocomial infection rates in three

ICUs (medical-surgical, cardiovascular, and neurosurgical) of a large acute care teaching hospital setting.

Research Design and Rationale

Reason for Selection of Design

This was a historical prospective study in which data were analyzed from a 5-year period, enabling examination of the relationship between characteristics of nosocomial infections in three different ICUs. Quantitative data are more efficient and provide the researcher a greater ability to test the hypotheses. The study was less time consuming because analysis was from secondary data using statistical software. Additionally, quantitative evaluation was selected because the data for this research study included actual numbers, frequencies, and counts of cases that may help identify data patterns. The goal for the quantitative research was to classify features and be able to count them and then be able to construct statistical models so that the research could be explained by what was observed. The clinical component provided quantitative health status measures of device-associated infections that can impact knowledge, policy changes, clinical technique changes, and behavioral changes regarding quality healthcare.

Strengths and Key Points of the Research Design

Key points with regard to the strengths of a quantitative research design include statistical representation, estimation of magnitude and distribution impacts, clear documentation methods, addressing confounding factors by holding constant certain demographic traits and risk factors (i.e., diabetes, obesity, and smoking habits), and a standardized approach. Control of biases, including selection bias, was completed by selecting all ICU patients with device-associated HAIs while determining the dissimilarities and similarities of patients by comparing differences in mean APACHE II scores and chi-squared tests for each subgroup of demographic

traits and risk factors. In this study I addressed confounding factors, such as controlling for age and gender, when comparing the mean APACHE II scores for each HAI type and non-DAIs (Tables 10-19). I took into account patients' illness severity scores using the APACHE II score. I did not aggregate the three ICU patient populations in order to prevent masking of aggregated data that can provide better insights to the data. Confidentiality of the patients was maintained by randomly assigned numbers.

Methodology

Study Variables and Measures

Dependent variables included numbers of nosocomial device-related infections (CLABSI, CAUTI, and VAP), the three ICUs, and incidence rates of device-related nosocomial infections (Table 1). Independent variables included demographics that were age, gender, and race; risk factors such as diabetes, obesity, and smoking; types of microorganisms; and severity of illness (APACHE II Score). The data were collected by identifying the number of device-related infections and device days from 2010 – 2014. Data from positive lab results from the electronic health record, for patients with device-related infections, were used in a systematic, empirical investigation to determine the number of cases and incidence rates of infections. The denominator was a count of the number of patients with a device, such as central line, Foley catheter, and ventilator, in each of the ICUs for each month. Microorganisms were investigated to determine if there were any trend clusters with regard to these types of factors. Trend clusters represent same genus and species observed three or more times within a unit. The data were collected, and the comparisons were examined by creating frequency tables and percentage rates to calculate for each factor. Incidence rates were the number of each device-associated infection calculated for each month. The denominator was the population at risk, which was reflected in

the device days. In the incidence rates for the study, I looked at the number of HAIs on a yearly basis for 5-years. The SIR used NHSN data, which were comprised of observed (number of infections) to the expected (expected number of infections) HAIs. For example the denominator was the expected number of CLABSI for each location, which was calculated by multiplying the location's number of central line days by the NHSN rate and dividing by 1,000. The SIR is a summary measure used to track HAIs at a national, state, or local level over time within each population type. A SIR of 1.0 means the observed number of infections is equal to the number that was expected or predicted using NHSN aggregate data. A SIR above 1.0 means the number of infections observed in a particular unit is higher than what was predicted for that particular population. By NHSN definition, if a patient has been classified for one device-associated infection, the patient was not counted twice for other infections if the organism was the same (See Appendix B for definitions). Conversely, each device-associated infection with a different microorganism was counted as a separate infection (CDC, 2015a). These data were analyzed and compared between three different types of ICUs. The aggregate NHSN national pooled mean of similar patient populations in other academic medical centers in the United States was used to compare the ICU populations for this academic medical center. The data for each ICU population were derived from aggregate pooled means of comparable patient populations. The SIR allows summarization of data within similar patient populations by adjusting for differences in incidence in infections among the population/location types. The SIR adjusts for patients of varying risk within each facility, which includes risk factors associated with different patient populations. Data analysis included descriptive statistics; incidence infection rates; and frequency distributions with tables, bar graphs, and/or charts using an Excel database, IBM SPSS 21, and Stata (IC 12.1 version).

Study Population

The population for this study was adult male and female patients admitted to the three ICUs (medical-surgical, cardiovascular, and neurosurgical) of a large acute care teaching hospital within a period of 5 years, from 2010 – 2014. An official record of patients admitted was obtained from TheraDoc, which is a data mining software that abstracts information from EPIC, the electronic patient health record at the institution. Inclusion criteria included HAI (1-5) and non-HAI patients (1-4):

1. Patient must be adult male or female >18-years-old.
2. Admitted to one of three ICUs (medical surgical, cardiovascular, and neurosurgical) of the acute care teaching hospital between the time period of January 1, 2010–December 31, 2014.
3. Length of stay in the acute care facility >2 days.
4. Device used while hospitalized (central-line, Foley catheter, or ventilator).
5. Met NHSN criteria for a device-related infection for CAUTI, CLABSI, and VAP (Appendix B). The NHSN criteria is met by taking the number of device associated infections for a given period divided by the number of device days for the same time period for each ICU population.

There were three ICU types being evaluated in this study. The three units included a medical-surgical ICU, cardiovascular ICU, and a neurosurgical ICU. Each ICU was analyzed separately and compared to one another for similarities and differences. The total number of beds for all combined intensive care units was 67. The investigation included any positive device-related HAI that was linked to the use of central lines, Foley catheters, and mechanical ventilation. The denominator included the entire ICU populations who had devices in a given

month. This included patients who had device associated HAIs and those at risk but without device-associated infections. This enabled incidence rates to be developed. The study population size included all patients identified as having a central line, Foley catheter, and/or on a ventilator in a medical surgical ICU, cardiovascular ICU, and neurosurgical ICU during the 5-year period. Each DAI identified was counted once, and there were no duplication of HAIs counted per device according to NHSN criteria. For example, a patient may acquire a CLABSI, CAUTI, and/or VAP. The NHSN guidelines and criteria were used when identifying all of the device associated infections (Appendix B).

Data Collection

The research analyzed secondary data of all patients that were admitted to the three ICUs from 2010–2014 extracted from Epic, a health information management system of medical records. The data was validated by the Infection Prevention and Control Department of the acute care research hospital using TheraDoc. The data analyzed was the number of device-related infections and device days by month and year, demographics, patient APACHE score, and microorganisms related to their infections. Patients with a device (central line, Foley catheter, and/or ventilator) were (according to IC policy) to be monitored daily, along with monthly evaluations of device utilization rates, infection incidence rates and SIRs. The utilization ratio for central lines, Foley catheters and ventilators was estimated by month and year by the researcher. This was done by taking the number of device days for each ICU. Device days were obtained by counting the devices to estimate the total number of CLABSIs, CAUTIs, and VAPs among patients in the ICUs, the infection prevention department used the total number of infections and divided by the number of device days in order to obtain the infection rates per 1000 (Appendix D). To calculate device utilization rates, the number of device days were divided by census days

for each CLABSI, CAUTI, and VAP. The pooled mean for CLABSI, CAUTI, and VAP infection rates were specific to each ICU and were obtained from the National Healthcare Safety Network (NHSN). The guidelines used were from the NHSN (Appendix B) and were implemented by both the ICUs and the Infection Prevention Department. Table 1 provides information about which variables were used to answer each research question. The SIR is calculated by determining the expected number which equals to the number of device days multiplied by NHSN rate divided by 1000. The formula is Expected Number = Number of Central Line Days x (NHSN Rate/1000). Once the expected number of infections is calculated, the SIR calculation can be determined by using the Observed Number of infections divided by the Expected Number of infections. The formula for SIR is: Observed/Expected.

Table 1

Description of Variables Corresponding to Research Questions and Database Source

Research Question	Dependent Variable	Independent Variable	Source
RQ1	# of CLABSI # of CAUTI # of VAP	Medical/Surgical ICU Cardiovascular ICU Neurosurgical ICU	Epic TheraDoc
RQ2	CLABSI CAUTI VAP	APACHE Score includes Severity of Illness measured by: temperature, mean arterial pressure, heart rate, respiratory rate, oxygenation, arterial pH, serum potassium, serum sodium, serum creatinine, hematocrit, white blood cells count, coma score, age, and chronic health; obesity, diabetes, smoking	Epic Patient chart review
RQ3	Healthcare-associated Infections (HAIs) ICU type	Age, gender, ethnicity, and race	Epic TheraDoc
RQ4	Types of HAI # of HAI	Microorganisms Gram-stain Genus/species Susceptibility patterns ICU type	Epic TheraDoc

Data Analysis

The Informatics Department from the Academic Medical Center provided de-identified datasets for the purpose of this research. Information was abstracted from the limited dataset needed for this research study. Data was downloaded to Excel from Epic and TheraDoc by the Infection Prevention & Control Department personnel. A clarity report was created with a line listing for each patient that was admitted into the ICUs during 2010 through 2014. All the patients required information was included in the report. During the same admission, if a patient had multiple microbiological cultures from the same source and same organism, the duplicate patient listing was removed to prevent double counting. The academic medical center agreed to provide the de-identified data from the Informatics Department, and therefore, there should not have been a conflict of interest. The data was analyzed using SPSS software, version 21 and Stata IC 12.1 version. Descriptive statistics, as frequencies, were used for categorical demographic data (gender, race, and ethnicity). For this study American Indian/Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander were grouped into "Other" category for Race and Ethnicity for data analysis purposes due to the small number of population within each group. The mean age was calculated for each set of device-associated infections (CLABSI, CAUTI, and VAP) and compared for differences. Setting parameters helped to standardize the study into select age groups which was useful for comparing rates between population and determining the severity of disease using the APACHE II scores. The APACHE II score uses a standardized scoring system which can help to predict mortalities. Calculations were performed with the HAI groups in this study. The HAI and non-HAI groups were further analyzed in regard to their association with the following comorbidities: diabetes and obesity. Another risk factor examined was smoking. The research population was adult male and female. Additionally,

descriptive statistics such as frequencies were used for reporting microorganisms and comorbidities within the known device associated HAI patients. As for the device-associated infections, it was the average of infections per device days. The mean and the standard deviation were used to compare the average and the measure of dispersion of device associated infections between the three ICUs according to the NHSN data.

The research questions were analyzed as follows:

RQ#1: Is there a difference in the incidence rates of device-related nosocomial infections between the different types of ICUs?

$H_0$1: There is no difference in the incidence rates of device-related nosocomial infections between the different types of ICUs.

$H_1$1: There is a difference in the incidence rates of device-related nosocomial infections between the different types of ICUs.

To determine the device (central-line, Foley catheter, or mechanical ventilator) which increases the chances of an ill person in the ICU of developing an HAI, the device-related infection incidence rates for CAUTI, CLABSI, and VAP were compared against the utilization ratio in each ICU. Utilization ratio was calculated by dividing device days by patient days (the number of patient in that unit daily). The utilization rate compared to the NHSN national pooled mean provided a picture of how many intra-devices were being used on a particular unit in order to determine over usage which can increase infections. Descriptive statistics as frequencies were used for device types in each ICUs. To determine if infection rates were higher in one type of ICU compared to other ICUs, the incidence rates and SIRs of CAUTI, CLABSI, and VAP in each ICU were compared. To calculate the incidence rates of device associated HAIs in each ICU, the number of cases was divided by device days multiplied by 1000 for each case identified

per month and year. The device days for central-lines, Foley catheters, and mechanic ventilators were calculated based on the number of patients with a device per day. To calculate device days, the number of patients who had a device was recorded each day at the same time, and the daily counts were added together at the end of the months. A SIR was determined by calculating the number of observed cases divided by the number of expected infections. The number of expected infections, known as the statistical prediction, is where each device associated infection such as CLABSI, CAUTI, and VAP ratio was calculated using a standard population during a baseline period. This period represented a standard population experience in each of the device associated healthcare associated infection categories. The expected number of infections was calculated by multiplying the number of device days by the NHSN pooled mean and dividing by 1000. The pooled mean originates from a defined baseline report (Dudeck et al., 2011). The SIR was a summary measure used to compare the hospital acquired infection (HAI) rate among one or more groups of patients to the mean rate for the similar NHSN patient population. An SIR greater than 1.0 indicated that more HAIs were observed than predicted, and an SIR less than 1.0 indicated that fewer HAIs were observed than predicted. The calculation of HAI rates for each device was the number of hospital acquired infections divided by the number of device days multiplied by 1000 in order to obtain rates. The numerator was each identified case of device associated HAI which occurred during the month. The denominator was the number of device days counted during the day, at the same time, in each intensive care unit for each infection category (see Table 2). Quarterly data were analyzed for the five year period (2010–2014) from the data provided by Infection Prevention. The standard deviations for the rates were calculated, and the mean was calculated yearly based on NHSN guidelines. The 50^{th} percentile bar is a standard provided by the NHSN for comparisons to the national average. The data were collected and the

comparisons were done by creating rate tables and SIR for each device. To test for differences in the infection rates and SIR by ICUs, analysis of variance (ANOVA) was used. Assumptions were tested and met for ANOVA. Post-hoc analysis was done to determine where the ICUs differed.

Table 2

Calculation of Device-related Healthcare Associated Infection Rates

Types of Device Associated Healthcare Associated Infections	Calculations
Ventilator Rates	# VAP cases/# of ventilator device days x 1000
Foley Catheter UTI Rates	# CAUTI cases/# of FC device days x 1000
Central Line BSI Rates	# CLABSI cases/# of CL device days x 1000

RQ#2: What is the association between severity of illness, measured by the Acute Physiology and Chronic Health Evaluation II (APACHE II) score, and CLABSI, CAUTI, and VAP?

$H_0$2: There is no association between severity of illness (APACHE score) and CLABSI, CAUTI, and VAP.

$H_1$2: There is an association between severity of illness (APACHE score) and CLABSI, CAUTI, and VAP.

The research study utilized the Acute Physiology and Chronic Health Evaluation (APACHE II) scoring system as a tool to determine the severity of a patient's illness within the first 24 hours of admission to the ICU (Knaus et al., 1985; Le Gall, 2005; Vincent & Moreno, 2010). The APACHE II scoring system is based on age, chronic health problems, and 12 physiologic variables (temperature, mean arterial pressure, heart rate, respiratory rate, oxygenation, arterial pH, serum sodium, serum potassium, serum creatinine, hematocrit, white

blood cells count, and Glasgow coma score for measure of neurologic function) (Knaus et al., 1985; Vincent & Moreno, 2010). The APACHE scoring system was used to determine the severity of illness and to abstract the data manually (Table 7-9). By quantifying the disease severity upon admission to the ICUs, the study was able to identify the association between patients' conditions and device-related HAIs. Table 1 shows the components used to determine severity of illness for research question 2.

APACHE II scores of patients admitted to the ICUs were calculated using a web-based APACHE II analysis system. Descriptive statistics were used to analyze APACHE II scores by computing the mean total score and standard deviation of patients with a device. To determine the correlation between each of the device-associated HAIs (CAUTI, CLABSI, and VAP) and APACHE II score, odds ratio and Chi-square analyses were used. To test for differences in APACHE scores between patients who had CLABSI, CAUTI, and VAPs, analysis of variance (ANOVA) was used.

RQ#3: What is the association between age, gender, race and ethnicity from the device associated HAIs identified in the three different adult ICUs within an academic medical facility?

$H_0$3: There is no association between age, gender, race and ethnicity from the device associated HAIs identified in the three different adult ICUs within an academic medical facility?

$H_1$3: There is an association between age, gender, race and ethnicity from the device associated HAIs identified in the three different adult ICUs within an academic medical facility?

Descriptive statistics (frequencies) were used for categorical risk factors (age, gender, race and ethnicity). To determine the association between categorical risk factors and acquiring device-related HAI in the three ICUs, the frequencies of patients with devices who developed HAIs and patients with devices who did not develop HAIs was compared using Chi-square

statistics. The categories for age were divided into 18-29, 30-39, 40-49, 50-59, and ≥60 years of age, and male and female for gender. Race and ethnicity were grouped by White/Caucasian, Hispanic, Black/African-American, and Other. This categorization was used for race and ethnicity consistent with the distribution utilized by the Texas Department of State Health Services for disease distribution analysis.

RQ#4: Are there significant differences in the types of microorganisms (e.g. genus, species and susceptibility according to the Clinical and Laboratory Standards Institute (Patel et al., 2015) which are associated with device-related HAIs in three adult ICUs within an academic medical facility?

$H_0$4: There are no significant differences in the types of microorganisms (e.g. genus, species, and susceptibility according to the Clinical and Laboratory Standards Institute (Patel et al., 2015) associated with device-related HAIs in three adult ICUs within an academic medical facility.

$H_1$4: There are significant differences in the types of microorganisms (e.g. genus, species susceptibility according to the Clinical and Laboratory Standards Institute (Patel et al., 2015) which are associated with device-related HAIs in three adult ICUs within an academic medical facility.

Descriptive statistics (frequencies and mean) were used to identify the different types of microorganisms associated with each of the HAIs within the three ICUs. Analysis of variance (ANOVA) was used to determine if there were differences in the types of microorganisms associated with device-related HAIs within the three ICUs. Prior to the use of the data, the assumptions were tested and conditions were met with the use of ANOVA. Additionally, for

each categorical risk factor, the study identified the predominant microorganisms in patients that develop device-related HAIs within the three ICUs.

Threats to Validity

The results of this research may help to establish association between the possible risk factors (such as age, gender, race, and ethnicity), disease severity, device utilization, ICU types, and HAIs. However, it was important to consider other variables that might affect the rate of infections. Variables that might affect infection rates include comorbidities of individual patients (see Table 10-17), varied ICU environments from year to year, and clinical staff turnover. Utilizing a standardized acuity scoring system, using the same ICU units for the patient population being studied may minimize possible sources of bias. Another threat to validity was that the NHSN definitions of healthcare-associated infections are periodically updated from year to year, which affects hospital staff in determining device-related infections, thus affecting the data.

Ethical Procedures

The researcher conducting the study is knowledgeable in infection prevention and control and has worked in an acute health care setting. Additionally, I manage the Infection Prevention and Control Department in the acute care hospital. For this study, the researcher completed the National Institute of Health "Protecting Human Research Participants" training course. Access to hospital patient database was granted by the Vice President of Hospital Quality, who also serves as the Hospital Chief Quality Officer (Appendix C). Patient data was de-identified and replaced with a unique study identification number to maintain patient confidentiality and privacy. The Academic Medical Center provided personnel from the Informatics Department to extract the necessary data set for this study. The dataset contained a unique identifier for each patient. I only

accessed patient information as a student according to HIPAA guidelines. The limited data set was transferred into an Excel spreadsheet without patient identifiers. No experimental medical procedures were performed for this research study. Since this was a retrospective study, future patient admissions were not used. Data was secured on my personal computer to enable access and data was not altered. De-identified data will be maintained for 5 years and then destroyed. The research study was approved by the Walden University Institutional Review Board (IRB-07-31-15-0151358) and the hospital Institutional Review Board (IRB-8843) prior to implementation.

Summary

This historical prospective study used targeted surveillance to measure device associated infections in three different ICUs by using the definitions of the NHSN. This research used a quantitative historical prospective methods approach and was conducted at a University Medical Center that included an initiative that was in line with a current organizational priority to reduce the incidence of device associated HAI, such as CLABSI, CAUTI, and VAP. The target population was all patients who had a positive confirmed healthcare associated infection with central venous lines, Foley catheters, or on a ventilator in a medical surgical, cardiovascular, and neurosurgical adult acute care intensive care unit. The measurement of device-associated infection rates, incidence, microbiological pathogen profiles and risk factors were essential in determining any patterns or trends within each ICU. The statistical analysis provided in Chapter 4 presents the necessary comparative tools to evaluate and examine the components of device associated infections in the three different ICUs noted.

Chapter 4: Results

Introduction

This research study was implemented in order to examine and compare device associated nosocomial infections with three different ICUs within an academic medical hospital. I compared multiple factors and attempted to compare incidence rates of device-related nosocomial infections between three types of ICUs (cardiovascular, medical-surgical, and neurosurgical) within an academic medical institution. The hypothesis was that there was no difference in the incidence rates of device-related nosocomial infections between the three ICUs. I also looked at the association between the severity of illness of patients, measured by the APACHE II score, and CLABSI, CAUTI, and VAP. There was a statistically significant difference in APACHE II scores of those who acquired device-associated infections between the three ICUs (Tables 7-8). Furthermore, I examined the association between age, gender, race, ethnicity, and HAI status of patients in the three adult ICUs. It was found that age, gender, race, and ethnicity were not associated with an HAI (Tables 3 and 9). Finally, I looked for significant differences in the types of microorganisms associated with device-related nosocomial infections in the three adult ICUs. For Research Question 3, it was found that there was an association between types of microorganisms associated with device-related HAIs in the three adult ICUs within an academic medical facility (Tables 23-24). This chapter provides the results of the data analysis conducted to answer the research questions related to HAIs within the three academic ICUs studied.

Data Collection

I analyzed secondary data of all patients admitted to the three ICUs (cardiovascular, medical-surgical, and neurosurgical) from 2010-2014 who developed a device-related

nosocomial infection and those patients who did not develop a HAI. The data were extracted from Epic, a health information management system of medical records and validated by the infection prevention and control department at the academic medical center. This included calculating APACHE II scores, identification of device-associated nosocomial infections, identifying organisms, and capturing demographic data. Patient identifiers were removed prior to obtaining the data for analysis, and numerical identifiers were assigned for each case to avoid duplicate counts of the same HAI. The timeframe for data collection was 4 weeks. There were a total of 321 patients identified as having device-related nosocomial infections; however, two patients were excluded from the study because they did not meet the inclusion criteria due to age. The research study was specific to the three ICUs within two hospitals of an academic medical facility that serve surrounding areas including nearby states. There were a total of 4,213 patients admitted to the three ICUs who met the inclusion criteria from 2010-2014, with an average age of 59.13 (SD = 16.10). From 2010-2014, most patients were admitted to the medical-surgical ICU (MSICU; 55.31%, *n* = 2,330), followed by the neurosurgical ICU (NSICU; 27.46%, *n* = 1,157). Over half of the study population were males (53.07%, *n* = 2,236); female: 46.93%, *n* = 1,977. The majority of the population were Caucasians (60.43%, *n* = 2,546), followed by African Americans (25.30%, *n* = 1,066; Table 3). The population included all patients admitted to the ICU within the 5-year study time frame that met the device-associated HAI criteria and those who did not have an HAI.

Results

The demographics of patients who met criteria for the study were 60.43% Caucasian, 25.30% African American, 13.05% Hispanic or Latino, and 1.21% in other category (Table 3). Most of the patients in the study were male (53.07%, *n* = 2,236) with the distribution being

statistically significant at $p < 0.001$. The majority of patients who were admitted to the three adult ICUs between 2010 and 2014 were ≥60 years of age (53.52%, $n = 2,255$) followed by 50-59 years (21.55%, $n = 908$), 40-49 years (11.56%, $n = 487$), 30-39 years (7.24%, $n = 305$), and 18-29 years (6.12%, $n = 258$). Between 2010 and 2014, all patients who met the study inclusion criteria were admitted to the medical-surgical ICU (55.31%, $n = 2,330$) followed by neurosurgical ICU (27.46%, $n = 1,157$) and cardiovascular ICU (17.23%, $n = 726$). The majority of patients who developed HAIs were Caucasians (65.52%, $n = 209$) followed by African Americans (20.38%, $n = 65$), and Hispanic or Latino (10.66%, $n = 34$), being statistically significant at $p < 0.001$; and these 319 HAI patients had a mean age of 58.49 (SD = 14.41), and the non-HAI group had a mean of 59.19 (SD=16.23); however, the differences in age were not statistically significant by the *t*-test ($p = 0.455$). Within the 5-year period, the majority of patients identified with device-related nosocomial infections were in medical-surgical ICU (40.75%, n = 130), followed by neurosurgical (33.54%, n = 107), and cardiovascular ICU (25.71%, n = 82). The distribution was statistically significant ($p < 0.001$).

With respect to the demographic and infection distribution in CVICU, most of the patients were male ($n = 437$, 60.19%; Table 3). According to the chi-square test for gender and patients with or without HAI, there was no statistically significant association found between patients of either gender with an HAI and those without an HAI ($p = 0.297$). While most patients were at least 60 years of age ($n = 388$, 53.44%), there was no statistically significant association between patients of any age group with an HAI versus those without an HAI ($p = 0.100$). In contrast, there was a statistically significant association between patients of any ethnicity without an HAI and those with an HAI ($p < 0.001$). The majority of patients were Caucasian ($n = 421$, 57.99%), followed by African Americans ($n = 194$, 26.72%), Hispanic/Latino ($n = 99$, 13.64%),

and all other racial/ethnic groups (n = 12, 1.65%); the distribution among the racial/ethnic groups was statistically dissimilar ($p < 0.001$).

With respect to the demographic and infection distribution in MSICU, 54.03% of the patients were male (n = 1,259; Table 3). According to the chi-square test for gender and patients with or without HAI, the distribution was statistically dissimilar ($p < 0.001$). While 56.65% patients were at least 60 years of age (n = 1,320), there was no significant association between age group and the number of patients with or without HAI ($p = 0.477$). There were more Caucasians (55.32%, n = 1,289) than any other racial/ethnic group: there were 676 African Americans (29.01%), 335 Hispanics/Latinos (14.38%), and 30 for all else (1.29%). There was no statistically significant association between racial/ethnic groups and the number of patients with or without HAI ($p = 0.138$).

With respect to the demographic and infection distribution in NSICU, there were more female patients (n = 617, 53.33%) than male patients (n = 540, 46.67%; Table 3). According to the chi-square test for gender and patients with or without an HAI, there was no statistically significant association ($p = 0.069$). While more patients aged at least 60 years had acquired an HAI compared to other age groups (n = 40, 37.38%), there was no significant association between the age of the patient and the number of patients with or without an HAI ($p = 0.176$). Caucasians were the majority racial/ethnic group (n = 836, 72.26%), followed by African Americans (n = 196, 16.94%), Hispanic/Latinos (n = 116, 10.03%), and all other race/ethnic groups (n = 9, 0.78%). Although most patients who acquired an HAI were Caucasian (n = 73, 68.22%), the distribution between race and HAI status was statistically similar ($p = 0.054$). Overall, HAIs increase as the patient's age increases. The study did show that confounder of HAI was age.

Table 3

Demographics and Clinical Characteristics of Patients across Three Adult Intensive Care Units, 2010-2014

Demographic and Infection Distribution	**All Patients (*n* = 4213)**	**Patients without HAI (*n* = 3894)**	**Patients with HAI (*n* = 319)**	**P value**
Sex -- n (%)				**<0.001***
Male	2236 (53.07)	2101 (53.95)	135 (42.32)	
Female**	1977 (46.93)	1793 (46.05)	184 (57.68)	
Age -- n (%)				**0.751**
18-29	258 (6.12)	244 (6.27)	14 (4.39)	
30-39	305 (7.24)	282 (7.24)	23 (7.21)	
40-49	487 (11.56)	448 (11.50)	39 (12.23)	
50-59	908 (21.55)	837 (21.49)	71 (22.26)	
≥60	2255 (53.52)	2083 (53.49)	172 (53.92)	
Race/Ethnicity† -- n (%)				**<0.001***
African American	1066 (25.30)	1001 (25.71)	65 (20.38)	
Caucasian	2546 (60.43)	2337 (60.02)	209 (65.52)	
Hispanic or Latino	550 (13.05)	517 (13.25)	34 (10.66)	
Other	51 (1.21)	40 (1.03)	11 (3.45)	
ICU Location -- n (%)				**<0.001***
Cardiovascular (CVICU)	726 (17.23)	644 (16.54)	82 (25.71)	
Medical-Surgical (MSICU)	2330 (55.31)	2200 (56.50)	130 (40.75)	
Neurosurgical (NSICU)	1157 (27.46)	1050 (26.96)	107 (33.54)	

Note. Chi-square test was used to obtain the p-values

† Other category included American Indian/Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander

* Statistically significant at $p \leq 0.05$

** Females comprised 46.93% of all patients, however, females with HAI comprised 57.68%

Mean age for the 319 HAI patients was 58.49 (SD = 14.41), while those without an HAI had a mean age of 59.19 (SD = 16.23, n = 3,894). The mean age differences were not statistically significant $p = 0.455$ by t-test.

Table 3 continued

Demographics and Clinical Characteristics of CVICU Patients, 2010-2014

CVICU Demographic and Infection Distribution	All Patients	Patients without HAI	Patients with HAI	P value
Sex -- n (%)				**0.297**
Male	437 (60.19)	392 (60.87)	45 (54.88)	
Female	289 (39.81)	252 (39.13)	37 (45.12)	
Age -- n (%)				**0.102**
18-29	43 (5.92)	43 (6.68)	0 (0.00)	
30-39	51 (7.02)	45 (6.99)	6 (7.32)	
40-49	88 (12.12)	77 (11.96)	11 (13.41)	
50-59	156 (21.49)	142 (22.05)	14 (17.07)	
≥60	388 (53.44)	337 (52.33)	51 (62.20)	
Race/Ethnicity† -- n (%)				**<0.001***
African American	194 (26.72)	182 (28.26)	12 (14.63)	
Caucasian	421 (57.99)	366 (56.68)	56 (68.29)	
Hispanic or Latino	99 (13.64)	90 (13.98)	9 (10.98)	
Other†	12 (1.65)	7 (1.09)	5 (6.10)	

Note. Chi-squared tests were used to obtain the p-values

* Statistically significant at $p \leq 0.05$

† Other category included American Indian/Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander

Table 3 continued

Demographics and Clinical Characteristics of MSICU Patients, 2010-2014

MSICU Demographic and Infection Distribution	All Patients	Patients without HAI	Patients with HAI	P value
Sex -- n (%)				**<0.001***
Male	1,259 (54.03)	1,210 (55.00)	49 (37.69)	
Female	1,071 (45.97)	990 (45.00)	81 (62.31)	
Age -- n (%)				**0.477**
18-29	143 (6.14)	134 (6.09)	9 (6.92)	
30-39	157 (6.74)	151 (6.86)	6 (4.62)	
40-49	243 (10.42)	234 (10.64)	9 (6.92)	
50-59	467 (20.04)	442 (20.09)	25 (19.23)	
≥60	1,320 (56.65)	1,239 (56.32)	81 (62.31)	
Race/Ethnicity† -- n (%)				**0.138**
African American	676 (29.01)	640 (29.09)	36 (27.69)	
Caucasian	1,289 (55.32)	1,209 (54.95)	80 (61.54)	
Hispanic or Latino	335 (14.38)	325 (14.73)	11 (8.46)	
Other†	30 (1.29)	27 (1.23)	3 (2.31)	

Note. Chi-squared tests were used to obtain the p-values

* Statistically significant at $p \leq 0.05$

† Other category included American Indian/Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander

Table 3 continued

Demographics and Clinical Characteristics of NSICU Patients, 2010-2014

NSICU Demographic and Infection Distribution	All Patients	Patients without HAI	Patients with HAI	P value
Sex -- n (%)				**0.069**
Male	540 (46.67)	499 (47.52)	41 (38.32)	
Female	617 (53.33)	551 (52.48)	66 (61.68)	
Age -- n (%)				**0.176**
18-29	72 (6.22)	67 (6.38)	5 (4.67)	
30-39	97 (8.38)	86 (8.19)	11 (10.28)	
40-49	156 (13.48)	137 (13.05)	19 (17.76)	
50-59	285 (24.63)	253 (24.10)	32 (29.91)	
≥60	547 (47.28)	507 (48.29)	40 (37.38)	
Race/Ethnicity† -- n (%)				**0.054**
African American	196 (16.94)	179 (17.05)	17 (15.89)	
Caucasian	836 (72.26)	763 (72.67)	73 (68.22)	
Hispanic or Latino	116 (10.03)	102 (9.71)	14 (13.08)	
Other†	9 (0.78)	6 (0.57)	3 (2.80)	

Note. Chi-squared tests were used to obtain the p-values

† Other category included American Indian/Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander

Research Question 1 and Hypothesis

RQ#1: Is there a difference in the incidence rates of device-related nosocomial infections between the different types of ICUs?

$H_0$1: There is no difference in incidence rates of device-related nosocomial infections between the different types of ICUs.

$H_1$1: There is a difference in the incidence rates of device-related nosocomial infections between the different types of ICUs.

There were 204 identified Catheter-associated Urinary Tract Infections (CAUTI), 61 Central-line Bloodstream Infections (CLABSI), and 54 Ventilator-associated Pneumonias (VAP)

(Table 5). It was found that from 2010 – 2014, CVICU had the highest incidence rate for CLABSI (1.16 per 1000 CL days, *sd* = 0.56, range = 0.5 – 1.8) (Table 4). In 2012, CLABSI rates were lowest for the three ICUs (Appendix D). However, the difference in CLABSI incidence rates in the three ICUs was not statistically significant ($p = 0.349$) (Table 4). MSICU had the highest CAUTI rate from 2010 – 2014 between the three ICUs (3.98 per 1000 Foley days, *sd* = 1.07, range = 2.6 – 5.1) (Table 4). However, CAUTI rates were lowest in 2014 for the three ICUs (Figure 3). The difference in the CAUTI infection rate between the three ICUs was not statistically significant ($p = 0.187$) (Table 4). NSICU had the highest incidence rate for ventilator associated pneumonia (4.67 per 1000 vent days, *sd* = 3.60, range = 1.6 – 10.4) compared to other ICUs with the highest rate being in 2010 (Table 4, Figure 4). A chi-square test shows that the distribution of the VAP rate across the ICUs is statistically similar ($p = 0.052$) (Table 4); however, a Pearson correlation has shown statistical significance for VAP rates specifically in NSICU (Appendix D). If the study would have used a larger sample, there may have been possible significance in the *p* value. In this study, NSICU patients were shown to have a higher rate of developing a ventilator associated pneumonia than the other two ICUs. From this study it can be concluded that neurologic disease may be a risk factor for VAP development. The implication is that while the distribution of the VAP rate is statistically similar across the ICUs, the VAP rate is correlated with the VAP rate within NSICU. Comparison of device associated infection rates total in the three ICUs from 2010 to 2014 is seen in Figure 5.

In the 5-year period of 2010-2014, CVICU had the highest mean SIR for CLABSI compared to the other two ICUs; however, the difference was not statistically significant ($p = 0.136$) (Table 5). The difference in mean SIRs for CAUTI in the three ICUs was statistically significant ($p = 0.027$) (Table 5). In contrast, differences in VAP SIR across the ICUs were

statistically insignificant ($p = 0.096$) (Table 5). The Bonferroni post-hoc analysis was used to compare between the HAI groups because the post-hoc analysis test was flexible enough to be used on any statistical test. Bonferroni post-hoc analysis revealed that the CAUTI SIR for NSICU was statistically significant ($p = 0.046$; Table 5, Appendix E).

Table 6 shows the aggregated correlation between device utilization and device infection rate in 2010-2014 across the three ICUs. The mean device infection rate (DIR) for CAUTI is 3.58 ± 1.02; for CLABSI is 0.92 ± 0.64; and for VAP is 1.75 ± 2.77. The mean device utilization ratio (DUR, which is calculated by number of device days divided by the number of patient days) for CAUTI is 0.61 ± 0.11; for CLABSI is 0.62 ± 0.16; and for VAP is 0.31 ± 0.06. CAUTI has a Pearson correlation coefficient of 0.43, being statistically insignificant at $p = 0.11$. Similarly, CLABSI has a 0.35 correlation coefficient that is statistically insignificant at $p = 0.21$. Finally, the coefficient for VAP is -0.34 at $p = 0.21$. Overall, aggregating the information for the three ICUs does not reveal a statistically significant association between a device-associated infection and its infection rate nor its utilization ratio. The research compared the device utilization rates in the five year period between the three ICUs (Figure 6, Appendix E). CVICU had the highest central line utilization and ventilator utilization rates compared to other ICUs, and their rate was above the NHSN national pooled mean (Figure 6). NSICU had the highest CAUTI utilization rates compared to CVICU and MSICU, and the national pooled mean (Figure 6). However, utilization rates of any device were not correlated to device infection rates.

Table 4

Incidence Rates of Device-related Nosocomial Infections in the Three ICUs, 2010 – 2014

	Location	Mean	Std. Deviation	Minimum	Maximum	*p*-value
CLABSI Rate	CVICU	1.16	0.56	0.5	1.8	
	MSICU	1.10	0.41	0.6	1.5	
	NSICU	0.6	0.87	0	1.9	
	Total	0.95	0.65	0	1.9	0.349
CAUTI Rate	CVICU	2.86	1.24	1.5	4.6	
	MSICU	3.98	1.07	2.6	5.1	
	NSICU	3.92	0.61	3.2	4.6	
	Total	3.59	1.08	1.5	5.1	0.187
VAP Rate	CVICU	1.36	1.54	0.50	4.10	
	MSICU	0.99	0.91	0	2.44	
	NSICU	4.67	3.60	1.60	10.4	
	Total	2.34	2.75	0	10.4	0.052

Note. Rates are calculated per 1000 device line days
Statistical significance tests performed with ANOVA
Pearson correlation demonstrates within ICU statistical significance ($p \leq 0.05$) in NSICU with VAP rate (Appendix D)

Table 5

Standardized Infection Ratio (SIR) of Device-related Nosocomial Infections in the Three ICUs, 2010 – 2014

	Location	n	Mean SIR	Std. Deviation	Minimum	Maximum	*p*-value
CLABSI SIR	CVICU	24	1.46	0.72	0.6	2.3	
	MSICU	30	0.90	0.35	0.5	1.3	
	NSICU	7	0.56	0.82	0	1.8	
	Total	61	0.97	0.72	0	2.3	0.136
CAUTI SIR	CVICU	45	1.60	0.72	0.8	2.6	
	MSICU	87	1.66	0.44	1.1	2.1	
	NSICU††	72	0.78	0.13	0.6	0.9	
	Total	204	1.35	0.62	0.6	2.6	0.027†
VAP SIR	CVICU	13	0.78	0.91	0.30	2.4	
	MSICU	13	0.62	0.55	0	1.5	
	NSICU	28	2.24	1.74	0.70	5	
	Total	54	1.21	1.33	0	5	0.096

Note. †ANOVA shows significant difference in mean CAUTI SIR by unit location (p=0.027)
††Significant difference based on Bonferroni post-hoc analysis within unit (p=0.046)

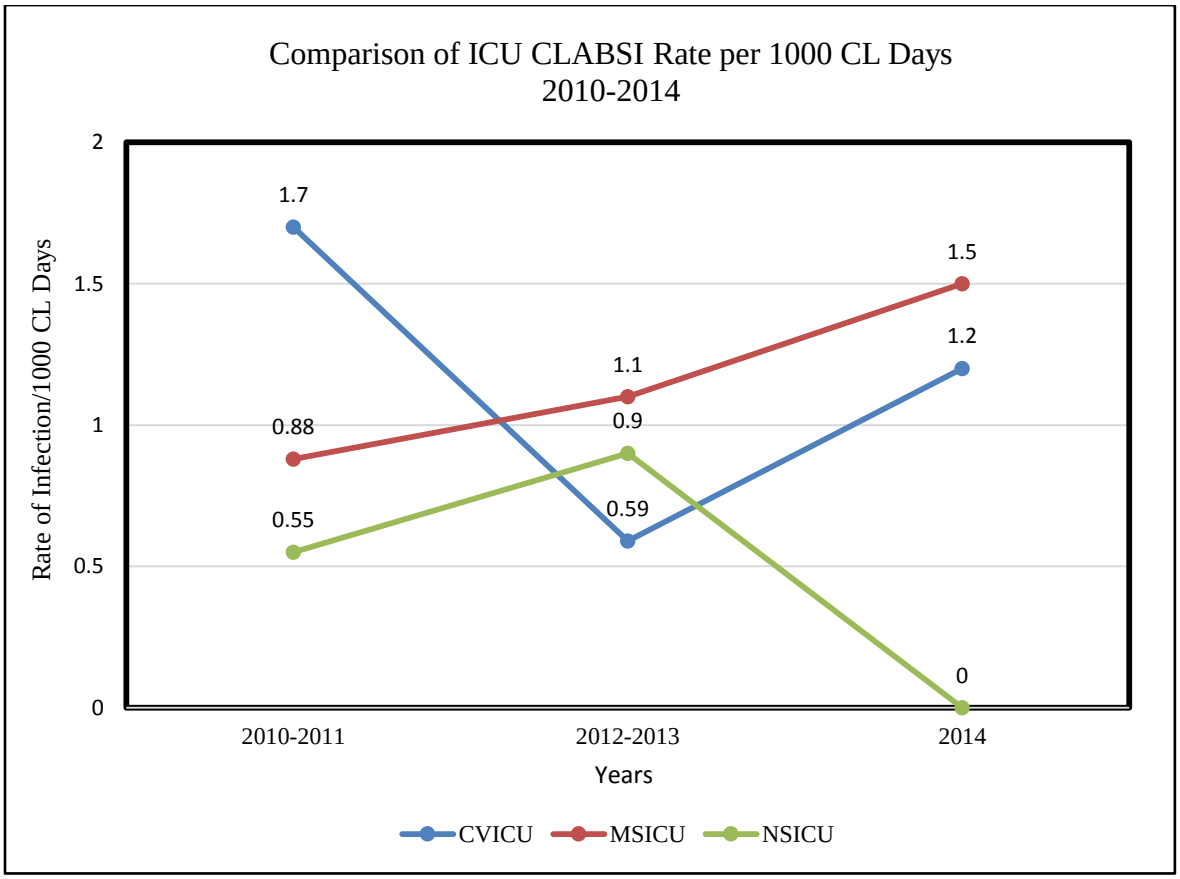
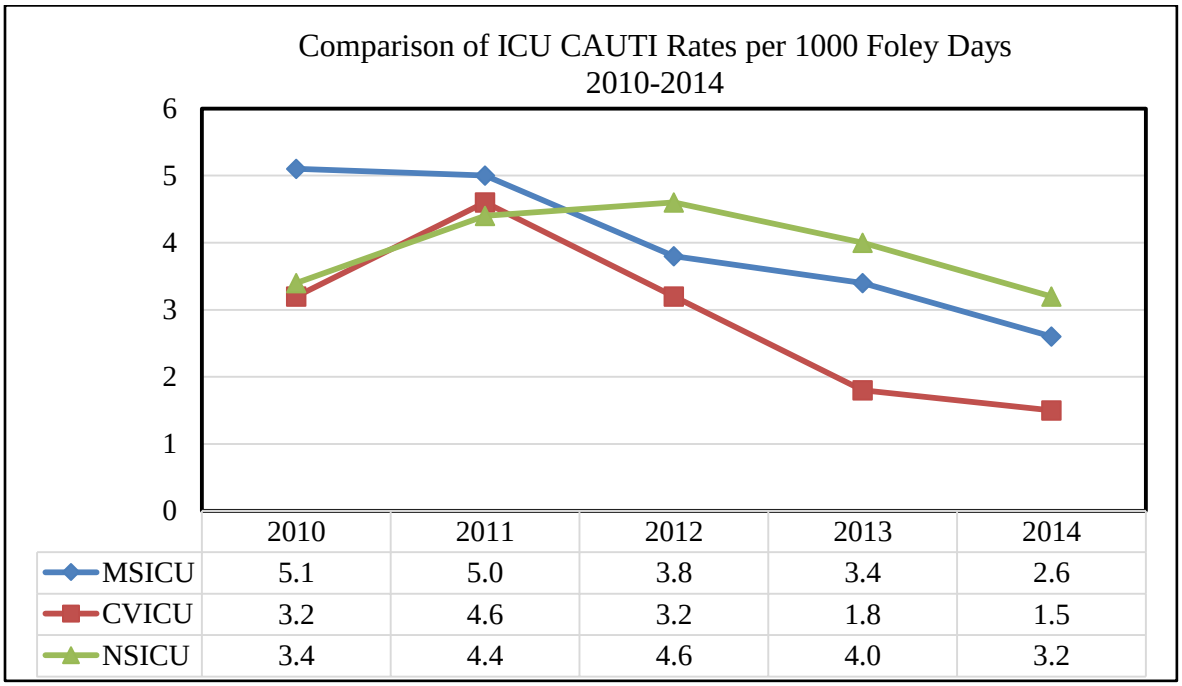


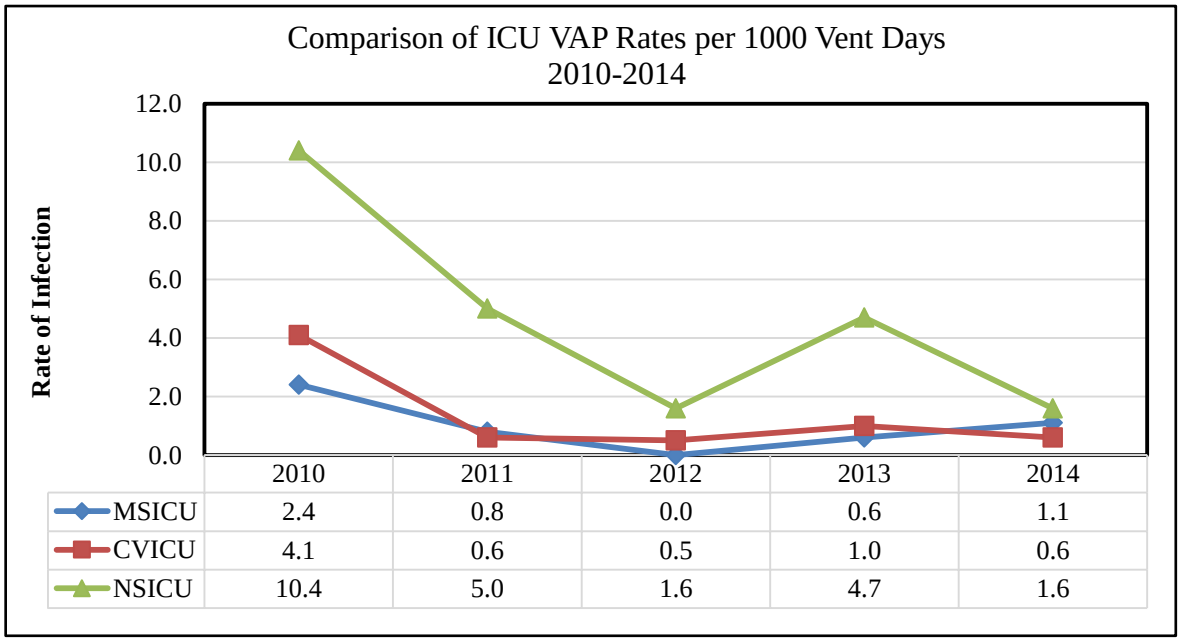
Figure 2. Central-line associated bloodstream infection (CLABSI) rate over a period of 5 years in three intensive care units.

The difference in CLABSI incidence rates in the three ICUs was not statistically significant (p = 0.349) as shown on Table 4.



	2010	2011	2012	2013	2014
MSICU	5.1	5.0	3.8	3.4	2.6
CVICU	3.2	4.6	3.2	1.8	1.5
NSICU	3.4	4.4	4.6	4.0	3.2

Figure 3. Cather-associated urinary tract infection (CAUTI) rate over a period of 5 years in three ICUs.
CAUTI infection rate was not statistically significant as shown by ANOVA (Table 5: $p = 0.187$).



	2010	2011	2012	2013	2014
MSICU	2.4	0.8	0.0	0.6	1.1
CVICU	4.1	0.6	0.5	1.0	0.6
NSICU	10.4	5.0	1.6	4.7	1.6

Figure 4. Ventilator-associated pneumonia (VAP) rate over a period of 5 years in three ICUs.
VAP rate difference was not statistically significant between the three ICUs as shown by ANOVA (Table 4: $p = 0.052$).

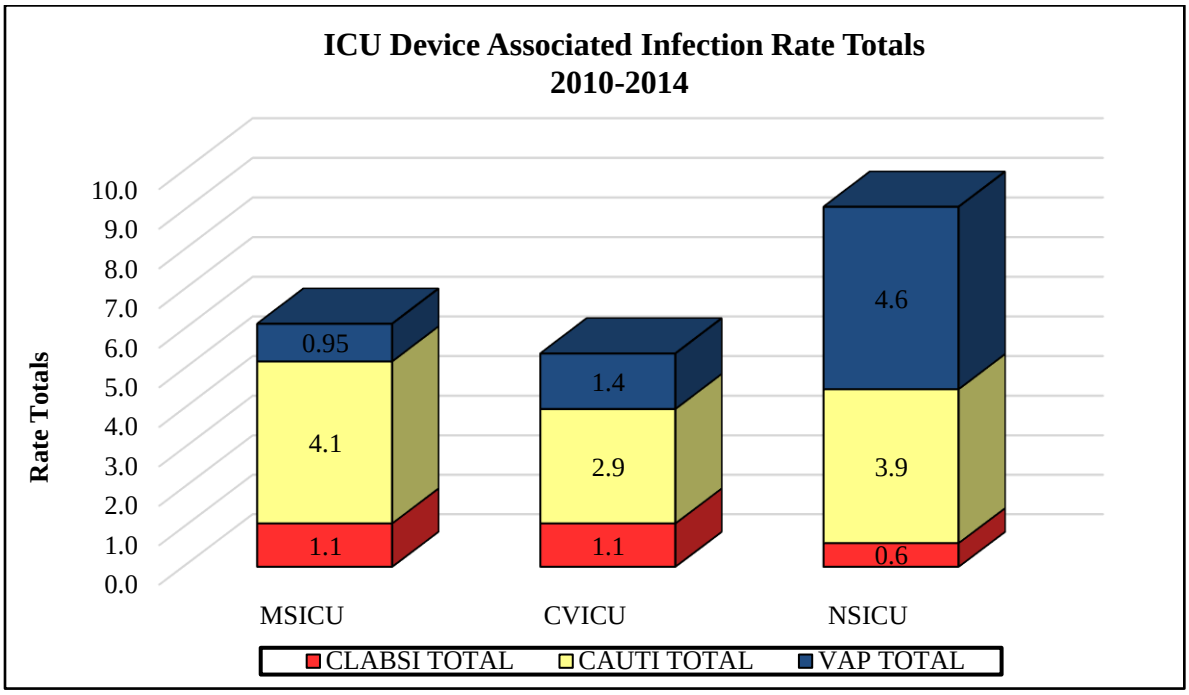


Figure 5. Comparison of device associated infection rates per 1000 device line days in the three ICUs from 2010-2014

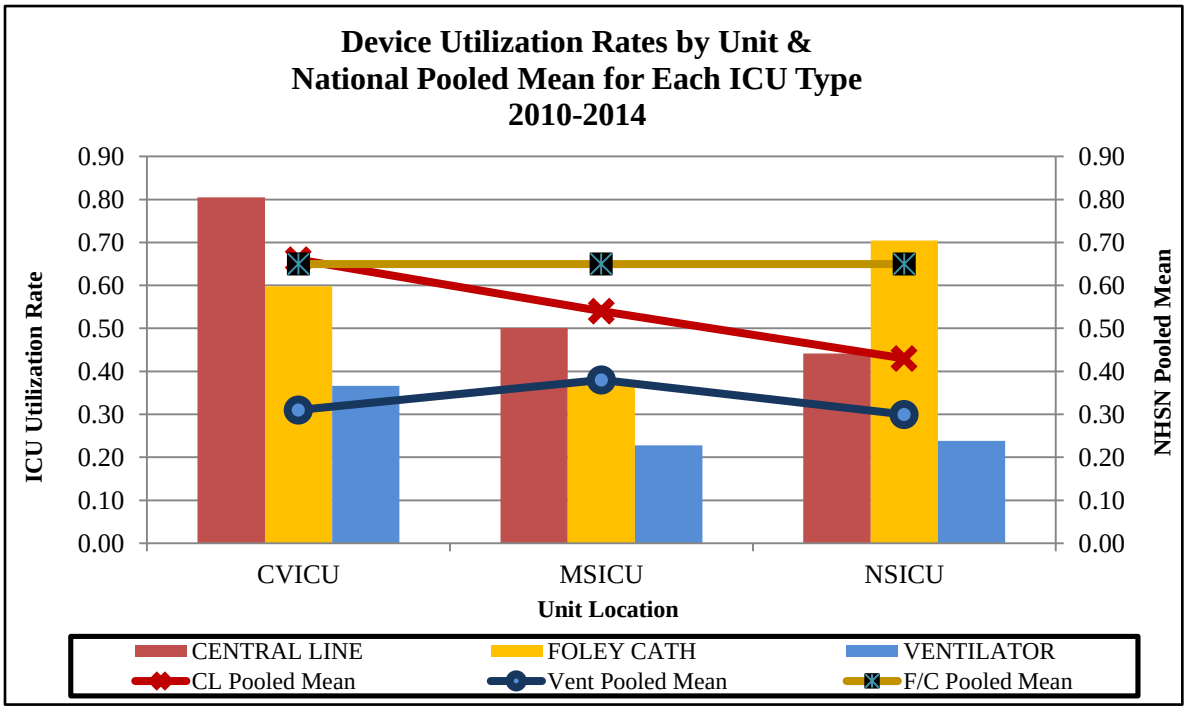


Figure 6. Device utilization rates in the three ICUs from 2010-2014 compared to NHSN national utilization rates pooled mean

Table 6

Correlation between Device Utilization and Device Infection Rate across the ICUs, 2010-2014

Device Associated Infection	Device Infection Rate		Device Utilization Ratio (DUR)*		Pearson correlation	*p*-value
	Mean	Standard Deviation	Mean	Standard Deviation		
CAUTI	3.58	1.02	0.61	0.11	0.43	0.11
CLABSI	0.92	0.64	0.62	0.16	0.35	0.21
VAP	1.75	2.77	0.31	0.06	-0.34	0.21

Note. *DUR is calculated by number of device days/number of patient days

Research Question 2 and Hypothesis

RQ#2: What is the association between severity of illness, measured by the Acute Physiology and Chronic Health Evaluation II (APACHE II) score, and CLABSI, CAUTI, and VAP?

$H_0$2: There is no association between severity of illness (APACHE score) and CLABSI, CAUTI, and VAP.

$H_1$2: There is an association between severity of illness (APACHE score) and CLABSI, CAUTI, and VAP.

The mean severity of illness score for the patients identified with an HAI was 20.99 (*SD* = 8.71) with possible score of 71 indicating the most severe condition of a patient within 24 hours of admission within the intensive care unit (Table 7). The mean score for non-HAI patients was 20.67 ± 7.88 (Table 7). APACHE II scores among Non-HAI patients were similar across all

3 ICU types. Aggregating all three ICUs has led to a statistically insignificant association between the APACHE II score of patients who did and did not acquire a device associated nosocomial infection ($p = 0.494$) (Table 7). Disaggregating the ICUs, patients who acquired VAP in all three ICUs combined had highest mean APACHE score compared to those who acquired CAUTI and CLABSI; however, the difference in mean APACHE scores between the three types of device associated infections was not statistically significant (p=0.333) (Table 8). Those who were admitted to CVICU had a higher mean score (23.22 ± 8.67) than the patients without an HAI (20.51 ± 7.94) ($p = 0.004$). Similarly, patients in the MSICU with an HAI had a higher mean score (23.15 ± 8.72) than the non-HAI patients (20.76 ± 7.92) ($p < 0.001$) (Table 7). In contrast, the HAI APACHE II scores (16.65 ± 7.01) ($p < 0.001$) were significantly lower than the Non-HAI APACHE II scores (20.58 ± 7.74) among NSICU patients (Table 7). As such, there were unit-level statistical significant associations ($p_{CVICU} = 0.004$, $p_{MSICU} < 0.001$, and p_{NSICU} <0.001), revealing that the aggregation has masked significant differences.

There were statistically significant differences in mean APACHE scores between the units for each HAI type when analyzing each ICU individually (Table 8). For CAUTI, CVICU had a mean score of 23.11 ± 8.53, MSICU had 22.51 ± 8.03, and NSICU had 16.29 ± 7.15 ($p <$ 0.001). For CLABSI, CVICU had a mean score of 20.54 ± 9.21, MSICU had 24.13 ± 11.17, and NSICU had 14.00 ± 3.79 ($p = 0.048$). For VAP, CVICU had a mean score of 28.54 ± 5.75, MSICU had 25.15 ± 6.64, and NSICU had 18.25 ± 7.12 ($p < 0.001$). For non-device-associated infections, the mean APACHE score was 20.67 ± 7.88; however, their distribution among the ICUs was statistically similar ($p < 0.708$).

Across all infections, there statistically significant differences in the distribution for each ICU (Table 8). In the CVICU, the total mean APACHE score for every infection (including non-

infection) was 20.82 ± 8.07 ($p < 0.001$). In the MSICU, the total mean score was 20.89 ± 7.99 ($p = 0.005$). In the NSICU, the total mean score was 20.21 ± 7.76 ($p < 0.001$). Thus, similarly to the results of Table 7, the implications are that aggregating the ICUs dilutes significant differences, whereas associations exists at the unit level and infection level.

Table 7

Comparison of Mean APACHE II Scores Between HAI and Non-HAI Patients Within and Across Three ICU Units, 2010-2014

	Without HAI		**With HAI**		
Unit Location	**N**	**Mean APACHE Score ± sd**	**N**	**Mean APACHE Score ± sd**	**P-value from *t*-test**
Cardiovascular ICU (CVICU)	644	20.51 (±7.94)	82	23.22 ± 8.67	0.004*
Medical Surgical ICU (MSICU)	2200	20.76 (±7.92)	130	23.15 ± 8.72	<0.001*
Neurosurgical ICU (NSICU) †	1050	20.58 (±7.74)	107	16.65 ± 7.01	<0.001*
Total	**3894**	**20.67 (±7.88)**	**319**	**20.99 (± 8.71)**	**0.494†**

Note. *Statistically significant at $p \leq 0.05$.

† Significant difference of APACHE II scores based on Bonferroni post-hoc analysis in NSICU ($p < 0.001$)

††ANOVA results reveal a significant difference of APACHE II scores between ICU units ($p < 0.001$). Differences in mean scores are statistically significant even when controlling for age and sex ($p < 0.001$).

Table 8

Severity of Illness of ICU Patients within the Three ICUs which were Measured by the Acute Physiology and Chronic Health Evaluation II (APACHE II) Score in 2010-2014

Type of Device-associated Infections	Unit CVICU	MSICU	NSICU	Total	P-value from ANOVA
	Mean APACHE Std. Deviation N	Mean APACHE Std. Deviation N	Mean APACHE Std. Deviation N		
Catheter Associated Urinary Tract Infection (CAUTI)	23.11 8.53 45	22.51 8.03 87	16.29 7.15 72	20.45 8.40 204	<0.001*
Central Line Associated Bloodstream Infection (CLABSI)	20.54 9.21 24	24.13 11.17 30	14.00 3.79 7	21.56 10.23 61	0.048*
Ventilator Associated Pneumonia (VAP)	28.54 5.75 13	25.15 6.64 13	18.25 7.12 28	22.39 7.97 54	<0.001*
No Device-associated Infections	20.51 7.94 645	20.76 7.93 2,201	20.58 7.74 1,050	20.67 7.88 3,894	0.708
Total	20.82 8.07 727	20.89 7.99 2,331	20.21 7.76 1,157	20.69 7.94 4,213	
p-value from ANOVA	<0.001*	0.005*	<0.001*		0.333†

Note. *Statistically significant at $p \leq 0.05$.

†ANOVA has revealed further insignificant difference in mean APACHE score across the ICUs when controlling for age and sex ($p = 0.262$). NSICU have HAI patients with significantly lower APACHE II scores.

For individuals without risk factors (i.e. those without obesity, smoking habits, and diabetes) in each of the ICUs, an ANOVA reveals statistically significant differences in mean APACHE II scores between those without an HAI and those with an HAI for some subgroups of the sample as shown in Table 9. In the CVICU, the mean APACHE II score for male patients without an HAI is 19.80 ± 6.14, while male patients with an HAI have a mean score of 24.82 ± 6.98; and the difference in the means is statistically significant ($p = 0.013$). Additionally, the differences in the mean scores for those aged 60 and over are statistically significant ($p = 0.002$): the mean score of non-HAI patients aged at least 60 years is 19.41 ± 6.46 and the mean score for those with HAI for the same age group is 26.78 ± 6.14. The mean APACHE II score for Caucasian patients without an HAI is 19.36 ± 6.15, while Caucasian patients with an HAI have a mean APACHE II score of 25.80 ± 6.86. The differences in the mean APACHE scores are statistically significant ($p = 0.002$).

In the MSICU, female patients with an HAI (21.97 ± 8.62) have a statistically higher mean score than female patients without an HAI (19.96 ± 6.03) at $p = 0.093$. There is no statistically significant differences in mean APACHE score between male patients with and without an HAI in the MSICU (21.67 ± 3.79 vs. 20.03 ± 6.04, $p = 0.640$). As with CVICU Caucasian patients, there is a statistically significant difference in MSICU Caucasian patients with an HAI (21.67 ± 8.03) and without an HAI (19.97 ± 5.87) with p = 0.035.

Finally, for the NSICU, female patients without an HAI have a higher mean APACHE II score (18.76 ± 5.63) than female patients with an HAI (14.04 ± 8.48) at $p \leq 0.001$. With respect to age groups in the NSICU, there are statistically significant differences in mean APACHE II scores for those aged 18-29 (18.25 ± 6.38 without HAI vs. 14.04 ± 8.48 with HAI, $p = 0.003$) and those aged 50-59 (19.28 ± 5.57 without HAI vs. 12.91 ± 6.85 with HAI, $p = 0.001$). African

American NSICU patients are also found to have statistically significant different mean APACHE II scores (19.49 ± 4.98 without HAI vs. 10.40 ± 8.17 with HAI) at $p = 0.001$, as well as Hispanic/Latino patients (18.88 ± 5.45 without HAI vs. 10.00 ± 5.20 with HAI) at the same *p*-value of 0.001. Overall, the severity of illness for HAI patients entering into the neurosurgical ICU were lower, possibly due to the patient population comorbidities which were not as high as patients entering into the CVICU or MSICU.

In turn, patients without any risk factors were likely more at risk of contracting an HAI in CVICU and MSICU, but not at NSICU, which may be due to unobserved factors in the NSICU that is unaccounted in the data such as quality of care and medical history of the patient. CVICU and MSICU had HAI patients with significantly higher APACHE scores, as compared to the significantly lower APACHE scores for NSICU. Due to their more severe comorbidities, patients admitted to either MSICU or CVICU have a higher severity of illness. Neurological patients have lower mortality rates and are apt to have better outcomes than other types of ICUs due to their lower number of comorbidities as demonstrated by their lower APACHE II scores (Kurtz et al., 2011) (Table 7).

Table 9

Severity of Illness as Measured by APACHE II across the ICUs, 2010-2014 by Demographics (without Risk Factors)

Unit	Mean APACHE Score (SD) No HAI	Mean APACHE Score (SD) with HAI	N**	P-value (ANOVA)
CVICU				
Gender				
Female	18.87 (5.85)	22.67 (3.21)	79	0.357
Male	19.80 (6.14)	24.82 (6.98)	108	0.013
Age Group				
18-29	18.42 (3.82)	-	12	-
30-39	20.70 (3.56)	17.00 (2.83)	12	0.802
40-49	19.77 (6.49)	22.00 (0.00)	27	0.739
50-59	19.08 (5.87)	22.00 (5.66)	41	0.496
≥60	19.41 (6.46)	26.78 (6.14)	95	0.002*
Ethnicity/Race				
Caucasian	19.36 (6.15)	25.80 (6.86)	114	0.002*
African American	19.85 (6.17)	18.50 (0.71)	49	0.761
Hispanic or Latino	18.73 (5.11)	22.00 (0.00)	23	0.538
Other	16.00 (0.00)	24.00 (0.00)	2	-
MSICU				
Gender				
Female	19.96 (6.03)	21.97 (8.62)	323	0.093
Male	20.03 (6.04)	21.67 (3.79)	359	0.640
Age Group				
18-29	20.45 (6.85)	23.75 (4.03)	35	0.357
30-39	20.08 (6.18)	20.50 (16.26)	50	0.0931
40-49	20.03 (5.92)	20.75 (10.75)	67	0.824
50-59	19.76 (5.60)	21.50 (8.40)	137	0.410
≥60	20.02 (6.14)	22.19 (8.49)	393	0.175
Ethnicity/Race				
Caucasian	19.97 (5.87)	21.67 (8.03)	391	0.035*
African American	20.12 (6.30)	18.00 (9.51)	186	0.427
Hispanic or Latino	19.80 (6.35)	25.25 (7.89)	95	0.099
Other	19.00 (6.02)	27.33 (7.23)	11	0.083
NSICU				
Gender				
Female	18.76 (5.63)	14.04 (8.48)	157	≤0.001*
Male	19.13 (6.06)	16.91 (4.70)	145	0.238
Age Group				
18-29	18.25 (6.38)	5.67 (3.06)	27	0.003*
30-39	19.80 (4.97)	17.33 (5.51)	23	0.437
40-49	19.68 (5.88)	15.86 (11.04)	41	0.192
50-59	19.28 (5.57)	12.91 (6.85)	80	0.001*
≥60	18.54 (6.04)	18.27 (4.56)	131	0.886
Ethnicity/Race				
Caucasian	18.83 (6.10)	17.23 (7.13)	218	0.253
African American	19.49 (4.98)	10.40 (8.17)	50	0.001*
Hispanic or Latino	18.88 (5.45)	10.00 (5.20)	32	0.001*
Other	19.00 (0.00)	22.00 (0.00)	2	-

Note. *Statistically significant at $p \leq 0.05$.
The dash symbol (-) marks unproduced p-values due to low sample sizes of either the non-HAI patients, HAI patients, or both
**N represents the Total for both HAI and Non-HAI patients for each unit.

For patients with diabetes only (i.e. those with diabetes but do not have obesity nor smoking habits), an ANOVA has revealed statistically significant differences in mean APACHE II scores for only two groups: African American patients in the CVICU and MSICU patients aged 50-59 in Table 10. African American CVICU patients without an HAI have a mean APACHE II score of 28.92 ± 3.25 in comparison to those with an HAI of mean APACHE II score of 15.00 ($p = 0.001$), while MSICU patients aged 50-59 without an HAI possess a mean APACHE II score of 23.61 ± 7.75 in relation to those with an HAI having a mean score of 6.00 ($p = 0.032$). Low sample sizes for patients with only diabetes may have contributed to statistical insignificance in many of the subpopulations for each ICU.

Table 10

Severity of Illness as Measured by APACHE II across the ICUs, 2010-2014 by Demographics (Patients with only Diabetes)

Unit	Mean APACHE Score (SD) No HAI	Mean APACHE Score (SD) with HAI	N	P-value (ANOVA)
CVICU				
Gender				
Female	25.50 (8.22)	16.00 (0.00)	17	0.290
Male	23.19 (9.83)	22.00 (9.90)	39	0.869
Age Group				
18-29	11.67 (9.81)	-	3	-
30-39	28.00 (6.24)	-	3	-
40-49	20.33 (12.50)	29.00 (0.00)	4	0.609
50-59	26.10 (11.00)	-	10	-
>60	24.26 (8.33)	15.50 (0.71)	36	0.151
Ethnicity/Race				
Caucasian	21.61 (9.87)	16.00 (0.00)	32	0.580
African American	28.92 (3.25)	15.00 (0.00)	14	0.001*
Hispanic or Latino	24.44 (11.22)	29.00 (0.00)	10	0.710
Other	-	-	-	-
MSICU				
Gender				
Female	25.56 (7.74)	23.58 (8.13)	59	0.426
Male	23.27 (9.35)	31.33 (2.52)	81	0.142
Age Group				
18-29	24.33 (9.07)	26.00 (0.00)	8	0.814
30-39	24.00 (12.03)	35.00 (0.00)	12	0.402
40-49	23.46 (11.11)	-	13	-
50-59	23.61 (7.75)	6.00 (0.00)	34	0.032*
>60	24.72 (8.34)	25.82 (6.43)	85	0.676
Ethnicity/Race				
Caucasian	23.85 (9.16)	22.00 (8.91)	82	0.588
African American	25.34 (7.98)	28.80 (6.06)	52	0.353
Hispanic or Latino	22.93 (9.38)	28.50 (3.54)	17	0.430
Other	23.00 (0.00)	-	1	-
NSICU				
Gender				
Female	24.11 (9.02)	12.00 (7.07)	46	0.352
Male	25.00 (8.00)	-	31	-
Age Group				
18-29	21.25 (12.69)	-	4	-
30-39	25.13 (9.00)	-	8	-
40-49	24.40 (7.88)	-	10	-
50-59	25.17 (9.49)	-	12	-
>60	24.49 (8.34)	18.00 (7.07)	43	0.288
Ethnicity/Race				
Caucasian	23.65 (8.82)	13.00 (0.00)	55	0.237
African American	27.50 (6.94)	23.00 (0.00)	15	0.542
Hispanic or Latino	24.86 (9.28)	-	7	-
Other	-	-	-	-

Note. The dash symbol (-) marks unproduced p-values due to low sample sizes of either the non-HAI patients, HAI patients, or both.
**N represents the Total for both HAI and Non-HAI patients for this specific Unit.

For people with smoking habits only (i.e. those with smoking habits but do not have obesity nor diabetes), an ANOVA reveals statistically significant differences in mean APACHE scores between those who have and do not have an HAI for some groups in each of the ICUs in Table 11. In the CVICU, male patients without an HAI were found to have a lower mean APACHE II score (20.43 ± 8.52) than male patients with an HAI (26.78 ± 7.40), being statistically different at $p = 0.033$. In contrast, the mean scores between female CVICU patients with and without an HAI do not have a statistically significant association ($p = 0.622$). In the MSICU, patients aged 50-59 have a statistically significant difference in mean APACHE II scores between those without and with an HAI (20.49 ± 7.78 vs. 30.67 ± 14.57) respectively at $p = 0.032$. In the NSICU, patients aged 40-49 without an HAI have a higher mean APACHE II score (19.91 ± 6.60) than those with an HAI (13.29 ± 3.40), being statistically significant at $p = 0.014$. Caucasian NSICU patients have a statistically significant difference in mean APACHE II scores between those without and with an HAI (20.84 ± 7.56 vs. 17.94 ± 7.94) respectively at $p = 0.047$. Thus, patients with only smoking habits (i.e. no other risk factors) were likely more at risk of contracting an HAI in CVICU and MSICU, but not at NSICU, which may be due to unobserved factors in the NSICU that are unaccounted for in the data such as quality of care and medical history of the patient.

Table 11

Severity of Illness as Measured by APACHE II across the ICUs, 2010-2014 by Demographics (Only Patients with Smoking Habits)

Unit	Mean APACHE Score (SD) No HAI	Mean APACHE Score (SD) with HAI	N**	P-value (ANOVA)
CVICU				
Gender				
Female	19.53 (6.21)	20.67 (7.14)	60	0.622
Male	20.43 (8.52)	26.78 (7.40)	111	0.033*
Age Group				
18-29	18.20 (6.01)	-	10	-
30-39	17.33 (5.91)	22.00 (0.00)	13	0.464
40-49	19.68 (9.17)	-	-	-
50-59	17.85 (7.00)	20.33 (9.45)	36	0.569
≥60	21.95 (7.90)	24.57 (7.78)	90	0.255
Ethnicity/Race				
Caucasian	20.95 (7.84)	22.64 (7.61)	91	0.457
African American	19.02 (7.12)	21.00 (4.24)	52	0.670
Hispanic or Latino	19.71 (9.19)	-	-	-
Other	21.50 (7.78)	34.00 (0.00)	4	0.151
MSICU				
Gender				
Female	20.55 (7.89)	20.00 (4.58)	230	0.878
Male	20.20 (7.90)	23.27 (9.16)	302	0.147
Age Group				
18-29	18.93 (7.45)	20.00 (0.00)	30	0.889
30-39	19.37 (7.07)	-	-	-
40-49	19.11 (6.79)	-	-	-
50-59	20.49 (7.78)	30.67 (14.57)	95	0.032*
≥60	20.81 (8.24)	21.06 (6.51)	312	0.906
Ethnicity/Race				
Caucasian	20.82 (7.97)	22.62 (9.00)	313	0.431
African American	19.51 (7.73)	24.50 (4.32)	140	0.119
Hispanic or Latino	20.32 (7.93)	8.00 (0.00)	74	0.127
Other	15.20 (2.05)	-	-	-
NSICU				
Gender				
Female	20.70 (8.00)	17.57 (6.61)	169	0.089
Male	21.29 (7.62)	18.19 (8.26)	151	0.129
Age Group				
18-29	19.55 (5.86)	20.00 (2.83)	22	0.917
30-39	22.24 (8.38)	13.00 (8.49)	27	0.146
40-49	19.91 (6.60)	13.29 (3.40)	41	0.014*
50-59	21.10 (7.81)	17.45 (7.63)	83	0.152
≥60	21.17 (8.28)	20.60 (7.81)	147	0.798
Ethnicity/Race				
Caucasian	20.84 (7.56)	17.94 (7.64)	237	0.047*
African American	22.31 (8.45)	17.00 (1.41)	51	0.384
Hispanic or Latino	19.56 (8.58)	16.33 (8.14)	30	0.541
Other	23.00 (0.00)	21.00 (0.00)	2	-

Note. *Statistically significant at $p \leq 0.05$.

The dash symbol (-) marks unproduced p-values due to low sample sizes of either the non-HAI patients, HAI patients, or both

**N represents the Total for both HAI and Non-HAI patients

For individuals with obesity only (i.e. those with obesity but do not have smoking habits nor diabetes) (Table 12), an ANOVA has revealed statistical significance in mean APACHE II scores for NSICU male patients: 24.31 ± 9.92 for male patients without an HAI and 12.83 ± 3.19 for male patients with an HAI ($p = 0.007$). Because many other demographic groups in each ICU did not have statistically significant associations with contracting an HAI, obesity by itself may act as a weak confounding factor.

Table 12

Severity of Illness as Measured by APACHE II across the ICUs, 2010-2014 by Demographics (Patients with only Obesity)

Unit	Mean APACHE Score (SD) No HAI	Mean APACHE Score (SD) with HAI	N**	P-value (ANOVA)
CVICU				
Gender				
Female	22.36 (8.60)	15.75 (10.75)	32	0.172
Male	23.74 (10.07)	20.50 (12.02)	36	0.664
Age Group				
18-29	26.00 (4.24)	-	2	-
30-39	22.71 (6.97	-	7	-
40-49	21.50 (7.73)	13.75 (10.44)	16	0.132
50-59	24.00 (12.11)	-	16	-
≥60	23.20 (9.45)	24.50 (6.36)	27	0.851
Ethnicity/Race				
Caucasian	23.00 (10.37)	18.40 (11.04)	38	0.365
African American	23.75 (8.70)	12.00 (0.00)	21	0.203
Hispanic or Latino	22.11 (7.69)	-	9	-
Other	-	-	0	-
MSICU				
Gender				
Female	24.02 (9.40)	24.89 (11.71)	130	0.792
Male	24.41 (10.12)	27.17 (9.70)	134	0.516
Age Group				
18-29	24.18 (10.11)	27.00 (4.24)	19	0.707
30-39	22.11 (9.32)	26.00 (11.31)	20	0.587
40-49	27.52 (8.38)	30.67 (6.66)	36	0.533
50-59	24.29 (9.81)	20.33 (18.82)	48	0.523
≥60	23.68 (10.02)	25.60 (10.95)	141	0.676
Ethnicity/Race				
Caucasian	23.29 (9.32)	26.60 (11.42)	143	0.288
African American	24.17 (10.15)	22.33 (13.20)	78	0.761
Hispanic or Latino	27.57 (10.55)	27.00 (4.24)	37	0.940
Other	26.00 (6.93)	-	6	-
NSICU				
Gender				
Female	22.56 (9.55)	20.00 (7.37)	78	0.467
Male	24.31 (9.92)	12.83 (3.19)	54	0.007*
Age Group				
18-29	19.43 (10.98)	-	7	-
30-39	22.31 (11.40)	17.00 (8.45)	17	0.407
40-49	24.67 (11.20)	19.00 (7.94)	12	0.443
50-59	23.38 (9.78)	10.00 (1.41)	28	0.069
≥60	23.65 (9.14)	18.40 (6.02)	68	0.213
Ethnicity/Race				
Caucasian	23.06 (9.54)	19.38 (7.71)	101	0.290
African American	24.88 (11.79)	15.25 (3.86)	21	0.129
Hispanic or Latino	22.25 (7.09)	10.50 (2.12)	10	0.057
Other	-	-	0	-

Note. *Statistically significant at $p \leq 0.05$.
The dash symbol (-) marks unproduced p-values due to low sample sizes of either the non-HAI patients, HAI patients, or both
**N represents the Total for both HAI and Non-HAI patients for this specific unit

For patients with both smoking habits and diabetes but do not have obesity (Table 13), only two groups are found to have statistically significant differences in mean APACHE II scores between those with and without an HAI: male MSICU patients (30.75 ± 11.15 with HAI vs. 19.71 ± 8.68 without HAI, $p = 0.015$) and Caucasian MSICU patients (28.71 ± 8. 71 with HAI vs. 18.97 ± 8.62 without HAI, $p = 0.005$). Because of the inconsistency in statistical significance across the ICUs for each of the demographic groups, there may exist unobserved aspects of the individual ICUs for which are not accounted in the data that could aid in explaining differences in statistical significance. Nonetheless, for what is provided, there is a noticeable indication that patients who both have diabetes and smoking habits (but do not have obesity) may be at more risk of contracting an HAI.

Table 13

Severity of Illness as Measured by APACHE II by ICU Type, 2010-2014 by Demographics (Patients with both Smoking Habits and Diabetes)

Unit	Mean APACHE Score (SD) No HAI	Mean APACHE Score (SD) with HAI	N**	P-value (ANOVA)
CVICU				
Gender				
Female	20.00 (7.53)	23.75 (4.99)	27	0.350
Male	20.32 (9.22)	19.13 (9.42)	42	0.743
Age Group				
18-29	22.17 (9.22)	-	6	-
30-39	22.00 (8.49)	17.00 (0.00)	3	0.715
40-49	19.00 (12.12)	28.00 (0.00)	4	0.586
50-59	19.46 (7.42)	13.00 (0.00)	14	0.418
≥60	20.12 (8.94)	21.11 (8.84)	42	0.770
Ethnicity/Race				
Caucasian	20.97 (9.15)	21.67 (9.12)	42	0.840
African American	20.00 (8.30)	13.00 (0.00)	16	0.428
Hispanic or Latino	18.38 (6.50)	17.00 (0.00)	9	0.848
Other	12.00 (0.00)	23.00 (0.00)	2	-
MSICU				
Gender				
Female	20.00 (9.07)	24.00 (6.04)	81	0.335
Male	19.71 (8.68)	30.75 (11.15)	118	0.015*
Age Group				
18-29	21.56 (8.46)	-	18	-
30-39	17.82 (8.17)	-	11	-
40-49	17.82 (8.09)	-	22	-
50-59	19.00 (7.68)	32.00 (0.00)	40	0.103
≥60	20.50 (9.50)	26.38 (9.20)	108	0.095
Ethnicity/Race				
Caucasian	18.97 (8.62)	28.71 (8.71)	97	0.005*
African American	21.69 (8.93)	21.00 (8.49)	64	0.914
Hispanic or Latino	18.29 (8.72)	-	35	-
Other	25.00 (9.54)	-	3	-
NSICU				
Gender				
Female	19.31 (7.79)	18.00 (8.49)	54	0.817
Male	21.17 (7.71)	16.60 (3.21)	53	0.198
Age Group				
18-29	17.50 (13.44)	-	2	-
30-39	20.83 (8.30)	12.00 (0.00)	7	0.370
40-49	20.74 (8.03)	-	19	-
50-59	22.48 (8.47)	17.67 (6.03)	24	0.357
≥60	19.12 (7.22)	18.00 (2.65)	55	0.793
Ethnicity/Race				
Caucasian	20.41 (7.78)	15.80 (3.83)	73	0.195
African American	17.63 (6.61)	16.00 (0.00)	17	0.815
Hispanic or Latino	21.88 (8.59)	-	16	-
Other	24.00 (0.00)	-	1	-

Note. *Statistically significant at $p \leq 0.05$.
The dash symbol (-) marks unproduced p-values due to low sample sizes of either the non-HAI patients, HAI patients, or both.
**N represents the Total for both HAI and Non-HAI patients for this specific unit.

For people with both obesity and diabetes but do not have smoking habits (Table 14), an ANOVA shows that there exists statistical significant differences in mean APACHE II scores in CVICU and MSICU patients. In the CVICU, patients aged 50-59 without an HAI have a lower mean score (18.10 ± 3.81) than those with an HAI (28.50 ± 12.02), being statistically significant at $p = 0.028$. African American CVICU patients have a higher mean APACHE II score (37.00) than the same patients without an HAI (19.30 ± 5.60), being statistically significant at $p = 0.015$. In the MSICU, patients aged 50-59 have a higher mean APACHE II score (36.00) than the same patients without an HAI (20.70 ± 6.46), being statistically significant at $p = 0.030$. Hispanic/Latino MSICU patients with an HAI possess a higher mean score of 36.00 than those without an HAI (18.79 ± 3.08) ($p < 0.001$). Although low sample sizes for patients with an HAI in each of the ICUs are a major possible factor in producing statistically insignificance for many of the subpopulation groups, statistical significance in the two ICUs may indicate that the interaction of obesity and diabetes may subject patients to be more at risk of contracting an HAI. Prior research has found that patients with obesity and diabetes are more vulnerable to HAIs (Masud & Vykoukal, 2011).

Table 14

Severity of Illness as Measured by APACHE II by ICU Type, 2010-2014 by Demographics (Patients with both Obesity and Diabetes)

Unit	Mean APACHE Score (SD) No HAI	Mean APACHE Score (SD) with HAI	N**	P-value (ANOVA)
CVICU				
Gender				
Female	20.40 (7.41)	27.83 (10.07)	21	0.076
Male	22.31 (6.68)	25.50 (10.61)	28	0.532
Age Group	.			
18-29	22.00 (8.29)	-	4	-
30-39	26.33 (11.55)	-	3	-
40-49	20.00 (0.00)	-	1	-
50-59	18.10 (3.81)	28.50 (12.02)	12	0.028*
≥60	22.52 (7.08)	26.83 (9.79)	29	0.230
Ethnicity/Race				
Caucasian	22.38 (7.10)	24.00 (8.65)	30	0.634
African American	19.30 (5.60)	37.00 (0.00)	11	0.015*
Hispanic or Latino	24.20 (8.70)	37.00 (0.00)	6	0.250
Other	17.50 (6.36)	-	2	-
MSICU				
Gender				
Female	20.66 (5.59)	21.29 (9.62)	71	0.795
Male	21.40 (6.26)	22.00 (0.00)	74	0.924
Age Group				
18-29	23.14 (6.89)	-	7	-
30-39	16.60 (4.93)	26.00 (0.00)	6	0.157
40-49	23.08 (6.17)	-	13	-
50-59	20.70 (6.46)	36.00 (0.00)	24	0.030*
≥60	20.93 (5.70)	18.17 (7.19)	95	0.261
Ethnicity/Race				
Caucasian	21.77 (6.51)	22.00 (4.00)	89	0.951
African American	20.57 (5.48)	17.25 (8.96)	34	0.300
Hispanic or Latino	18.79 (3.08)	36.00 (0.00)	20	<0.001*
Other	19.00 (1.41)	-	2	-
NSICU				
Gender				
Female	20.63 (6.17)	20.00 (0.00)	31	0.920
Male	20.73 (6.52)	-	30	-
Age Group				
18-29	27.50 (7.78)	-	2	-
30-39	19.25 (9.46)	-	4	-
40-49	19.69 (4.59)	20.00 (0.00)	14	0.950
50-59	22.67 (7.09)	-	15	-
≥60	19.73 (5.85)	-	26	-
Ethnicity/Race				
Caucasian	20.32 (6.04)	-	41	-
African American	21.80 (6.86)	20.00 (0.00)	11	0.808
Hispanic or Latino	20.57 (6.16)	-	7	-
Other	23.00 (14.14)	-	2	-

Note. *Statistically significant at $p \leq 0.05$.
The dash symbol (-) marks unproduced p-values due to low sample sizes of either the non-HAI patients, HAI patients, or both.
**N represents the Total for both HAI and Non-HAI patients for this specific unit.

For individuals with both obesity and smoking habits (i.e. those who do not have diabetes) (Table 15), the results of an ANOVA have shown statistical significant differences in mean APACHE II scores only for three groups, all within the CVICU: male patients, patients aged 40-49, and African American patients. Male CVICU patients with an HAI have a higher mean APACHE II score (29.20 ± 11.80) than those without an HAI (17.48 ± 7.64), with the difference being statistically different at $p = 0.003$. CVICU patients aged 40-49 with an HAI also have a higher mean score (27.75 ± 11.00) than those without an HAI (15.56 ± 6.04) at $p = 0.023$ (Table 16). Finally, African American CVICU patients with an HAI possess a greater mean score of 39.00 than those without an HAI at 18.94 ± 8.65 ($p = 0.038$). As a result, CVICU patients with both obesity and smoking habits may be at more risk of contracting an HAI. According to Karlsson & Beck, (2010), obesity can cause impairment of the immune system which can affect pulmonary functions making patients more susceptible to infections.

Table 15

Severity of Illness as Measured by APACHE II by ICU Type, 2010-2014 by Demographics (Patients with both Obesity and Smoking Habits)

Unit	Mean APACHE Score (SD) No HAI	Mean APACHE Score (SD) with HAI	N**	P-value (ANOVA)
CVICU				
Gender				
Female	21.20 (7.28)	21.13 (10.63)	38	0.981
Male	17.48 (7.64)	29.20 (11.80)	51	0.003*
Age Group				
18-29	23.40 (10.16)	-	5	-
30-39	22.50 (9.59)	9.50 (0.71)	8	0.119
40-49	15.56 (6.04)	27.75 (11.00)	13	0.023*
50-59	17.46 (6.86)	25.33 (10.41)	16	0.122
≥60	19.09 (7.53)	27.25 (12.18)	47	0.055
Ethnicity/Race				
Caucasian	19.45 (7.31)	22.43 (12.41)	56	0.363
African American	18.94 (8.65)	39.00 (0.00)	19	0.038*
Hispanic or Latino	16.13 (8.43)	21.25 (9.18)	12	0.357
Other	17.00 (0.00)	34.00 (0.00)	2	-
MSICU				
Gender				
Female	18.50 (6.94)	20.33 (8.48)	124	0.533
Male	18.68 (7.72)	20.33 (7.65)	129	0.537
Age Group				
18-29	21.00 (6.59)	-	19	-
30-39	20.54 (7.77)	-	13	-
40-49	22.22 (7.20)	26.50 (6.36)	29	0.423
50-59	16.77 (7.13)	17.00 (9.56)	64	0.951
≥60	18.09 (7.21)	20.44 (7.00)	128	0.346
Ethnicity/Race				
Caucasian	18.55 (7.39)	19.27 (8.57)	120	0.761
African American	18.71 (7.72)	23.67 (4.73)	90	0.274
Hispanic or Latino	18.45 (6.58)	22.00 (0.00)	41	0.597
Other	18.50 (4.95)	-	2	-
NSICU				
Gender				
Female	18.13 (7.15)	21.40 (4.39)	58	0.322
Male	19.00 (7.47)	14.00 (2.83)	58	0.353
Age Group				
18-29	18.33 (8.71)	-	6	-
30-39	17.14 (7.99)	12.00 (0.00)	8	0.569
40-49	16.50 (5.81)	-	14	-
50-59	19.89 (7.09)	20.00 (3.56)	32	0.977
≥60	18.65 (7.61)	21.50 (7.78)	56	0.605
Ethnicity/Race				
Caucasian	18.65 (7.50)	20.25 (3.10)	82	0.674
African American	19.74 (7.61)	15.00 (0.00)	20	0.552
Hispanic or Latino	16.25 (5.08)	19.50 (10.61)	14	0.474
Other	-	-	0	-

Note. *Statistically significant at $p \leq 0.05$.
The dash symbol (-) marks unproduced p-values due to low sample sizes of either the non-HAI patients, HAI patients, or both.
**N represents the Total for both HAI and Non-HAI patients for this specific unit.

To summarize, the possible confounders are smoking habits (Table 11, 13, and 15), obesity (Table 12, 14, and 15), and an interaction of one of the previous two risk factors with diabetes (Table 13, 14). Diabetes seems to only confound the relationships when patients also have smoking habits or obesity (Tables 13, 14). Diabetes is one of the largest emerging threats to health care due to the associated reduced response of T cells, neutrophil function and lack of humoral immunity which causes increased susceptibility to infections (Casqueiro, Casqueiro & Alves, 2012). Notably in this study, diabetes by itself has shown to be protective against contracting an HAI for African American CVICU and MSICU patients aged 50-59 (Table 10). The implications are that smoking habits and obesity may subject patients to be more at risk of contracting an HAI (Tables 11-15), while diabetes can produce the same effect only if the patient also possesses another risk factor (Tables 13-15). Risk factors such as diabetes, obesity and smoking are predisposing factors which may lead to a decreased host defense (Masud & Vykoukal, 2011).

Research Question 3 and Hypothesis

RQ#3: What is the association between age, gender, race, ethnicity and HAI status in three different adult ICUs within an academic medical facility?

$H_0$3: There is no association between age, gender, race and ethnicity from the device associated HAIs identified in the three different adult ICUs within an academic medical facility?

$H_1$3: There is an association between age, gender, race and ethnicity from the device associated HAIs identified in the three different adult ICUs within an academic medical facility?

The data analysis for this research question was comprised of the entire population who entered into any of the three ICUs during 2010-2014. The total population was looked at to ascertain population diversity. The data analysis for this research question narrowed down the

involved specific demographics which were abstracted to determine particular associations in obtaining an HAI from one of three adult ICUs within an academic medical center. The mean age for the 319 patients who had HAI status was 59.2 (*SD*=16.2), while those without an HAI had a mean age of 58.5 (SD=14.4, n = 3,896). The mean age differences were not statistically significant p = 0.4508 by t-test. Most patients who acquired infections were in the ≥60 age group (n=172) (Table 17). Majority of the infections were CAUTI with 204 infections of the 319 infections. More females had CAUTI; however, more males had CLABSI (Table 18). There was statistical significance found between those with no infections and those with infections within race and ethnicity in CVICU (X^2=18.2, df=3, p<0.001) (Table 16). In MSICU, it was found that there was a statistical significance between those who acquired an HAI and those who did not in males and females (X^2=14.8, df=1, p<0.001) (Table 16).

The relationships between risk factors and patients contracting an HAI, CVICU patients who smoke tend to contract an HAI (p = 0.023), with most having CAUTI than other HAIs (Table 21). Across the ICUs, correlation was statistically significant association between smoking habits and whether the patient has HAI in the CVICU (p = 0.023), while diabetes was associated with HAI in the MSICU (p = 0.009), being weakly positive (r = 0.054) and the correlation is weakly negative at -0.087 and statistically significant at p = 0.003 in the NSICU (Table 21). Aggregating all the ICUs does not show statistically significant associations ($p_{diabetes}$ = 0.594, $p_{obesity}$ = 0.223, $p_{smoking}$ = 0.191) (Table 22).

Table 16

Demographic and Risk Factors of Patients with No HAI and with HAI in Three Adult ICUs

Demographic and Risk Factors	CVICU[††]		MSICU[†*]		NSICU[***]	
	No HAI	HAI	No HAI	HAI	No HAI	HAI
Sex -- n (%)[†*]						
Male	392 (60.9)	45 (54.9)	1210 (55.0)	49 (37.7)	499 (47.5)	41 (38.3)
Female	252 (39.1)	37 (45.1)	990 (45.0)	81 (62.3)	551 (52.5)	66 (61.7)
Age -- n (%)						
18-29	43 (6.7)	0 (0.0)	134 (6.1)	9 (6.9)	67 (6.4)	5 (4.7)
30-39	45 (7.0)	6 (7.3)	151 (6.9)	6 (4.6)	86 (8.2)	11 (10.3)
40-49	77 (12.0)	11 (13.4)	234 (10.6)	9 (6.9)	137 (13.1)	19 (17.8)
50-59	142 (22.1)	14 (17.1)	442 (20.1)	25 (19.2)	253 (24.1)	32 (29.9)
≥60	337 (52.43)	51 (62.2)	1239 (56.3)	81 (62.3)	507 (48.3)	40 (37.4)
Race/Ethnicity -- n (%)[††]						
African American	182 (28.3)	12 (14.6)	640 (29.1)	36 (27.7)	179 (17.1)	17 (15.9)
Caucasian	365 (56.7)	56 (68.3)	1209 (55.0)	80 (61.5)	763 (72.7)	73 (68.2)
Hispanic or Latino	90 (14.0)	9 (11.0)	325 (14.7)	11 (8.5)	102 (9.7)	14 (13.1)
Other[†]	7 (1.1)	5 (6.1)	27 (1.2)	3 (2.3)	6 (0.6)	3 (2.8)
Risk Factors						
Obesity	208 (85.6)	35 (14.4)	713 (93.2)	52 (6.8)	325 (92.6)	26 (7.4)
Diabetes	180 (85.3)	31 (14.7)	553 (92.3)	46 (7.7)	273 (95.1)	14 (4.9)
Smoking	315 (86.1)	51 (13.9)	1029 (94.7)	58 (5.3)	530 (90.6)	55 (9.4)

Note. [†] Other category included American Indian/Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander

[††] There was statistical significance found between those with no infections and those with infections within race and ethnicity in CVICU (X^2=18.2, df=3, p<0.001). CVICU HAI vs. No HAI by gender is not statistically significantly different.

[†*] Statistical significance was also found between those with no infections and those with infections within gender in MSICU (X^2=14.8, df=1, p<0.001). Males had less HAIs than females.

[***]NSICU HAI vs. No HAI by gender is not statistically significant.

**Male aggregated total = 2236 (No HAI = 2101; HAI = 135)

**Female aggregated total = 1977 (No HAI = 1793; HAI = 184)

Table 17

Associations between Age and HAI Type

UNIT	HAI Type	Age					
		18-29	**30-39**	**40-49**	**50-59**	**60+**	**Total**
CVICU	CAUTI	0	3	3	7	32	45
$X^2 = 8.293$	CLABSI	0	2	7	4	11	24
$p = 0.217$	VAP	0	1	1	3	8	13
	Total		**6**	**11**	**14**	**51**	**82**
MSICU†	CAUTI	6	3	7	12	59	87
$X^2 = 7.382$	CLABSI	2	2	1	10	15	30
$p = 0.496$	VAP	1	1	1	3	7	13
	Total	**9**	**6**	**9**	**25**	**81**	**130**
NSICU	CAUTI	5	5	14	23	25	72
$X^2 = 7.466$	CLABSI	0	1	2	2	2	7
$p = 0.487$	VAP	0	5	3	7	13	28
	Total	**5**	**11**	**19**	**32**	**40**	**107**

Note. †Using Stata, Chi-square test shows statistical significance when controlling for sex (MSICU female patients: $p = 0.023$). The categorical age distribution across HAI patients is similar to that of the Non-HAI patients, there is a gradient such that with each increase in age category there was an observed increase in the proportion of patients within that category. HAIs increase as age increases.

Across the ICUs in Table 17, none of the associations between age and HAI type are statistically significant: the test for CVICU has a *p*-value of 0.217 ($X^2 = 8.293$, n = 82), MSICU has $p = 0.496$ ($X^2 = 7.382$, n = 130), and NSICU has $p = 0.487$ ($X^2 = 7.466$, n = 107). Across the ICUs, older patients (50-59 and 60+) with an HAI outnumbered all other age groups in every type of HAI except in the CVICU for patients with CLABSI, in which the number of those aged 40-49 (7) were greater than the number of those aged 50-59 (4). Notably for MSICU patients, controlling for sex results were statistically significant (MSICU female patients: $p = 0.023$), indicating that older female patients may be more likely to contract an HAI, especially a CAUTI,

than other patients. As such, the sex of the patient may matter more as a confounding factor than the age group.

Table 18

Associations between Sex and HAI Type

		Sex		
UNIT	**HAI Type**	**Male**	**Female**	**Total**
CVICU	CLABSI	21	3	24
X^2 = 19.831	CAUTI	15	30	45
p <0.001*	VAP	9	4	13
	Total	**45**	**37**	**82**
MSICU	CLABSI	18	12	30
X^2 = 8.618	CAUTI	26	61	87
p = 0.013*	VAP	5	8	13
	Total	**49**	**81**	**130**
NSICU	CLABSI	3	4	7
X^2 = 2.435	CAUTI	24	48	72
p = 0.296	VAP	14	14	28
	Total	**41**	**66**	**107**

Comparing the ICUs in Table 18, CVICU and MSICU have shown statistical significance (p_{CVICU} <0.0001 and p_{MSICU} = 0.013), while NSICU has not (p_{NSICU} = 0.296). In the CVICU, male patients outnumber female patients for CLABSI 7:1, female patients outnumber male patients 2:1 for CAUTI, and male patients again outnumber female patients for VAP 9:4. Overall, nearly 55% of patients with an HAI were male in the CVICU, with the statistical significance suggesting that male patients in the CVICU were more likely to contract an HAI. In the MSICU, female patients outnumber male patients for every HAI type except CLABSI: male patients outnumber female patients 3:2 for CLABSI, while female patients outnumber male

patients 61:26 for CAUTI and 8:5 for VAP. Approximately 58% of patients with any type of HAI were female, with the statistical significance implying that female patients in the MSICU were more likely to get an HAI. In the NSICU, female patients again outnumber male patients for all HAI types except VAP, which they tie: female patients outnumber male patients 4:3 for CLABSI and 2:1 in CAUTI, while the number of patients with VAP was the same for both sexes (i.e. 1:1). Statistical insignificance suggests that neither sex were more likely to contract an HAI.

Table 19

Associations between Ethnicity/Race and HAI Type

		Ethnicity/Race				
UNIT	**HAI Type**	**Caucasian**	**Hispanic/Latino**	**African American**	**Other**	**Total**
CVICU†	CLABSI	17	5	1	1	24
X^2 = 9.876	CAUTI	29	2	10	4	45
p = 0.130	VAP	10	2	1	0	13
	Total	**56**	**9**	**12**	**5**	**82**
MSICU	CLABSI	21	3	6	0	30
X^2 = 7.624	CAUTI	50	6	29	2	87
p = 0.267	VAP	9	2	1	1	13
	Total	**80**	**11**	**36**	**3**	**130**
NSICU††	CLABSI	3	1	3	0	7
X^2 = 6.124	CAUTI	48	10	12	2	72
p = 0.409	VAP	22	3	2	1	28
	Total	**73**	**14**	**17**	**3**	**107**

Note. † Chi-square test shows statistically significance when controlling for age and gender (female CVICU patients aged 50-59: p = 0.017; female CVICU patients aged 60+: p = 0.019).
†† Chi-square test shows statistically significance when controlling for age and gender (female NSICU patients aged 50-59: p = 0.021).

Across the ICUs in Table 19, none of the associations between ethnicity/race and HAI type are statistically significant: the test for CVICU has a *p*-value of 0.130 ($X^2 = 9.876$, sample size = 82), MSICU has $p = 0.267$ ($X^2 = 7.624$, sample size = 130), and NSICU has $p = 0.409$ ($X^2 = 6.124$, sample size = 107). However, when controlling for age and gender, female CVICU aged 50-59 (p = 0.017) and aged 60+ (p = 0.019) were statistically significant across the ethnic groups in relation to HAI types. Similarly, female NSICU patients aged 50-59 were found to be statistically significant (p = 0.021). In the CVICU, nearly 70% of patients with an HAI were Caucasian, while approximately 15% of patients with an HAI were African American—the remaining patient populations were Hispanic/Latino and other groups. For each HAI type, the number of Caucasians was greater than the number of the African Americans, Hispanic/Latinos, and other ethnicities/races. In the MSICU, the percentages were similar: over 60% of patients with an HAI were Caucasian, while almost 30% were African American and 10% were Hispanic/Latino and other ethnic groups. In the NSICU, close to 70% of patients with HAI were Caucasian, 16% were African American, and the rest were Hispanic/Latino and other ethnicities/races. Thus, race may not have a strict association with a type of HAI, but it may be confounded by age and gender.

Table 20

Associations between Risk Factors and HAI Types

		Risk Factors					
		Diabetes		**Obesity**		**Smoking†**	
UNIT	**HAI Type**	**N**	**Y**	**N**	**Y**	**N**	**Y**
CVICU	CLABSI	17	7	14	10	14	10
	CAUTI	27	18	25	20	16	29
	VAP	7	6	8	5	1	12
		$X^2 = 1.239$		$X^2 = 0.162$		$X^2 = 9.412$	
		$p = 0.538$		$p = 0.922$		$p = 0.009$*	
MSICU	CLABSI	19	11	14	16	14	16
	CAUTI	56	31	57	30	51	36
	VAP	9	4	7	6	7	6
		$X^2 = 0.145$		$X^2 = 3.531$		$X^2 = 1.304$	
		$p = 0.930$		$p = 0.171$		$p = 0.521$	
NSICU	CLABSI	6	1	6	1	3	4
	CAUTI	62	10	53	19	37	35
	VAP	25	3	22	6	12	16
		$X^2 = 0.188$		$X^2 = 0.678$		$X^2 = 0.686$	
		$p = 0.910$		$p = 0.713$		$p = 0.710$	

Note. * Statistically significant at $p \leq 0.05$

†Smoking is not statistically significant when controlling for age for each ICU. Chi-square test shows results to be statistically significant when controlling for gender (CVICU Males: $p = 0.032$) or ethnicity (CVICU Caucasians: $p = 0.042$), but not for both simultaneously.

All through the ICUs in Table 20, CVICU patients who smoke tend to contract an HAI ($p = 0.009$), with most having CAUTI than other HAIs. The association is not significant for patients who smoke when controlling for age for each ICU; however, when controlling for either sex or ethnicity but not both simultaneously, the *p*-values are statistically significant (CVICU males: $p = 0.032$ vs. CVICU Caucasians: $p = 0.042$). Changes in statistical significance with respect to different combinations of demographic variables imply that sex and ethnicity/race are confounding factors in those with smoking habits who contract an HAI in the CVICU. Thus, sex

and ethnicity/race behave as catalyst variables for those who smoke and contract an HAI. Across the ICUs in Table 21, association was statistically significant association between smoking habits and whether the patient has HAI in the CVICU ($p = 0.024$). Diabetes was associated with HAI in the MSICU ($p = 0.009$), being weakly positive (r = 0.054). For NSICU, the correlation is weakly negative at -0.087 and statistically significant at $p = 0.003$. In Table 22, the distribution between any HAI type and whether a patient possesses a risk factor on an aggregated basis is statistically similar ($p_{diabetes} = 0.594$, $p_{obesity} = 0.223$, and $p_{smoking} = 0.191$), indicating that the ICU-specific level of analysis reveals more significant associations than aggregation (Table 22).

Table 21

Risk Factors of Patients Admitted to Each ICU

UNIT	HAI	Diabetes**		Obesity		Smoking	
		N	Y	N	Y	N	Y
CVICU	NO	464	180	436	208	329	315
	YES	51	31	47	35	31	51
	chi-square	X^2=3.426, p=0.064		X^2=3.523, p=0.061		X^2=5.133, p=0.023*	
MSICU**	NO	1647	553	1487	713	1172	1029
	YES	84	46	78	52	72	58
	chi-square	X^2=6.750, p=0.009*		X^2=3.207, p=0.073		X^2=0.230, p=0.632	
NSICU**	NO	777	273	725	325	520	530
	YES	93	14	81	26	52	55
	chi-square	X^2=8.685, p=0.003*		X^2=2.034, p=0.154		X^2=0.033**, p=0.855	

Note. *Smoking was correlated with acquiring a device-associated infection in CVICU (r = 0.085, $p = 0.023$). **In MSICU, Pearson correlation between HAI and diabetes is weakly positive at 0.054, but statistically significant ($p = 0.009$). Thus, MSICU patients with diabetes have a weak association with acquiring a type of HAI. For NSICU, the correlation is weakly negative at -0.087, being statistically significant ($p = 0.003$).

Table 22

Risk-Factors of Patients with Device-Associated Infections and Patients with No Infections

HAI	Diabetes		Obesity		Smoking	
	N	**Y**	**N**	**Y**	**N**	**Y**
CLABSI	42	19	34	27	31	30
CAUTI	145	59	135	69	104	100
VAP	41	13	37	17	20	34
No Infection	2888	1006	2648	1246	2020	1874
Chi-square	X^2=1.900, p=0.594		X^2=4.387, p=0.223		X^2=4.749, p=0.191	

Note. No statistically significant correlation found between comorbidities and device-associated infections.

Research Question 4 and Hypothesis

RQ#4: Are there significant differences in the types of microorganisms (e.g. genus, species, and susceptibility according to the Clinical and Laboratory Standards Institute (Patel et al., 2015) which are associated with device-related HAIs in three adult ICUs within an academic medical facility?

$H_0$4: There are no significant differences in the types of microorganisms (e.g. genus, species, and susceptibility according to the Clinical and Laboratory Standards Institute (Patel et al., 2015) associated with device-related HAIs in three adult ICUs within an academic medical facility.

$H_1$4: There are significant differences in the types of microorganisms (e.g. genus, species susceptibility according to the Clinical and Laboratory Standards Institute (Patel et al., 2015) which are associated with device-related HAIs in three adult ICUs within an academic medical facility.

It was found from Chi-square analysis that the pattern of microbes was dissimilar for the three HAIs considered, 83% of yeast infections were associated with CAUTI (X^2=56.759, p<0.001) (Table 23). Additionally, microorganism was significantly associated with ICU location (X^2=28.536, p<0.001) (Table 24). The microorganisms contributing to CLABSI and CAUTI are listed in Tables 26 and 27, respectively. It was found that the majority of the CLABSIs were caused by gram-positive bacteria, while CAUTIs were predominantly gram-negative bacteria, and the majority of VAPs identified were clinically defined without bacterial infections (see Appendix B for Pneumonia Flow Diagram).

The number of multidrug resistant microorganisms identified in all three ICUs was thirty seven or 13% of the organisms identified (Figure 7). The distribution of yeast was significantly lower in both males and females in NSICU. The distribution of the microorganisms was statistically dissimilar with female patients in the three ICUs (X^2 = 25.653, p < 0.001), while the distribution with respect to males was similar (X^2 = 6.159, p = 0.188) (Table 25).

Table 23

Distribution of Microorganisms and Device-Associated Infections

Microorganism[2]	Device-Associated Infection			Total
	CAUTI	CLABSI	VAP	
Gram positive cocci	21	31	8	60
Gram negative rods	125	18	18	161
Yeast	58	12	0	70
Total	204	61	26	291[1]

Note. [1]Some Ventilator Associated Pneumonias are clinically defined
[2]Microorganism was found to be associated with device-associated infections (X^2=56.759, p<0.001)

Table 24

Distribution of Device-Related Bacterial Infections Across the Three Adult ICUs

Microorganism[2]	ICU			Total
	CVICU	MSICU	NSICU	
Gram positive cocci	17	25	18	60
Gram negative rods	32	58	71	161
Yeast	24	40	6	70
Total	73	123	95	291[1]

Note. [1]Total excludes clinically defined Ventilator Associated Pneumonias (VAPs)
[2] Microorganism was found to be associated with type of intensive care units (X^2=28.536, p<0.001)

Table 25

ICU-specific Gender Breakdown of Various Microbes

		ICU Type		
Gender	Microorganism	CVICU	MSICU	NSICU
Female†	GPC	4	14	9
	GNR	16	35	46
	YST	14	28	2
Male	GPC	13	11	9
	GNR	16	23	25
	YST	10	12	4

Note. † Microorganism was significant in females between the three ICUs (X^2=25.653, p < 0.001) but not for males (X^2 = 6.159, p = 0.188). For Males & Females when considered together: (X^2 = 28.536, p < 0.001).

Table 26

Microorganisms Contributing to CLABSI

CLABSI Organisms		
Gram-negative rods	Acinetobacter baumanni	2
	Escherichia coli	4
	Enterobacter cloacae	1
	Klebsiella pneumonia	4
	Pseudomonas aeruginosa	4
	Serratia marcescens	1
	Stenotrophomonas maltophilia	2
Gram-positive cocci	Enterococcus faecalis	7
	Enterococcus faecium	1
	Methicillin-resistant Staphylococcus aureus	1
	Staphylococcus aureus	1
	Staphylococcus epidermidis	7
	Vancomycin-resistant Enterococcus	13
	Streptococcus milleri	1
Yeast	Candida species	12
Total		61

Table 27

Microorganisms Contributing to CAUTI

CAUTI Organisms		
Gram-negative rods	Citrobacter amalonaticus	1
	Escherichia coli	62
	Enterobacter aerogenes	3
	Enterobacter cloacae	2
	Klebsiella pneumonia	25
	Morganella morganii	2
	Proteus mirabilis	4
	Pseudomonas aeruginosa	25
	Stenotrophonas maltophilia	1
Gram-positive cocci	Enterococcus faecalis	15
	Vancomycin-resistant Enterococcus	6
Yeast		58
Total		204

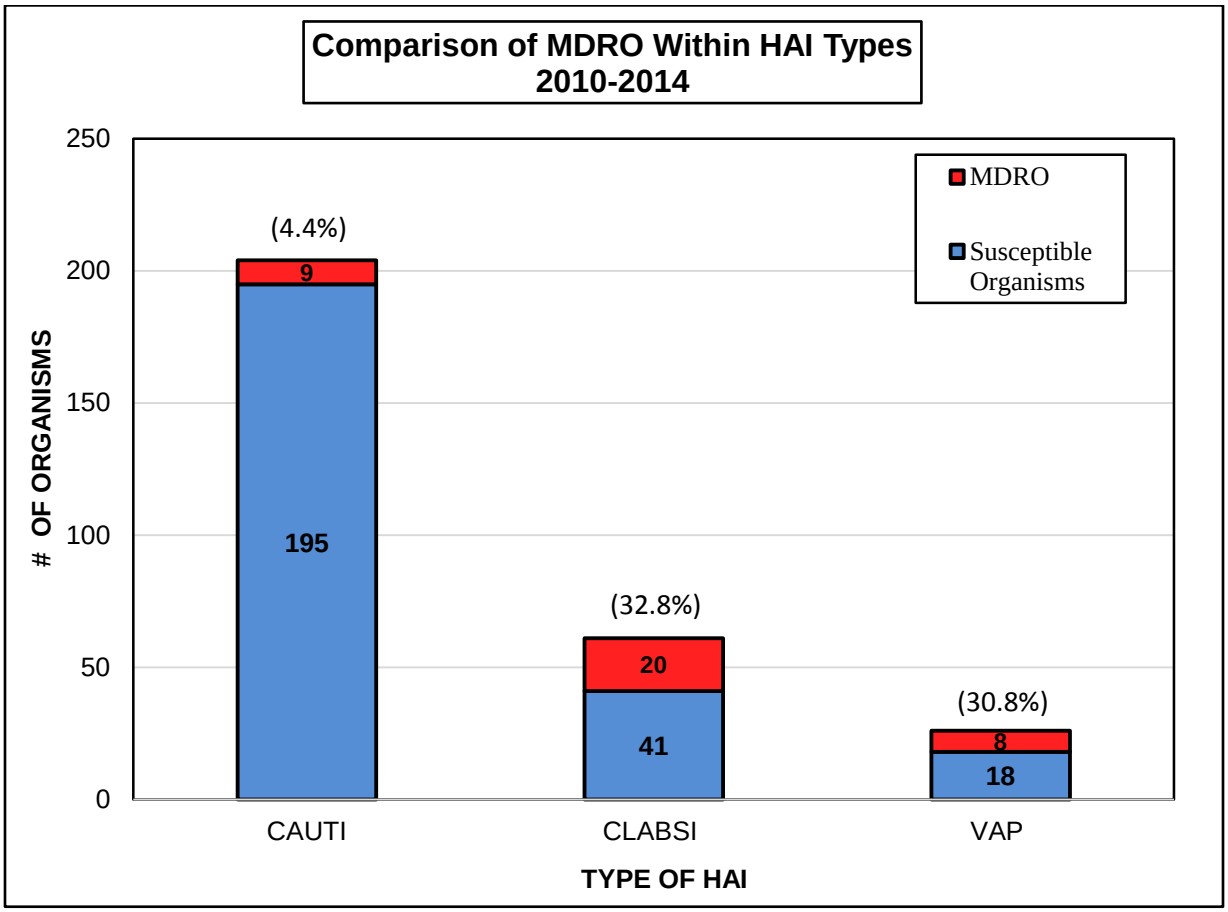


Figure 7. Multidrug resistant organisms compared to susceptible organisms. See Appendix F for additional MDRO information.

Summary

Chapter 4 provided the results overview of analyzed data for this research study. Majority of patients in the study from 2010-2014 were admitted to the MSICU (55.3%), Caucasians (60.4%), males (53.1%), and 60 years or older (53.6%) (Table 3). Those who acquired device-associated infections while hospitalized were primarily Caucasians (65.5%), females (57.7%), 60 years or older (53.9%), and were in MSICU (40.8%) (Table 3). The majority of the device-associated infections within the 5-year study period in the academic medical center were CAUTI (63.9%). It was found that there was no statistically significant difference in incidence rates of any device-related nosocomial infections between the three ICUs

between 2010 and 2014 (Table 4). There was no significant statistical difference in CLABSI and VAP SIR of device-related nosocomial infections between the three ICUs (Table 5). However, there was a statistically significant difference in CAUTI SIR ($p = 0.027$) (Table 5). The difference was found in NSICU (Table 5). The study also analyzed the association between utilization of devices and infections rates, and no significant correlation was found (Table 6). Furthermore, there was no significant difference found in mean severity of illness scores (measured by the APACHE II) across the ICUs (Table 7). However, there was a significant difference in mean severity of illness scores of patients within the three ICUs, specifically in NSICU (Table 7). Significant difference of APACHE II scores was based on Bonferroni post-hoc analysis in NSICU ($p < 0.001$) (Table 8). After analyzing risk associations (Tables 11-15), the difference in the mean APACHE II scores, between those who acquired an HAI and those patients who did not acquire an HAI among several demographic groups has revealed the possible confounders to be smoking habits (Table 11, 13 and 15), obesity (Table 12, 14, and 15), and an interaction of one of the previous two risk factors with diabetes (Table 13, 14) between those with and without an HAI. Correlation was statistically significant between diabetes and acquiring a device-associated infection in MSICU ($r = 0.054$, $p = 0.009$) and NSICU ($r = -0.087$, $p = 0.003$) (Table 21). Smoking was correlated with acquiring a device-associated infection in CVICU ($r = 0.085$, $p = 0.023$) (Table 21). In MSICU, Pearson correlation between HAI and diabetes is weakly positive at 0.054, but statistically significant (0.009) (Table 21). Thus, MSICU patients with diabetes have a weak association with acquiring a type of HAI. For NSICU, the correlation is weakly negative at -0.087, being statistically significant (0.003).

Chi-square analysis found some significant differences between demographic characteristics and types of infections, as well as between types of organisms and types of

infections. The significant and non-significant findings of this research will be discussed in Chapter 5 and will include recommendations for future research and implications for social changes concerning healthcare.

Chapter 5: Discussion

Introduction

The purpose of the this study was to evaluate the characteristics and trends of device-associated nosocomial infections (CLABSI, CAUTI, VAP) from 2010-2014 in three ICUs of a major teaching medical center. Guidelines from the NHSN served as the definitions for inclusion criteria for the study for device-associated infections. The research study was a quantitative analysis of secondary data abstracted from the electronic medical records of an academic medical facility in the state of Texas.

Selected medical records of patients admitted to the three ICUs (cardiovascular, medical-surgical, and neurosurgical) within two hospitals of an academic medical facility between 2010 and 2014 were obtained from their department of informatics. Cases were defined as patients who developed a device-associated infection from either a central line, Foley catheter, or a ventilator while hospitalized greater than 2 calendar days. The majority of patients were Caucasian and older than 60 years of age; I found that female patients comprised 57.7% of all patients with an HAI ($p < 0.001$, Table 3). Differences in CLABSI, CAUTI, and VAP incidence rates within 5 years were not statistically significant across the ICUs (Table 4). The mean CAUTI SIR was different in NSICU within the 5-year study period compared to other ICUs ($p= 0.027$; Table 5). SIRs for other device-associated infections were not statistically significant (Table 5). Furthermore, device utilization rates were not found to be correlated with specific device infection rates. The mean severity of illness scores was significantly lower in the NSICU patients who developed a device-associated infection (Table 7). The mean severity of illness scores may be attributed to the fact that the NSICU patient population is primarily admitted with neuropathophysiology issues without concurrent renal, liver, or cardiopulmonary comorbidities.

Interpretation of Findings

Research Question 1

In Research Question 1, I examined differences in incidence rates associated with ICU device-related nosocomial infections. I found that MSICU had the highest CAUTI rate with a mean of 3.98 for the entire 5-year period between the three ICUs. CVICU had the highest incidence rate for CLABSI with a mean of 1.16 and a standardization infection ratio of 1.4 compared to the other two ICUs. The highest incidence rate for ventilator associated pneumonias was in the neurosurgical ICU with a mean of 4.67 (Table 4). I found that CVICU had the highest rate for use of ventilators and central lines (Figure 6). The highest usage of Foley catheters was observed in the neurosurgical ICU (Figure 3). The utilization findings were not correlated to infection rates (Table 6). However, with VAP cases, the neurosurgical ICU had a high rate during 2010 through 2012 and then leveled off the following 2 years (Figure 6). In findings for the three ICUs, I identified CVICU as having the lowest CAUTI rate (Figure 3). The neurosurgical ICU had the lowest CLABSI rate, which could be attributed to the lower rate of utilization of central lines (Figure 2). The findings revealed that neurosurgical ICU had the highest VAP rate (4.6; Figure 5) and standardized infection ratio (2.24; Table 5) while utilizing the lowest number of ventilator days as compared to the other two ICUs (Table 6). However, in this study, the neurosurgical ICU had a lower rate of CAUTI and CLABSI (CAUTI 3.9; CLABSI 0.6) as compared to the national pooled mean of other academic medical centers (CAUTI 5.3; CLABSI 0.9; See Figure 6, Appendix E; Dudeck et al., 2015). There was a significant difference in mean CAUTI SIR by unit location (p=0.027; Table 5). The significant difference based on Bonferroni post-hoc analysis within unit (p=0.046) for neurosurgical ICU (NSICU; Table 5). The ANOVA results revealed a statistically insignificant difference between

the CLABSI, CAUTI, and VAP rates between the three ICUs (Table 4: $p_{CLABSI} = 0.349$, $p_{CAUTI} = 0.187$, $p_{VAP} = 0.052$).

Research Question 2

In Research Question 2, I studied the association between the severity of illness (APACHE score) and CLABSI, CAUTI, and VAP for each of the three ICUs in an academic medical facility. The APACHE score is a severity of disease classification system that only looks at the first 24 hours after being admitted into the ICU. In this study, the difference in mean APACHE scores between the three types of device-associated infections was not statistically significant when aggregated (p=0.331; Table 8). When disaggregating by ICU, there were statistically significant differences ($p_{CAUTI} < 0.001$, $p_{CLABSI} = 0.048$, $p_{VAP} < 0.001$), showing that aggregation has masked significant associations (Table 8). The Bonferroni post-hoc analysis was used to help compare the groups and recognize differences between the groups. I found that patients admitted to NSICU who acquired a device-associated infection had a statistically lower mean APACHE II score based on Bonferroni post-hoc analysis (p <0.001) compared to those who were admitted to CVICU and MSICU (Table 7). In analyzing the ICUs individually, I found statistical significant differences in mean APACHE II scores between the specific ICU and patients contracting an HAI. For any type of HAI, there was a statistically significant difference in mean APACHE II scores ($p_{CVICU} = 0.004$, $p_{MSICU} < 0.001$, $p_{NSICU} < 0.001$; Table 7). Additionally, there were statistically significant differences in mean APACHE II scores between the units for all three HAI types ($p_{CAUTI} < 0.001$, $p_{CLABSI} = 0.048$, $p_{VAP} < 0.001$; Table 8).

I determined that patients in the three ICUs who had the highest APACHE score were more vulnerable in acquiring a VAP as compared to those who acquired a CAUTI and/or a CLABSI. When controlling for age and gender differences, the mean scores were statistically

significant when comparing between APACHE II scores and ICU units ($p < 0.001$). Comparisons of the three types of device associated infections with severity of illness ($p = 0.331$) illustrated no significant differences when controlling for age and gender ($p = 0.262$; Table 8).

Comparing the APACHE II means over several demographic groups by ICU with respect to different combinations of risk factors as shown in Tables 9 through Table 15 has revealed the possible confounders to be smoking habits (Table 11, 13, and 15), obesity (Table 12, 14, and 15), and an interaction of one of the previous two risk factors with diabetes (Table 13, 14) between those with and without an HAI. Smoking habits by itself may confound the relations between demographic groups and contracting an HAI (Table 11), as well as its interaction with the other risk factors (i.e., smoking habits and diabetes or obesity; Table 13 and 15). Diabetes seems to only confound the relationships when patients also have either smoking habits or obesity. Notably, diabetes by itself has shown to be protective against contracting an HAI for African American CVICU and MSICU patients aged 50-59 (Table 10).

Research Question 3

The third research question involved the association between age, gender, race, and ethnicity with regard to acquiring a HAI in three different adult ICUs within an academic medical facility. I found that most of the device-related nosocomial infections were attributed to patients who were over 60 years of age. The majority of the patient population was Caucasian for all three ICUs (Table 3), which did not aid in the determination of race and ethnicity being a factor for acquiring a device-associated infection. Chen et al. (2009) found that the most common nosocomial infection was CAUTI, and it was predominantly in the medical surgical ICU. Other scholars have shown that the most common nosocomial infections in ICUs were respiratory tract infections which were linked to mechanical ventilator pneumonias (Rosenthal et

al., 2012). In this study, I found that the most common infection was CAUTI followed by bloodstream infections, which were also identified in this study (Figure 5). The female gender had a higher occurrence for CAUTI, while the male gender represented the majority of the CLABSIs identified for all three ICUs (Table 18). Furthermore, I found MSICU as having the highest rate for CAUTI (4.1 per 1000 urinary catheter days), while CVICU had the highest rate of CLABSI (1.1 per 1000 central line days), and neurosurgical ICU had the highest rate for VAP (4.6 per 1000 mechanical ventilator days) (Figure 5).

For the chi-squared tests involving the associations of demographic traits and risk factors across the ICUs for each HAI type, there is a statistically significant association with an HAI and age for female MSICU patients (p = 0.023, Table 17); otherwise, no statistically significant association was found between age and HAI type. As such, the gender of the patient may matter more as a confounding factor than the age group. Across the ICUs, none of the associations between ethnicity/race and HAI type are statistically significant at the ICU specific level: the test for CVICU has a *p*-value of 0.130 (X^2 = 9.876, n = 82), MSICU has p = 0.267 (X^2 = 7.624, n = 130), and NSICU has p = 0.409 (X^2 = 6.124, n = 107; Table 19). Statistical insignificance remains even when controlling for age and sex. Thus, race may not be a confounding variable. Finally, for risk factors, CVICU patients who smoke tend to contract an HAI (p = 0.009), with most having CAUTI than the others (Table 20). The association is not significant for patients who smoke when controlling for age; however, when controlling for either sex or ethnicity but not both simultaneously, the p-values are statistically significant (CVICU males: p = 0.032 vs. CVICU Caucasians: p = 0.042; Table 20). Changes in statistical significance with respect to different combinations of demographic variables implies that sex and ethnicity/race are confounding factors in those with smoking habits and contract an HAI in the CVICU. Thus, sex

and ethnicity/race behave as an initiator for those who smoke and contract an HAI. Furthermore, Pearson correlations show statistically significance between diabetes and acquiring a device-associated infection in MSICU and a negative correlation in NSICU (Appendix D). In MSICU, Pearson correlations between HAI and diabetes are weakly positive at 0.054, but statistically significant (0.009; Appendix D). Thus, diabetic patients in MSICU have a weak association with acquiring a device associated healthcare infection. As for the patients in NSICU who were statistically significant with a *p-value* of 0.003, had a Pearson correlations that was weakly negative at -0.087. Thus, NSICU patients with diabetes have a weak association with not acquiring an HAI infection.

Research Question 4

The last research question examined the differences in the types of microorganisms and susceptibilities which were associated with device-related HAIs in the three adult ICUs within the academic medical facility. The data analysis discovered that the majority of the HAIs were caused by gram negative rods (Table 23-24). The gram negative rods were associated with the majority of the CAUTI and VAP infections. Doshi et al. (2009) demonstrated comparable findings of gram negative rods associated with the majority of CAUTIs. In this study, the majority of CAUTIs were attributed to gram negative bacteria with the majority being identified as E. coli (Table 27). The gram negative bacteria were further grouped as 99 cases caused by bacteria from the Enterobacteriaceae family. The non-fermenting gram negative rods accounted for only 26 of the CAUTI cases with Pseudomonas aeruginosa being the majority of the cases. There were 58 cases of yeast and 21 cases of gram positive bacteria causing CAUTI. However, for the CLABSI cases, the major cause of infection was caused by gram positive cocci. The CLABSI organism distribution consisted of 31 gram positive bacteria, 18 gram negative bacteria

and 12 yeast. The CLABSI cases had the majority of multidrug resistant organisms (MDRO's) with 20 identified as cause of infection. The most common MDRO identified was vancomycin resistant enterococcus (VRE) which were found to be the cause of 13 cases of CLABSI and 6 cases of CAUTI. There were only 12.7% of MDRO's identified for all three device-related infections within the three adult ICUs. There were a total of 161 gram negative bacteria contributing to the device-related infections in the ICUs. NSICU had the highest number of gram negative rods with a total of 71 followed by MSICU and then CVICU (Table 24). The second group of organisms contributing to the HAIs were yeast in which there was a total of 70 infections associated with the three types of intensive care units. The results found that of the total HAIs in MSICU, 40 cases were attributed to yeast (Table 24). The yeast were found causing infections in patients who had Foley catheters followed by patients who had placement of central lines. Gram positive cocci contributed to the majority (51%) of central line-associated bloodstream infections. Of all the MDRO's identified, 51.4% were vancomycin resistant enterococcus (VRE). VRE was the most commonly identified pathogen causing device-associated HAIs at this academic medical center (Tables 26-27, Figure 7). The results from this study are different from what was identified in the literature. On the contrary, literature review has identified MRSA more often as the common pathogen causing healthcare associated infections (Doshi et al., 2009). In this study, there were only 5 MRSA infections contributing to 13.5% of the MDRO cases. The MRSA infections were attributed to one CLABSI and four VAP cases.

VRE was found to cause 21% of CLABSIs and only 2.9% of CAUTIs. Microbiologically speaking, one would think that VRE as an enteric bacteria would demonstrate higher device associated CAUTIs. This would be due to the proximity of the urethral indwelling

catheter to the enteric flora of the perirectal area. In this study, central lines were associated with a higher number of VRE device associated infections. These findings are in contrast to MRSA being identified in other studies as common pathogens causing HAIs. Staph species, Staph aureus, Enterococcus species and Candida species have been found in literature to be the most prevalent bacteria with central line and other device associated infections (O'Grady et. al., 2011). According to O'Grady et al. (2011), MRSA was the most common reported bacteria causing device associated infections and accounts for more than 50% of the Staphylococcus aureus isolates identified in the ICUs. MRSA was demonstrated to cause 8.5% of the HAIs reported to the National Healthcare Safety Network during the period of 2009-2010 (Sievert et al., 2013). According to the literature review, VRE is associated with increased ICU cost, hospital mortality and length of stay. There is a high risk of acquisition of VRE from the hospital environment which could contribute to device associated HAIs (Sydnor & Perl, 2011). This information may be useful for future research and may provide additional information regarding the relationship of VRE with device associated infections. Other findings in this study, revealed that the microorganisms isolated from ICU patients were statistically significant in females between the three ICUs (X^2=25.653, p<0.001) but not for the male gender (X^2 = 6.159, p = 0.188; Table 25).

Lower socioeconomic status has been linked to poor health outcomes due to lack of access to health care services (Saydah, Imperatore, & Beckles, 2013). Therefore, once admitted to an acute care setting, the poor health conditions make these patients more susceptible to acquiring HAIs. In the broader picture, improving socioeconomic status for all demographics could help in reducing the likelihood of acquiring healthcare associated infections. The significance of this study was to examine the findings in order to understand the incidence rates and SIR associated with each ICU (Tables 4-6). The findings should be able to provide

information that was necessary in continuously improving patient safety and patient outcomes. This study allows the opportunities for exploration of some components of the eco-social theory and how each factor affects acquiring a healthcare associated infection. This can place emphasis on the patterns of HAIs which may develop within a set population (Krieger, 2001). The model provided a context of health analysis and could help to determine the overall understanding of health outcomes.

Limitations of the Study

This research study used three different intensive care units within an academic medical center in the state of Texas. It was assumed that patients in the three ICUs had unique clinical dispositions requiring them to be admitted to the different ICU locations (cardiovascular, medical-surgical, and neuro) with varying clinical services and characteristics. The findings from this study may not be generalizable to other academic medical facilities causing potential bias as well. The other limitations to consider involve predisposed patients that can develop particular illnesses and infections which can cause a high occurrence of devices associated infections. The varying types of ICUs may affect the types of infections and organisms revealed. Since the ICUs were different in characteristics for services provided based on clinical needs of patients (neuro, cardiovascular, medical-surgical), it was assumed that patients received unique clinical care based on individual unit, thus affecting infection rates. Because the patient populations are subject to multiple characteristics, such as differences in demographics and severity of illness, the nature of the patients confound interpretations of the results. Comparing the patient populations has revealed that while they were similar for most traits of the patient, comparing the sex of the patient with respect to the HAI type (i.e., analyzing male patients subject to the different types of HAI across the ICUs and then comparing those results to female patients

subject to the same characteristics) has revealed statistically significant differences (Table 3), notably for patients with smoking habits (Table 11). Similar differences in statistical significance were found for several ethnic/racial group constant when determining the subgroup of patients who smoke and acquire a type of HAI (Table 11). Although an attempt to control the confounding factors was made, a limitation of this approach in this study is that the lifestyles of the patients, such as specific dieting habits, are not recorded in the clinical data. The potential impact on the results may cause differences in the statistical significance in the chi-squared tests and thus possible estimation bias in the *p*-values.

External factors such as different types of device brands and supplies used between the three ICUs, variables in collection of culture samples, and variances in insertion of devices and daily care by staff may contribute to an increased risk for developing a device associated HAI. Other limitations include definition changes which have led to fewer identified HAIs. For example, the NHSN CAUTI definitions for 2015 have excluded all yeast from the CAUTI criteria, whereas prior to 2015, yeast would have been considered a pathogen contributing to a CAUTI. Future findings may show lower number of CAUTIs since Candida species have been found to be genitourinary tract colonizing organisms but are now excluded from the definition criteria. Female gender and indwelling urethral catheters are known risk factors for candiduria. Incorporation of the exclusion criteria may cause under representation of female gender urinary tract infections caused by Candida. (Pallet & Hand, 2010).

Recommendations for Future Research

Additional studies may include device utilization ratios in order to focus on excess use of device usage for each intensive care unit in an academic medical center. Since this study was unable to capture length of stay for all patients, further data analysis regarding morbidity and

mortality can be examined along with the length of stay can be reviewed in comparing each intensive care unit respectively. There could be more investigation focused on demographics and length of stay to include patients who were admitted to the intensive care units and did have a device in place while in the ICU but who did not develop a healthcare associated infection within this academic medical facility. Future research could look specifically at the neurosurgical ICU to investigate the high rate of VAP and the factors which could be involved in contributing to this infection rate. The correlation between the microorganisms identified and device associated infection type needs to be further investigated as to mode of transmission, portal of entry and each susceptible host. Due to limited data, researcher was unable to conduct a case control study, however, future study could possibly be a case control study which will examine all patients with central lines, Foley catheters and ventilators within each specific ICU in an academic medical facility.

Implications for Social Change

Patients who are admitted into an intensive care unit of a hospital are likely to have an increased occurrence of device associated HAIs. Literature review has shown that during hospitalization, every patient who was admitted into an ICU and has a device such as a central line, Foley catheter or a ventilator placement has a higher chance of developing a device associated infection (Magil et al., 2014). The impact of these infections on patient outcomes are associated with increased length of stay, excess hospital cost, and an increased chance of morbidity. In this study, the researcher was unable to gather all the length of stay data for each patient and therefore was not able to evaluate LOS. In the United States, the estimated medical costs of HAIs are nearly $45 billion each year (Krein et al., 2012). It is estimated that over 1.7 million HAIs occur in patients who have been admitted into a hospital setting each year (Magill

et al., 2014). Literature review has shown that HAIs have resulted in 99,000 deaths in 2002, which places HAIs in the top ten causes of death in the United States depending on the risk factors and other disease factors the patient may already have present (Krein, et al., 2012). The social change implications from this research could aid in the understanding of the incidence associated with each device associated infection and the relationship attributed to each intensive care unit. Social change supports the need for guiding infection prevention and control for all three intensive care units to reduce the infection rates and produce healthier outcomes for patients and the community. Understanding the types of infections associated with each intensive care unit and the microorganisms attributing to the infections may provide further information providing interventions and best practice guidelines. A better understanding of knowledge for prevention and control of nosocomial infections could provide practice recommendations which may assist in the development of more effective guidelines. These types of changes and improvements could be used to process social attitudes in nursing care, antibiotic usage, behaviors, decision making, hand hygiene, maintenance and care of devices, and other important factors which could contribute to infection prevention.

Conclusion

Device associated HAIs are a threat to patient safety particularly those patients who are admitted into an intensive care unit. Additional attention should be given to each ICU relating to the types of organisms identified, and each type of device associated infection. The majority of gram positive bacteria identified in this study as the cause of CLABSI should be examined for proper skin preparation along with care bundles. According to Doshi (2009), over half of the CLABSIs identified are preventable with implementation evidence based practices for central line insertion and maintenance of lines. Skin flora such as gram positive bacteria are inclined to

be heavily present on the skin therefore potentially contributing to CLABSIs (Doshi et al., 2009). The link between CAUTIs and gram negative bacteria should be examined further. There should be standardized evidence based practices followed for all the ICUs. Surveillance monitoring with educational sessions should be considered to help provide better opportunity to make the necessary changes in healthcare practices for device insertion and maintenance. The ultimate goal should be to achieve a reduction in device-associated HAIs. There needs to be additional research to determine best practice for Foley and central line care. Additional studies and further findings should be performed on VRE isolates to determine infection patterns for this gram positive multidrug resistant organism since the study showed the increase number of VRE cases with these device-related ICU patient infections. This information could be helpful by targeting the organisms identified with each type of device associated infection as well as the types of devices identified with each ICU. A multifaceted approach can be beneficial to dissect the causes and commonalities with each infection. Further studies may be necessary to gather additional information as to implement risk reduction measures.

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Appendix A: Types of Device-related Healthcare Associated Infections

Catheter Associated Urinary Tract Infections

The SUTI criterion for 1a, as defined by the (Horan, Andrus, & Dudeck, 2008), include all of the following elements which must occur within a timeframe that does not exceed a gap of one calendar day between any two elements:

1) The patient had an indwelling urinary catheter in place for >2 calendar days and the catheter was in place on the day when all elements of the criterion were first present together

2) *And* patient displays at least one of the following signs or symptoms, with no other recognized cause(s): fever >38°C; suprapubic tenderness; costovertebral angle pain or tenderness.

3) *And* a positive urine culture of $\geq 10^5$ colony-forming units/ml with no more than two species of microorganisms.

OR

1) The patient had an indwelling urinary catheter in place for >2 days and had it removed <48 hours before all elements of the criterion were first present together.

2) *And* at least one of the following signs or symptoms, with no other recognized cause(s): fever >38°C; urgency; frequency; dysuria; suprapubic tenderness; costovertebral angle pain or tenderness.

3) *And* a positive urine culture of $\geq 10^5$ colony-forming units/ml with no more than two species of microorganisms.

The SUTI criterion for 2a include all of the following elements which must occur within a timeframe that does not exceed a gap of one calendar day between any two elements:

1) The patient had an indwelling urinary catheter in place for >2 calendar days and the catheter was in place on the day when all elements of the criterion were first present together.

2) *And* a positive urinalysis with at least one of the following: a positive dipstick for leukocyte esterase and/or nitrite; pyuria; microorganisms seen on Gram's stain of unspun urine.

3) *And* a positive urine culture of between 10^3 and 10^5 colony-forming units/ml with no more than two species of microorganisms (Horan et al., 2008),

OR

1) The patient had an indwelling urinary catheter in place for >2 days and had it removed <48 hours before all elements of the criterion were first present together.

2) *And* at least one of the following signs or symptoms, with no other recognized cause(s): fever >38°C; urgency; frequency; dysuria; suprapubic tenderness; costovertebral angle pain or tenderness,

3) *And* a positive urinalysis with at least one of the following: a positive dipstick for leukocyte esterase and/or nitrite; pyuria; microorganisms seen on Gram's stain of unspun urine,

4) *And* a positive urine culture of between 10^3 and 10^5 colony-forming units/ml with no more than two species of microorganisms (Horan et al., 2008).

The ABUTI criterion includes the following elements, all of which must occur within a timeframe that does not exceed a gap of one calendar day between any two elements:

1) The patient has had an indwelling urinary catheter in place for >2 days and either still has it in place or had it removed <48 hours before all elements of the criterion were first presented together.

2) *And* a positive urine culture of $\geq 10^5$ colony-forming units/ml with no more than two species of uropathogen microorganisms.

3) *And* a positive blood culture matching at least one uropathogen microorganism to the urine

culture, or at least two matching blood cultures drawn on separate occasions if the matching pathogen is a common skin commensal (Horan et al., 2008).

Ventilator Associated Pneumonia

PNU1 represents clinically defined pneumonia (CDC, 2012). PNU1 requires at least one of the following symptoms: fever (>38°C) with no other recognized cause; leukopenia (<4,000 white blood cells/mm^3) or leukocytosis (>12,000 WBC/mm^3); for patients >70 years old, altered mental status with no other recognized cause. Additionally, at least two of the following signs/symptoms must also be observed: changes in sputum characteristics, increased ventilator requirements, or any other dysfunctional changes in the patients' respiratory status (Peyrani, 2009).

PNU2 represents pneumonia with common bacterial or filamentous fungal pathogens and specific laboratory findings, and viral, *Legionella*, and other bacterial pneumonias with definitive laboratory findings (Peyrani, 2009). As discussed by Peyrani (2009), for pneumonia with specific pathogens and laboratory findings, and a minimum of one required symptom such as: fever (>38°C) ; leukopenia (<4,000 WBC/mm3) or leukocytosis (>12,000 WBC/mm3); mental status changes for any patient older than 70 years of age.. In addition the criteria for PNU 1 must be met as well. The following laboratory findings are also required as long as they are not related to another source of infection, a positive blood or pleural fluid culture, a positive quantitative culture from the lower respiratory track that is minimally contaminated, or a microscopic test which reveals ≥5% BAL-obtained cells that contain intracellular bacteria from a Gram stain. Furthermore, the histopathologic exam should reveal at least one of the following evidences of pneumonia: abscess and/or consolidation within the bronchioles and alveoli which

demonstrates PMN accumulation; quantitative cultures of lung parenchyma which contain fungal or pseudohyphae elements (Peyrani, 2009).

For PNU2 for viral, *Legionella*, and other bacterial pneumonias with definitive laboratory findings, only the laboratory criteria differ, the radiology and signs/symptom criteria are the same as PNU2 for pneumonia with common bacterial or filamentous fungal pathogens and specific laboratory findings (Peyrani, 2009). Definitive laboratory findings for *Legionella*, viral, and other bacterial pneumonias must be met. The laboratory findings must include at least one of the following:

> positive culture of virus or *Chlamydia* from respiratory secretions; positive detection of viral antigen or antibody from respiratory secretions; a fourfold rise in paired sera for pathogen; positive PCR for *Chlamydia* or *Mycoplasma*; positive micro-IF test for *Chlamydia*; positive culture or visualization by micro-IF of *Legionella* spp. from respiratory secretions or tissue; detection of *Legionella pneumophila* serogroup 1 antigens in urine by RIA or EIA; fourfold rise in *L. pneumophila* serogroup 1 antibody titer to ≥1:128 in paired acute and convalescent sera by indirect IFA. (Peyrani, 2009, p. 22-5)

According to Peyrani (2009) in the APIC Text, the PNU3 classification is reserved for pneumonia in immunocompromised patients. In addition to the radiology criteria, the signs/symptoms must include an immunocompromised patient who has at least one of the following:

> fever (>38°C) with no other recognized cause; leukopenia (<4,000 WBC/mm3) or leukocytosis (>12,000 WBC/mm3); for patients >70 years old, altered mental status with no other recognized cause; new onset of purulent sputum, or change in character of

> sputum, or increased respiratory secretions, or increased suctioning requirements; new onset or worsening cough, or dyspnea or tachypnea's; rales or bronchial breath sounds; worsening gas exchange, increased oxygen requirements, or increased ventilator demand; hemoptysis; pleuritic chest pain. The laboratory findings must include at least one of the following: matching positive blood and sputum cultures with candida spp.; evidence of fungi or *Pneumocystis carinii* from minimally contaminated LRT specimen from either direct microscopic exam or positive fungal culture. (Peyrani, 2009, p.22-5)

All of the pneumonia diagnostic criteria are listed in Table 1.

Appendix B: CDC Flow Diagrams for Device –Associated Infections

The flow diagrams of device associated infections were guidelines set by the Centers for Disease Control and Prevention to identify and classify healthcare associated infections.

Identification Central-line Bloodstream Infections (CLABSI)

Name:	MR#:	Unit:	DOB:	Age:	M F

Admitting Diagnosis:	Admit Date:	D/C Date:	Attending Physician:

Onset Date:	Culture Date:	# Bottles Positive:	Birth weight (gms) (Neonates only**): N/A**

†LABORATORY CONFIRMED BLOODSTREAM INFECTION (LCBI): LCBI Criteria 1 and 2 may be used for patients of any age, including patients < 1 year of age	**Type of Line**	**Insertion Date**	**D/C Date**	**CL Checklist Completed**
CRITERION- LCBI 1*:				
Date				
Recognized pathogen cultured from one or more blood cultures				
AND organism cultured from blood is not related to infection at another site				
CRITERION- LCBI 2*: (at least **one** of the following)				
Date				
Fever (>38^{0}C)				
Chills				
Hypotension				
AND:				
Common skin contaminant (i.e. diptheroids [*Corynebacterium* spp.], Bacillus spp. [not *B.anthracis*], *Propionibacterium* spp., coagulase-negative staphylococci [including *S. epi*], viridans group streptococci, *Aerococcus* spp., *Micrococcus* spp.) is cultured from **two** or more blood cultures drawn on separate				

Central Line: An intravascular catheter that terminates at or close to the heart or in one of the great vessels which is used for infusion, withdrawal of blood, or hemodynamic monitoring. The following are considered great vessels for the purpose of reporting central-line BSI and counting central-line days in the NHSN system:

- Aorta
- Pulmonary Artery
- Pulmonary Artery
- Superior Vena Cava
- Inferior Vena Cava
- Brachiocephalic Veins
- Internal Jugular Veins
- Subclavian Veins
- External Iliac Veins
- Common Iliac Veins
- Femoral veins

NOTES:

- An introducer is considered an intravascular catheter
- Neither the insertion site nor the type of device may be used to determine if a line qualifies as a central line
- Pacemaker wires & other nonlumened devices inserted into central blood vessels or the heart are **not** considered central lines, because fluids are not infused, pushed nor withdrawn through such devices

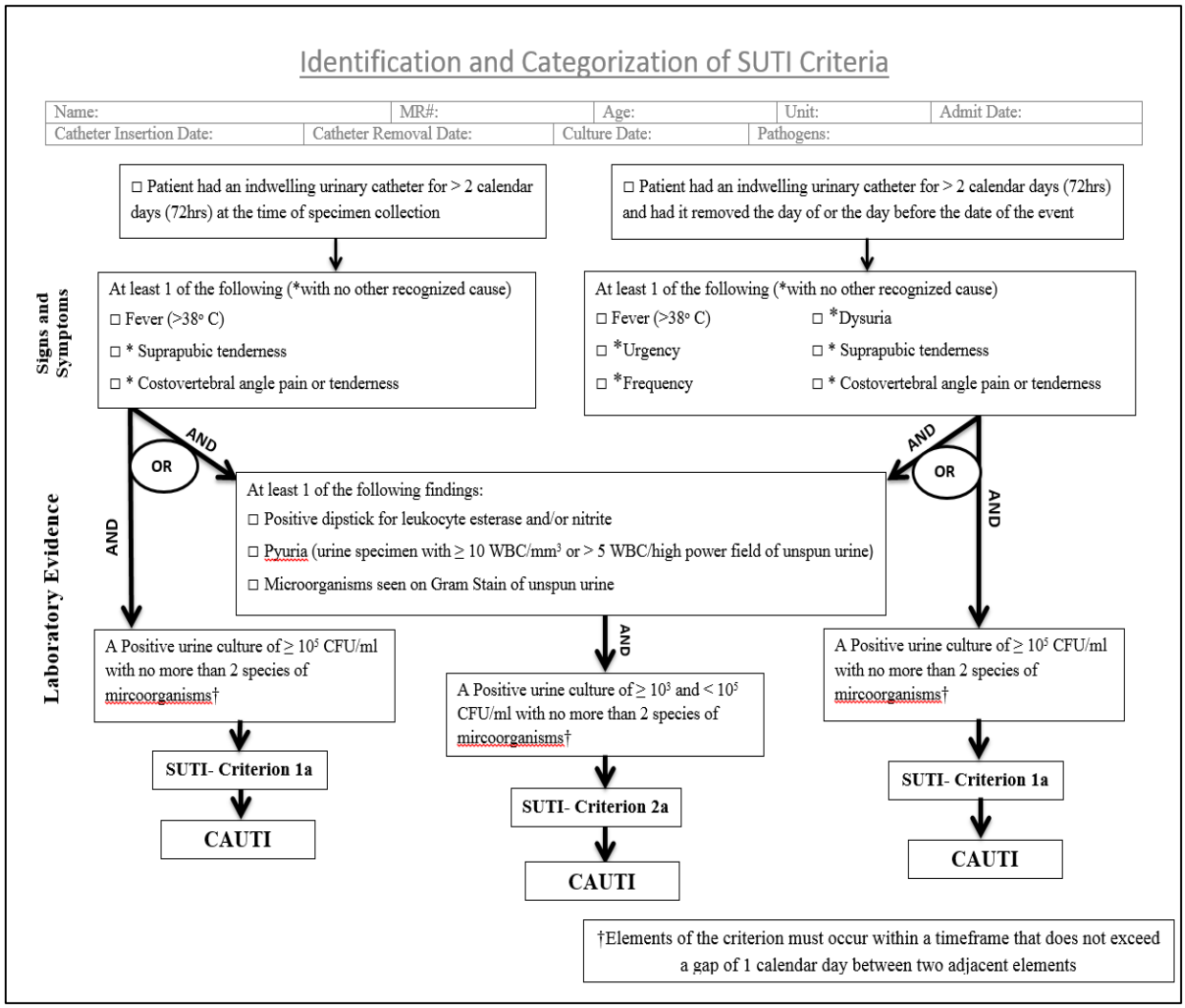
NOTES:

†LCBI Central Line (CL) or Umbilical Catheter UC) was in place for >2 calendar days when all elements of the LCBI infection criterion were first present together, with the day of device placement being Day 1

*Criterion elements must occur within a timeframe that does not exceed a gap of 1 calendar day

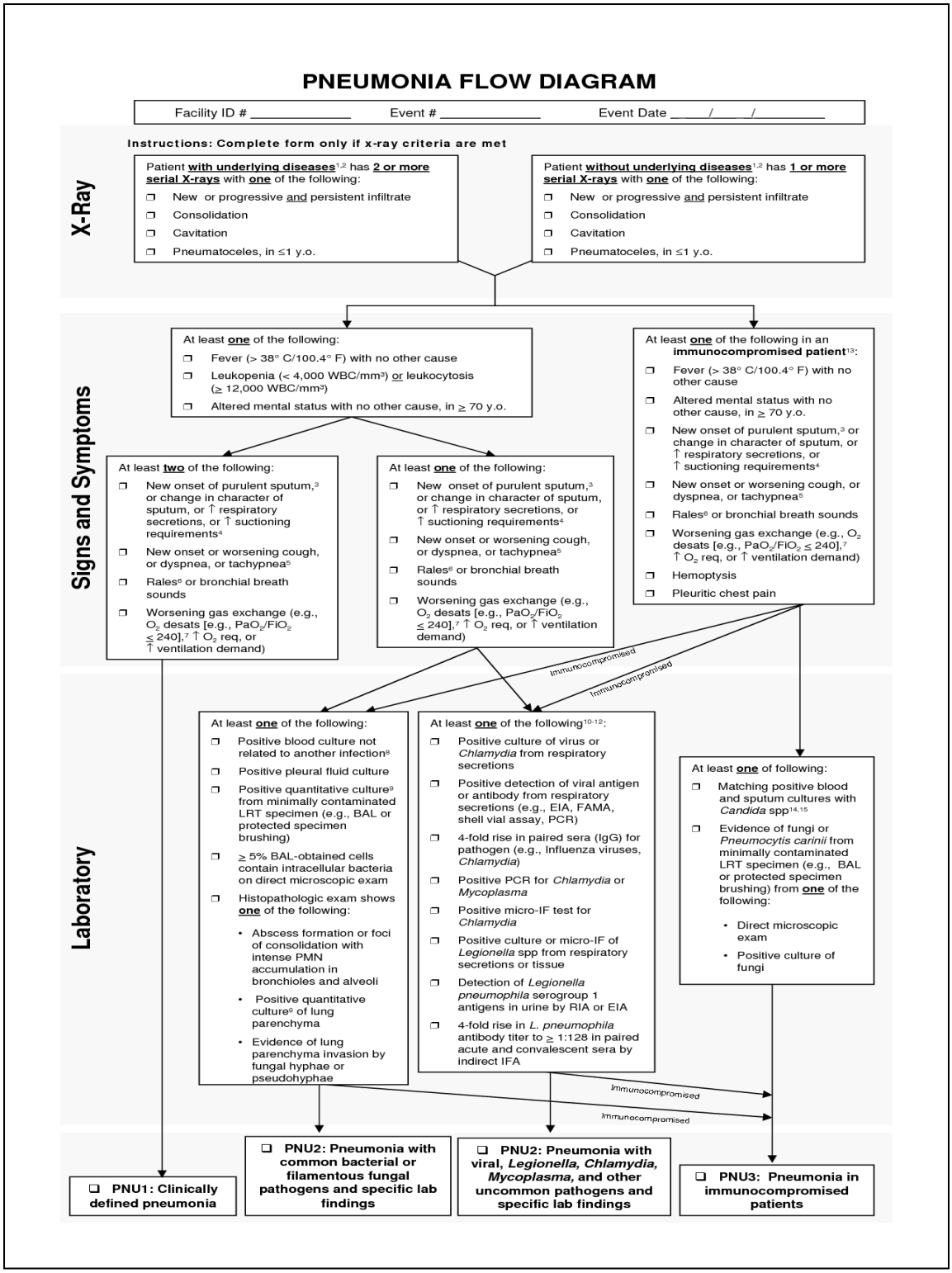
Adapted from CDC NHSN HAI information (CDC, 2015c)

Identification of Catheter-Associated Urinary Tract Infection (CAUTI)



Adapted from CDC NHSN HAI information (CDC, 2015b)

Identification of Ventilator Associated Pneumonia



Adapted from CDC NHSN HAI information (CDC, 2015d)

Appendix C: Data Use Agreement

The Data Use agreement for research purposes effective as of March 30, 2015 is entered into by and between Doramarie Arocha and UT Southwestern Medical Center. The purpose of this Agreement is to provide Data Recipient with access to a Limited Data Set ("LDS") for use in research in accord with the HIPAA and FERPA Regulations.

1. Definitions. Unless otherwise specified in this Agreement, all capitalized terms used in this Agreement not otherwise defined have the meaning established for purposes of the "HIPAA Regulations" codified at Title 45 parts 160 through 164 of the United States Code of Federal Regulations, as amended from time to time.

2. Preparation of the LDS. UT Southwestern Medical Center shall prepare and furnish to Data Recipient a LDS in accord with any applicable HIPAA or FERPA Regulations.

3. Data Fields in the LDS. No direct identifiers such as names may be included in the Limited Data Set (LDS). In preparing the LDS, UT Southwestern Medical Center shall include the **data fields specified as follows**, which are the minimum necessary to accomplish the research:

    a. Age, gender, race, ethnicity, microbiological laboratory positive cultures, severity of illness which will be measured by chart review of each patients temperature, mean arterial pressure, heart rate, respiratory rate, oxygenation, arterial pH, serum potassium, serum sodium, serum creatinine, hematocrit, white blood cells and count, coma score and chronic health problems.

    b. All device associated healthcare infections patient list from three intensive care units during 2010 through 2014 which includes demographics (age, gender, ethnicity, and race), temperature, mean arterial pressure, heart rate, respiratory rate, oxygenation, arterial pH, serum potassium, serum sodium, serum creatinine, hematocrit, white blood cells count, coma score, age, and chronic health, and the microorganisms causing the device-associated infections from TheraDoc and EPIC software which include items listed above.

    c. Personnel from the Informatics Department will provide the Limited Date Set (LDS) requested above with unique patient identifier. Access of patient records by the researcher will be limited to access rights as a student of Walden University and must adhere to HIPAA guidelines.

4. Responsibilities of Data Recipient. Data Recipient agrees to:

    a. Use or disclose of the LDS only as permitted by this Agreement or as required by law:

    b. Use appropriate safeguards to prevent use or disclosure of the LDS other than as permitted by this Agreement or required by law:

c. Report to Data Provider any use or disclosure of the LDS of which it becomes aware that is not permitted by this Agreement or required by law:

d. Require any of its subcontractors including the Informatics Department and the Infection Preventionists that receive or have access to the LDS to agree to the same restrictions and conditions on the use and/or disclosure of the LDS that apply to Doramarie Arocha under this Agreement: and

e. Not use the information in the LDS to identify or contact the individuals who are data subjects.

5. Permitted Uses and Disclosures of the LDS. Data Recipient may use and/or disclose the LDS for its Research activities only.

6. Term and Termination.
   a. Term. The term of this Agreement shall commence as of the Effective Date and shall continue for so long as Data Recipient retains the LDS, unless sooner terminated as set forth in this Agreement.

   b. Termination by Data Recipient. Data Recipient may terminate this agreement at any time by notifying the Data Provider and returning or destroying the LDS.

   c. Termination by Data Provider. Data Provider may terminate this agreement at any time by providing thirty (30) days prior written notice to Data Recipient.

   d. For Breach. Data Provider shall provide written notice to Data Recipient within ten (10) days of any determination that Data Recipient has breached a material term of this Agreement. Data Provider shall afford Data Recipient an opportunity to cure said alleged material breach upon mutually agreeable terms. Failure to agree on mutually agreeable terms for cure within thirty (30) days shall be grounds for the immediate termination of this Agreement by Data Provider.

   e. Effect of Termination. Sections 1, 4, 5, 6(e) and 7 of this Agreement shall survive any termination of this Agreement under subsections c or d.
7. Miscellaneous.
   a. Change in Law. The parties agree to negotiate in good faith to amend this Agreement to comport with changes in federal law that materially alter either or both parties' obligations under this Agreement. Provided however, that if the parties are unable to agree to mutually acceptable amendment(s) by the compliance date of the change in applicable law or regulations, either Party may terminate this Agreement as provided in section 6.

b. Construction of Terms. The terms of this Agreement shall be construed to give effect to applicable federal interpretative guidance regarding the HIPAA Regulations.

c. No Third Party Beneficiaries. Nothing in this Agreement shall confer upon any person other than the parties and their respective successors or assigns, any rights, remedies, obligations, or liabilities whatsoever.

d. Counterparts. This Agreement may be executed in one or more counterparts, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument.

e. Headings. The headings and other captions in this Agreement are for convenience and reference only and shall not be used in interpreting, construing or enforcing any of the provisions of this Agreement.

IN WITNESS WHEREOF, each of the undersigned has caused this Agreement to be duly executed in its name and on its behalf.

DATA PROVIDER	**DATA RECIPIENT**
Signed: Carl L. Gatt MD	Signed: Doramarie Arocha
Print Name: Carl L. Gatt MD	Print Name: Doramarie Arocha
Print Title: AVP Hospital Quality	Print Title: Research Student

Appendix D: Infection Numbers & Incidence Rates per 1000 Days for Each of the Three ICUs 2010-2015

CVICU	CLABSI	CL Days	Rate	CAUTI	F/C Days	Rate	VAP	Vent Days	Rate
2010	6	3842	1.56	10	3090	3.24	8	1941	4.12
2011	8	4352	1.84	15	3245	4.62	1	1804	0.55
2012	2	4120	0.49	10	3153	3.17	1	1968	0.51
2013	3	4339	0.69	6	3331	1.80	2	2021	0.99
2014	5	4303	1.16	4	2738	1.46	1	1798	0.56
TOTAL	24	20956	1.15	45	15557	2.89	13	9532	1.36
RATE	1.1			2.9			1.4		

MSICU	CLABSI	CL Days	Rate	CAUTI	F/C Days	Rate	VAP	Vent Days	Rate
2010	3	4636	0.65	23	4483	5.13	6	2456	2.44
2011	6	5596	1.07	25	5009	4.99	2	2623	0.76
2012	4	5304	0.75	16	4240	3.77	0	2623	0.00
2013	9	6053	1.49	14	4161	3.36	2	3283	0.61
2014	8	5188	1.54	9	3527	2.55	3	2742	1.09
TOTAL	30	26777	1.12	87	21420	4.06	13	13727	0.95
RATE	1.1			4.1			0.95		

NSICU	CLABSI	CL Days	Rate	CAUTI	F/C Days	Rate	VAP	Vent Days	Rate
2010	0	2684	0.00	13	3788	3.43	12	1150	10.43
2011	3	2794	1.07	18	4126	4.36	6	1212	4.95
2012	0	2392	0.00	18	3922	4.59	2	1237	1.62
2013	4	2059	1.94	14	3512	3.99	6	1268	4.73
2014	0	1468	0.00	9	2830	3.18	2	1284	1.56
TOTAL	7	11397	0.61	72	18178	3.96	28	6151	4.55
RATE	0.6			4			4.6		

Pearson Correlation Coefficients (P-value)			
	CVICU	**MSICU**	**NSICU**
CLABSI Rate	0.237	0.158	-0.395
	(0.395)	(0.574)	(0.145)
CAUTI Rate	-0.477	0.254	0.222
	(0.073)	(0.360)	(0.426)
VAP Rate	-0.26	-0.358	0.618
	(0.349)	(0.190)	(0.014)*
* Statistically significant at $p < 0.05$			

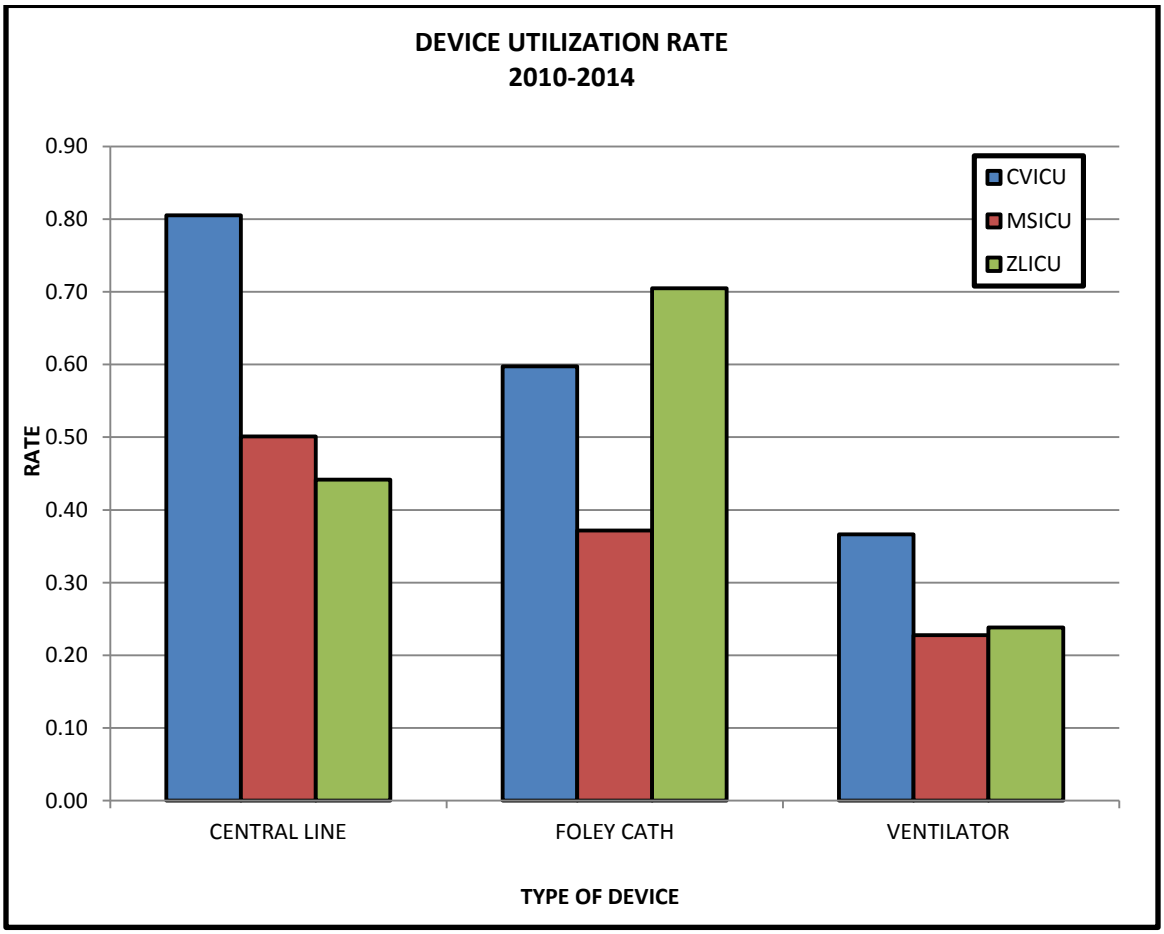
Appendix E: ICU SIR Ratios and Utilization Rates

SIR – HOSPITAL CLABSI RATE TABLE FOR ICU 2010-2014						
TYPE OF LOCATION	**# CLABSI**	**# CENTRAL LINE-Days**	**CLABSI Rate per 1000 CL Days**	**NHSN Rate per 1000 CL Days**	**EXPECTED # of CLABSI**	**INDIVIDUAL SIR**
MSICU	30	26777	1.1	1.1	29.5	**1.0**
CVICU	24	20956	1.1	0.8	16.8	**1.4**
NSICU	7	11397	0.6	0.9	10.3	**0.7**
TOTAL	61	59130	1.0		56.48	
Benchmark from NHSN Data Summary 2013 (Issued 2015)						
***p* value = 0.136**					**SIR = 1.08**	

SIR – HOSPITAL CAUTI RATE TABLE FOR ICU 2010-2014						
TYPE OF LOCATION	**# CAUTI**	**# FOLEY CATHETER DAYS**	**CAUTI Rate per 1000 Foley Days**	**NHSN Rate per 1000 Foley days**	**EXPECTED # of CAUTI**	**INDIVIDUAL SIR**
MSICU	87	21420	4.1	2.7	57.8	**1.5**
CVICU	45	15557	2.9	1.8	28	**1.6**
NSICU	72	18178	3.9	5.3	96.3	**0.7**
TOTAL	204	55155	3.7		182.18	
Benchmark from NHSN Data Summary 2013 (Issued 2015)						
***p* value = 0.027 significant for NSICU**					**SIR = 1.12**	

SIR – HOSPITAL VAP RATE TABLE FOR ICU 2010-2014						
TYPE OF LOCATION	**# VAP**	**# VENTILATOR DAYS**	**VAP RATE per 1000 Vent Days**	**NHSN RATE per 1000 Vent days**	**EXPECTED # of VAP**	**INDIVIDUAL SIR**
MSICU	13	13727	0.95	1.6	22	**0.5**
CVICU	13	9352	1.4	1.7	15.9	**0.8**
NSICU	28	6151	4.6	2.1	12.9	**2.2**
TOTAL	54	29230	1.8		50.78	
Benchmark from NHSN Data Summary 2013 (Issued 2015)						
***p* value = 0.096**					**SIR = 1.06**	

ICU Utilization Rates



Appendix F: Distribution of Organisms (%) by ICU and MDRO Status

Distribution of Organisms (%) by ICU based on MDRO Status

		ICU Type			
	Microorganism	**CVICU**	**MSICU**	**NSICU**	**TOTAL**
MDRO	**GNR**	40.00%	44.00%	16.67%	38.89%
$X^2 = 1.524$	**GPC**	60.00%	56.00%	83.33%	61.11%
$p = 0.467$	**YST**	0.00%	0.00%	0.00%	0.00%
	TOTAL	100.00%	100.00%	100.00%	100.00%
Non-MDRO	**GNR**	44.78%	47.42%	78.65%	57.71%
$X^2 = 34.397$	**GPC**	19.40%	11.34%	14.61%	14.62%
$p < 0.001$*	**YST**	35.82%	41.24%	6.74%	27.67%
	TOTAL	100.00%	100.00%	100.00%	100.00%

chi-squared test performed

* Statistically significant at $p < 0.05$

Distribution of Organisms (%) by HAI Type based on MDRO Status

		HAI Type			
	Microorganism	**CAUTI**	**CLABSI**	**VAP**	**TOTAL**
MDRO	**GNR**	55.56%	26.32%	50.00%	38.89%
$X^2 = 2.731$	**GPC**	44.44%	73.68%	50.00%	61.11%
$p = 0.255$	**YST**	0.00%	0.00%	0.00%	0.00%
	TOTAL	100.00%	100.00%	100.00%	100.00%
Non-MDRO	**GNR**	61.86%	29.27%	77.78%	57.71%
$X^2 = 39.247$	**GPC**	8.25%	41.46%	22.22%	14.62%
$p < 0.001$*	**YST**	29.90%	29.27%	0.00%	27.67%
	TOTAL	100.01%	100.00%	100.00%	100.00%

* Statistically significant at $p < 0.05$