Distribution Agreement

In presenting this thesis or dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

_____ _____

Joshua Mongillo Date

Incidence Trends in Hospital-Onset Bloodstream Infections in Grady Memorial Hospital, 2014-2017

By

Joshua Mongillo

MPH

Epidemiology

_____ [Chair's signature]

Scott Fridkin, M.D.

Committee Chair

Incidence Trends in Hospital-Onset Bloodstream Infections in Grady Memorial Hospital, 2014-2017

By

Joshua Mongillo

B.S., Allegheny College, 2016

Thesis Committee Chair: Scott Fridkin, M.D.

An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology

2019

Abstract

Incidence Trends in Hospital-Onset Bloodstream Infections in Grady Memorial Hospital, 2014-2017

By Joshua Mongillo

The overall purpose of this study was to analyze incidence trends in hospital-onset bloodstream infections in Grady Memorial Hospital from 2014 to 2017. Limited data regarding all BSIs occurring during hospital stay were prospectively recorded and reviewed by the infection preventionist team and reviewed to identify BSIs from 1/1/2014 to 12/31/2017. The hypothesis was that from 2014-2017, there was an increase in primary bloodstream infections and an unchanging rate of central line associated bloodstream infections and secondary bloodstream infections in Grady Memorial Hospital facility wide; and that the increase in primary bloodstream infection is attributed to an increase in *Staphylococcus aureus* related infections and confined to intensive care unit rooms compared to Wards. Using a poisson regression to examine if quarter significantly influenced bloodstream infections, it was determined that primary bloodstream infections significantly increased, on average, by 7.7% ($p<0.001$) per quarter in ward locations and 9.1% ($p=.03$) per quarter in intensive care units. The pathogen distribution for each bloodstream infection type was then examined to determine if there were specific pathogens causing the significant increase in primary bloodstream infections. There were no specific pathogens responsible for the increase in primary bloodstream infections. Possible reasons for the significant increase in primary bloodstream infections is the decrease in the amount of central lines and the increase in primary line usage. Device utilization ratios were calculated (central line days/patient days) for facility wide, intensive care unit, and ward locations. In all these settings, device utilizations were decreasing thus verifying a decrease in central line usage. Overall, bloodstream infections cost hospitals millions of dollars annually. This study showed that primary bloodstream infections at Grady Memorial Hospital significantly increased from 2014-2017 with no specific pathogen responsible for the increase.

Incidence Trends in Hospital-Onset Bloodstream Infections in Grady Memorial Hospital, 2014-2017

By

Joshua Mongillo

B.S., Allegheny College, 2016

Thesis Committee Chair: Scott Fridkin, M.D.

A thesis submitted to the Faculty of the

Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health in Epidemiology

2019

Table of Contents

Objective: Analyze incidence trends in rates of hospital-onset bloodstream infections (BSI), by type of infection (central line-associated bloodstream infections (CLABSI), primary bloodstream infections (PBSI), and secondary bloodstream infections (SBSI)), by pathogen from 2014-2017 at Grady Memorial Hospital.

Hypothesis: From 2014-2017, there is an increase in Primary BSIs and an unchanging rate of CLABSIs and secondary BSIs in Grady Memorial Hospital facility wide. The increase in primary BSI is attributed to an increase in *Staphylococcus aureus* related infections and confined to ICU rooms compared to Wards.

Introduction

Central Line Associated Bloodstream Infections (CLABSI):

Bloodstream infections are serious infections that occur when bacteria or yeast invade the circulatory system. These occur from complicated infections of the lungs, urinary system, or skin. However, many occur among patients already in the hospital. One specific type of BSI is central line associated bloodstream infections (CLABSI). A CLABSI is defined by the CDC as, "a primary bloodstream infection in a patient who had a central line at the time of or within the 48 hours before the onset of the infection"[5]. CLABSIs are a common infection in healthcare settings and result in thousands of deaths and billions of dollars in cost to the United States healthcare system yearly[1]. More specifically, 250,000 CLABSIs occur in hospitals each year with an attributable mortality of 12% to 25% for each infection and costing, on average, $25,000 for each infection[2].

These infections are often considered preventable and in recent years, there have been joint efforts by state and federal organizations to work with hospitals to lower the amount of hospital associated CLABSI nationwide. This effort has resulted in a decrease of 25,000 CLABSIs, or 58%, when comparing intensive care unit (ICU) CLABSIs from 2001 to 2009 with the greatest reduction coming from *Staphylococcus aureus* CLABSIs, 73% reduction, as compared to other pathogens such as gram negative (37% reduction), *Candida* spp. (46% reduction), and *Enterococcus* spp.(55% reduction)[3]. To further promote CLABSI reduction in hospitals, the Centers for Medicare and Medicaid Services (CMS) enacted the Hospital-Acquired Condition Reduction Program (HACRP), a pay for performance program to motivate hospitals to decrease negative healthcare outcomes, including CLABSIs[4]. Essentially, hospitals receive a total Hospital-Acquired Condition (HAC) score, which is a composite score based on the hospital's CLABSI, Catheter Associated Urinary Tract Infection (CAUTI), Surgical Site Infection (SSI), Methicillin-resistant Staphylococcus aureus (MRSA), and Clostridium difficile infection (CDI) rates as well as a CMS Recalibrated Patient Safety Indicator. These scores are then compared to that of other hospitals and those in the bottom 25% receive a 1% payment reduction from CMS[4]. This financial incentive has helped motivate hospitals to decrease the amount of CLABSIs reported. To participate in the CMS program, facilities must report these data to the Centers for Disease Control and Prevention's National Healthcare Safety Network (NHSN) and used for hospital funding through CMS most of the attention is being focused on them[6]. By design, NHSN tracks CLABSIs, but does not have

the capacity to track primary bloodstream infections that are not associated with a central line, which also cause morbidity among inpatients.

Peripheral Line/Primary BSI/Secondary BSI:

In hospitals, use of short term peripheral venous lines are very common. In fact, 330 million peripheral venous catheters are purchased each year in the United States[7]. Peripheral venous lines are generally considered to be safe, however, bloodstream infections can occur with an incidence of about 0.18%[8]. Using the case definition obtained from the CDC/NHSN, a primary bloodstream infection is "a laboratory confirmed bloodstream infection that is not secondary to an infection at another body site."[17] and a secondary bloodstream infection is defined as "A BSI that is thought to be seeded from a site-specific infection at another body site."[17]. The former, primary bloodstream infections can be central line-associated as discussed above, or non-central line associated. For this manuscript, we will use the term primary bloodstream infections to refer to those that are not central line-associated. The etiology of these primary bloodstream infections is at times uncertain, but often relate to infection starting at the insertion site of a peripheral venous catheter. Other causes may be infections starting at arterial catheter sites, occult skin or soft tissue infections, etc. Ideally, infection surveillance personnel can determine the body site infection (e.g., abdominal space infection) that has progressed to a bloodstream infection and categorize the bloodstream infection as secondary. Therefore, primary bloodstream infections are, by definition, a category of exclusion. Primary bloodstream infections related to peripheral venous lines can be devastating, resulting in preventable death

and financial burdens to hospitals; a systematic review on short term peripheral lines from Leonard Mermel indicates that the incidence of peripheral venous line bloodstream infections is around 0.18%. In comparison to central lines, peripheral lines are less likely to lead to a bloodstream infection with the risk of a central line bloodstream infection being 1.5 to 64 times higher than that of a peripheral line[8]. An important variable in determining the chance of infection is dwell time. More specifically, 54% and 60% of peripheral line bloodstream infections occurred in lines that were in place for greater than three days[9 10 11]. Therefore, if peripheral venous lines are remain in place for long periods of time (i.e.,>3 days), the risk of contracting a BSI increases.

Staphylococcus Aureus

There are many potential pathogens that could result in a bloodstream infection. These include but are not limited to *Staphylococcus aureus, Enterococcus* spp., *Candida* spp., *Enterobacter* spp., Coagulase Negative *Staphylococcus* (CNS), and *Pseudomonas aeruginosa.* The second most common and perhaps most dangerous pathogen to cause a bloodstream infection is *S. aureus*[13]. *S. aureus* bloodstream infections have significantly higher mortality rates due in part to metastatic infections and infective endocarditis, which is an infection of the endocardial surface of the heart[13 14]. Another factor that makes *S. aureus* a deadly pathogen is its ability to become drug resistant. Methicillin Resistant *Staphylococcus aureus* (MRSA) occurs when *S. aureus* becomes

resistant to a class of antibiotics related to penicillin which poses a problem in terms of treatment for this pathogen and greatly increases mortality with a 30 day mortality rate of 29%[16]. *Staphylococcus aureus* infects, on average, 100,000 peripheral line patients yearly in the United States[7] and a mean of 19% of *S. aureus* BSIs were from a peripheral line[8]. Along with the metastatic nature and higher attributable mortality of *S. aureus* related peripheral bloodstream infections, the duration of *S. aureus bacteremia* is longer in peripheral line bloodstream infections compared to non-peripheral line bloodstream infections with *S. aureus*[10]. Given the large usage of peripheral lines in today's healthcare facilities, the risks of primary and secondary bloodstream infections from peripheral venous lines must be examined further.

Methods

Study design and Overview

This is a cohort study of Grady Memorial Hospital patients, deceased or living, who meet the CDC/NHSN surveillance definition for an episode of hospital onset BSI between 1/1/2014 and 12/31/2017 with a medical record number (MRN). The definition of central line associated bloodstream infection, primary bloodstream infection, and secondary bloodstream infection are based on the Centers for Disease Control and Prevention (CDC)/National Health Safety Network surveillance definition described below[17]. Information such as age, infection location, number of pathogens causing infection, and pathogen groups including, *Staphylococcus aureus, Candida* spp., *Enterococcus* spp., *Enterobacter* spp., *Coagulase Negative Staphylococcus,* and

Pseudomonas aeruginosa were extracted from the patient's medical record to help with analyzing possible predictors for contracting a BSI.

Data collection and analysis:

Limited data regarding all BSIs occurring during hospital stay were prospectively recorded and reviewed by the infection preventionist team and reviewed to identify categorize the type of BSI. Numerator (number of hospital onset BSIs) and denominator data (number of inpatient days and/or central line days) for determining the rate of nosocomial BSIs were identified by review of infection control and microbiology laboratory records for Grady Memorial Hospital patients from 1/1/2014 to 12/31/2017 and from hospital administrative data (for patient days and device days). We evaluated characteristics of hospital onset-bloodstream infections (HO-BSI) by type of BSI from 2014-2017. Differences in characteristics by BSI type were assessed by comparisons to the reference group, primary bloodstream infections. We then compared incidence metrics and pathogen distribution between the most recent year (2017) and the first year (2014). Rates were calculated by dividing the number of primary, secondary, or central line associated bloodstream infections by the corresponding patient days or central line days depending on if it was yearly or quarterly data. Patient days were used for primary and secondary BSIs and central line days were used for CLABSIs. Incidence Density Ratios were calculated for comparison of rates for continuous variables and chi-square tests for categorical variables. A poisson regression was analyzed to determine the effect of quarters, on primary, secondary, and central line bloodstream infections. A poisson model was used because the data are counts and rates therefore poisson is the

best choice. Separate models were explored grouping all critical care locations into a critical care model, and all non-critical care locations into a ward location model. For each location, three separate models were explored, one model for each of the BSI types. Finally, a last model was created for all BSIs hospital wide. In all models, an offset was created based on the log of the number of central line or patient days for each quarter. If the BSI being observed was a CLABSI, then the offset used would be the log of the central line days. If the BSI was PBSI or SBSI then the offset used was the log of the patient days.

Case definitions:

Nosocomial BSIs are BSIs with onset greater than 48 hours after admission and will be classified as primary, central line associated, or secondary BSIs based on Centers for Disease Control and Prevention/National Healthcare and Safety Network surveillance definitions. Case definitions for each of these categories are as follows.

A primary BSI is defined as "a laboratory confirmed bloodstream infection that is not secondary to an infection at another body site."[17]

A CLABSI is defined as "A laboratory confirmed bloodstream infection (LCBI) where an eligible BSI organism is identified, and an eligible central line is present on the LCBI DOE or the day before." Where an eligible BSI is any "organism that is not an excluded pathogen for use in meeting LCBI or MBI-LCBI criteria" and an eligible central line is defined as "A central line that has been in place for more than two consecutive

calendar days (on or after central line day 3), following the first access of the central line, in an inpatient location, during the current admission." These lines remain eligible "until the day after removal from the body or patient discharge, whichever comes first".[17]

A secondary BSI is defined as "A BSI that is thought to be seeded from a site-specific infection at another body site."[17]

Results

Characteristics of Bloodstream Infections (Table 1)

Over the 4-year study period, 2014-2017, 825 bloodstream infections (BSIs) were identified and characterized. There were 229 primary bloodstream infections (PBSI), 330 secondary bloodstream infections (SBSI), and 266 central line associated bloodstream infections. Most of the bloodstream infections observed were secondary bloodstream infections (Table 1). There were significantly more PBSIs in patients aged 50-64 as compared to CLABSIs in the same age group and significantly more CLABSIs in patients aged 0-17 as compared to PBSIs in the same age group. For specific organism groups, CLABSIs and SBSIs had significantly less *Staphylococcus aureus* organisms compared to PBSIs (RR=0.45, p<0.001; RR=0.57, p=0.003) respectively. There were significantly less coagulase negative staphylococci in SBSIs as compared to PBSIs (RR=0.27, p<0.001) and significantly more Enterobacter spp. and *Pseudomonas aeruginosa* in CLABSIs compared to PBSIs (RR=1.55, p=0.001; RR=6.25, p<0.001), respectively. Also, CLABSIs were significantly more likely to be polymicrobial as compared to PBSIs (RR=1.36, p=0.004). Lastly, SBSIs and CLABSIs were more likely to be reported in an ICU than a Ward as compared to PBSIs (RR=2.36, p<0.001; RR=2.23, p<0.001), respectively.

Yearly Bloodstream Infection Frequency and Rates (Table 2, Figures 1 & 2)

While the overall rate of BSI per 1000 patient days remained unchanged between the first and last year of the study, there were changes in specific types of BSI. When examining PBSIs, they are consistently increasing from 2014-2017, starting with 37 PBSIs in 2014 and ending with 83 in 2017 (Table 2). There is an increase in PBSI rates steadily from 2014-2017. The rate of PBSI was 0.24 per 1,000 patient days in 2014 and increased to 0.48 per 1,000 patient days in 2017 (IDR=1.86, p=0.0012) whereas the rate of SBSIs decreased from 0.50 per 1,000 patient days in 2014 to 0.33 per 1,000 patient days in 2017 (IDR=0.66, p=0.014). There was no significant difference between for CLABSI rates in 2014 and 2017 (IDR=1.25, p=0.20).

Association of Organism Group by BSI Type (Table 3)

After observing a significant increase in PBSI in 2017 as compared to 2014 (Table 2). The organism groups examined in this study where displayed for each BSI type (PBSI, CLABSI, SBSI). There was no specific organism group that was significantly responsible for the increase in the rate of PBSI. There was also no specific organism group that was responsible for the significant decrease in SBSI in 2017 compared to 2014 (Table 3)

Intensive Care Units and Ward locations Quarterly BSI Rates (Table 4)

In order to look at a regression model, seven models were created (Table 4). Overall, there was no significant trending in the incidence of BSIs in the hospital, or within either critical care locations or ward locations alone (OR=0.99, p=0.20). However, in both ICUs and Ward settings, PBSI rates significantly increased each quarter. In ICUs, PBSIs increased on average by 9.1% per quarter (OR=1.091, p=0.03) and in Wards, PBSIs increased on average by 7.7% per

quarter (OR=1.077, p<0.001) (Table 4). In contrast, there was no significant quarterly trend for either CLABSIs or secondary BSIs.

Device Utilization Ratio (Figure 5, 6, and 7)

The device utilization ratio of central line days per patient day decreased over the study period, from roughly 0.2 to 0.15 for the hospital overall, from 0.5 to 0.4 among ICU locations, and from 0.14 to 0.10 among ward locations. This decrease suggests either an absolute decrease in use of intravenous catheters, or a shift in use of central venous catheters to peripheral venous catheters.

Discussion

Primary BSIs have increased, by about 7.7% and 9.1% per quarter over the 4-year study period in Ward and ICU settings respectively. This increase involved all pathogen groups and reflected the diversity of pathogens reported to be associated with CLABSI, suggesting the pathogenesis of the infections may be similar, with one major difference - no central line exposure in the PBSI group. We suspect that the PBSI cases developed these BSIs related to use of intravenous lines that are not considered central-venous lines. While it is important to figure out what is causing this increase in primary bloodstream infections, there does not seem to be a single pathogen group causing this increase, and pathogen mix was like that of CLABSI. This increase in happened in the context of stable CLABSI and SBSI rates both inside and outside of intensive care units. Also, the rate of primary BSIs in 2017 was 1.86 times that of primary BSIs in 2014 and the rate of secondary BSIs in 2017 was 0.66 times that of secondary BSIs in 2014. This

indicates a significant increase in primary BSIs from the first year of the study, 2014, to the last year, 2017 and a significant decrease in secondary BSIs. One hypothesis supported by this observation is that in the latter part of the study, secondary BSIs were being classified as primary BSIs either by intention or not. However, if this were the case, we would have expected the pathogen profile of the primary BSIs in the latter year of the study to reflect secondary BSIs, while in fact it still retained a profile more similar to CLBSIs, i.e., skin flora.

A second more likely reason for the increase in primary bloodstream infections could be that there has been an increase in non-central line usage, and a decrease in central lines. When observing the device utilization ratio of central line days to patient days the ratio is becoming smaller as time goes on in both ICU and Ward settings as well as overall in the hospital. This decreasing ratio emphasizes a decrease in the number of central line days and with a stable reporting of patient days. One scenario that is supported by these data is decreasing central lines use and instead, increasing use of non-central lines. If this is the case, then it makes sense that primary bloodstream infections are increasing if we are increasing the amount of non-central line usage. Also, if an increase in non-central line dwell time is corresponding with the increase in non-central line usage, the risk of infection increases. More specifically, if a non-central line is in place for more than 3 days, the risk of infection increases with between 54% and 60% of peripheral line bloodstream infections occurring in lines that were in place for greater than three days[9 10 11].

The potential limitations of this work include misclassification of CLABSIs, limited number of BSIs to perform sub-analysis by location type or pathogen group, and lack of more variables in models. There are financial incentives to reporting fewer CLABSIs and if reporting of CLABSIs are not being done correctly, whether by intent or not, is one flaw in the NHSN methodology of relying on subjective interpretation of complicated clinical data for a performance metric. Cognitive psychology studies have shown that there should be an expected underreporting of healthcare associated infections, especially those that can decrease funding, and economic theories have predicted this underreporting to increase as time goes on[18]. These teams might be more likely to define a bloodstream infection as primary or secondary as compared to a central line associated bloodstream infection because if the hospital has high CLABSI rates, then funding is decreased, however, the state has done validation efforts. When attempting to analyze the rates of pathogen specific groups and location type, there were some instances were zeroes were present, making it difficult or impossible to calculate rates. Lastly, the models created to analyze if BSI rates increased as time went on only included quarter as a variable. Ideally, we would want to include location as a possible variable and perhaps have an interaction term to get a better idea of how these variables influence BSI rates.

Conclusion

The findings presented confirm the suspicion of the Grady Memorial Hospital Infection Control Team that the incidence (i.e., patient-level risk) of PBSI has increased

over time; also, that these infections involve a similar distribution of pathogens as CLABSI and occurs during a period of decreasing use of Central lines. We suspect non-central line invasive device use has increased during this period and may be driving the observe changes in bloodstream infections occurring among hospitalized patients at Grady Memorial Hospital. The public health implications for this study are that as central line use is minimized, and peripheral line use increases among hospitalized patients, primary bloodstream infections prevention efforts related to peripheral line use may need more emphasize. Currently, quality standards and performance measurement focus on CLABSIs. Consideration should be made to track hospital-onset bloodstream infections overall, or all types of primary bloodstream infections. At Grady Memorial Hospital, specific efforts could be considered to address preventing PBSIs. Specifically for Grady Memorial Hospital, further description of the primary BSIs is needed to determine the type of catheter used, the duration of use (dwell time), and possibly the appropriateness of use of a peripheral vs. a central venous catheter to better understand the risks to patients using peripheral catheters both inside and outside of the critical care units.

Appendix

Table 1. Frequency of Bloodstream Infections by Infection Type and Characteristics at Grady Memorial Hospital, 2014-2017.

Characteristics		BSI Type n(%)					
		Primary	**CLABSI**	**Risk Ratio**	**Secondary**	**RiskRatio**	**Total**
Total		229	266		330		825
Age							
	0-17	2 (0.8)	14 (5.3)	6.03 (<0.01)	3 (0.9)	1.04 (0.99)	19 (2.3)
	18-49	44 (19.2)	67 (25.2)	1.31 (0.11)	77 (23.3)	1.21 (0.25)	188 (22.8)
	50-64	57 (24.9)	45 (16.9)	0.68 (0.03)	87 (26.4)	1.06 (0.70)	189 (22.9)
	65+	34 (14.9)	33 (12.4)	0.84 (0.43)	52 (15.8)	1.07 (0.77)	119 (14.4)
	Missing	92(40.2)	107 (40.2)		111 (33.6)		310 (37.6)
Organism Group							
	S. aureus	50(21.8)	26 (9.8)	0.45(<0.01)	41 (12.4)	0.57 (<0.001)	117 (14.2)
	Candida spp.	16 (7.0)	76 (28.6)	4.1 (<0.01)	23 (7.0)	1.00 (1.00)	115 (13.9)
	CNS spp.	47 (20.6)	66 (24.8)	1.21 (0.26)	18 (5.5)	0.27 (<0.01)	131(15.9)
	Enterococcus spp.	14 (6.1)	17 (6.4)	1.05 (0.90)	18 (5.5)	0.89 (0.73)	49 (5.9)
	Enterobacter spp.	54 (23.5)	47 (17.7)	0.75(0.11)	121 (36.6)	1.55 (<0.01)	222 (26.9)
	Pseudomonas aeruginosa	5 (2.2)	13 (4.9)	2.24 (0.12)	45 (13.6)	6.25 (<0.01)	63 (7.6)
Polymicrobial							
	No	152 (66.4)	155 (58.3)	0.88 (0.06)	179 (54.2)	0.82 (<0.01)	486 (58.9)
	Yes	77 (33.6)	111 (41.7)	1.24 (0.06)	151 (45.8)	1.36 (<0.01)	339 (41.1)

ICU							
	Yes	37 (16.16)	96 (36.1)	2.23 (<0.01)	126 (38.2)	2.36 (<0.01)	259 (31.4)
	No	113 (49.3)	62 (23.3)	0.47 (<0.01)	95 (28.8)	0.58 (<0.01)	270 (32.7)
	Missing	79 (34.5)	108 (40.6)		109 (33.3)		296 (35.9)

Note: BSI=Bloodstream Infections, CLABSI=Central Line Associated Bloodstream Infections, PBSI=Primary Bloodstream Infections, SBSI= Secondary Bloodstream Infections, CNS= Coagulase Negative Staphylococci. Enterobacter species includes *Escherichia coli*, *Klebsiella pneumoniae, Enterobacter gergoviae, Enterobacter cloacae, Enterobacter asburiae,* and *Enterobacter aerogenes.* CNS includes *Staphylococcus Epidermitis.* Enterococcus species includes *Enterococcus faecalis, Enterococcus durans, and Enterococcus gallinarum.* Candida species includes *Candida dubliniensis, Candida albicans, Candida tropicalis, Candida parapsilosis, Candida glabrata, Candida guilliermondii, Candida lusitaniae,* and *Candida kruseithen.*

Table 2. Rates of Bloodstream Infections by Type in 2014 and 2017 at Grady Memorial Hospital

	2014 n=177				2017 n=210					
BSI Type	**n (%)**	**Patient Line Days**	**Central Line Days**	**Rate***	**n (%)**	**Patient Line Days**	**Central Line Days**	**Rate***	**IDR**	**p-value****
All	177	152398		1.16	210	183690		1.14	0.98	0.88
CLABSI	64 (36.2)		29486	2.17	67 (31.9)		24666	2.71	1.25	0.20
PBSI	37 (20.9)	152398		0.24	83 (39.5)	183690		0.45	1.86	0.001
SBSI	76 (42.9)	152398		0.50	60 (28.6)	183690		0.33	0.66	0.014

Note: BSI=Bloodstream Infections, CLABSI=Central Line Associated Bloodstream Infections, PBSI=Primary Bloodstream Infections, SBSI= Secondary Bloodstream Infections

*Rate is per 1,000 patient days for PBSI and SBSI; per 1,000 central line days for CLABSI

** Significant p-value less than 0.05.

Table 3. Association of Bloodstream Infections (BSI) by BSI Type at Grady Memorial Hospital, 2014 vs 2017.

	2014 n (%)	2017 n(%)	RR	p-value*
All BSI	n=177	n=210		
Pathogen Group				
S. aureus	23 (13)	34 (16.2)	1.25	0.38
***Enterobacter* spp.**	50 (28.2)	63 (30.0)	1.06	0.70
CNS	24 (13.6)	26 (12.4)	0.91	0.73
***Enterococcus* spp.**	11 (6.2)	10 (4.8)	0.73	0.47
***Candida* spp.**	30 (16.9)	24 (11.4)	0.64	0.08
P. aeruginosa	15 (8.5)	16 (7.6)	0.9	0.75
Primary BSI	n=37	n=83		
Pathogen Group				
S. aureus	6 (16.2)	17(20.5)	1.26	0.61
***Enterobacter* spp.**	8 (21.6)	25 (30.1)	1.39	0.35
***Candida* spp.**	5 (13.5)	5 (6.0)	0.45	0.20
***Enterococcus* spp.**	0 (0)	4 (4.8)	N/A	N/A
CNS	8 (21.6)	11 (13.3)	0.61	0.26
P. aeruginosa	0 (0)	3 (3.6)	N/A	N/A
Secondary BSI	n=62	n=50		
Pathogen Group				
S. aureus	10 (16.1)	7 (14.0)	0.83	0.77
***Enterobacter* spp.**	27 (43.5)	26 (52.0)	1.19	0.38
Candida spp.	3 (4.8)	3 (6.0)	1.24	0.8
***Enterococcus* spp.**	6 (9.7)	3 (6.0)	0.62	0.51
CNS	4 (6.5)	2 (4.0)	0.62	0.61
P. aeruginosa	12 (19.4)	9 (18.0)	0.93	0.86
CLABSI	n=64	n=67		
Pathogen Group				
S. aureus	7 (10.9)	10 (14.9)	1.37	0.51
***Enterobacter* spp.**	13 (20.3)	12 (17.9)	0.88	0.73
***Candida* spp.**	22 (34.4)	16 (23.9)	0.69	0.19
***Enterococcus* spp.**	5 (7.8)	3 (4.5)	0.57	0.46
CNS	12 (18.8)	13 (19.4)	1.04	0.93
P. aeruginosa	3 (4.7)	4 (6.0)	1.27	0.77

Note: BSI=Bloodstream Infections, CLABSI=Central Line Associated Bloodstream Infections, PBSI=Primary
Bloodstream Infections, SBSI= Secondary Bloodstream Infections, CNS= Coagulase Negative Staphylococci. Enterobacter species includes *Escherichia coli*, *Klebsiella pneumoniae,*

Enterobacter gergoviae, Enterobacter cloacae, Enterobacter asburiae, and *Enterobacter aerogenes.* CNS includes *Staphylococcus Epidermitis.* Enterococcus species includes *Enterococcus faecalis, Enterococcus durans, and Enterococcus gallinarum.* Candida species includes *Candida dubliniensis, Candida albicans, Candida tropicalis, Candida parapsilosis, Candida glabrata, Candida guilliermondii, Candida lusitaniae,* and *Candida kruseithen.*
* Significant p-value less than 0.05.

Table 4. Estimate of quarterly change in infection incidence of three different bloodstream (BSI) infection categories by location, 2014-2017 Grady Memorial Hospital

Location			Intercept		Quarter		
	BSI Type	n	Estimate	SD	OR	95% CI	p-value**
Overall	All	16	-6.63	0.07	0.99	0.98,0.99	0.20
ICU							
	CLABSI*	16	-6.24	0.21	1.003	0.96,1.05	0.89
	PBSI	16	-8.77	0.42	1.091	1.01,1.18	0.03
	SBSI	16	-6.60	0.18	0.978	0.94,1.02	0.29
Ward							
	CLABSI*	16	-6.85	0.27	1.029	0.98,1.09	0.29
	PBSI	16	-8.95	0.24	1.077	1.03,1.12	<0.001
	SBSI	16	-8.27	0.21	0.979	0.94,1.02	0.36

Note: CLABSI=Central Line Associated Bloodstream Infection, PBSI=Primary Bloodstream Infection, SBSI=Secondary Bloodstream Infection, ICU=Intensive Care Unit.

* Central line days used as compared to patient days.

** Significant p-value less than 0.05.

Figure 1. Bloodstream Infection Frequency by Infection Type, 2014-2017

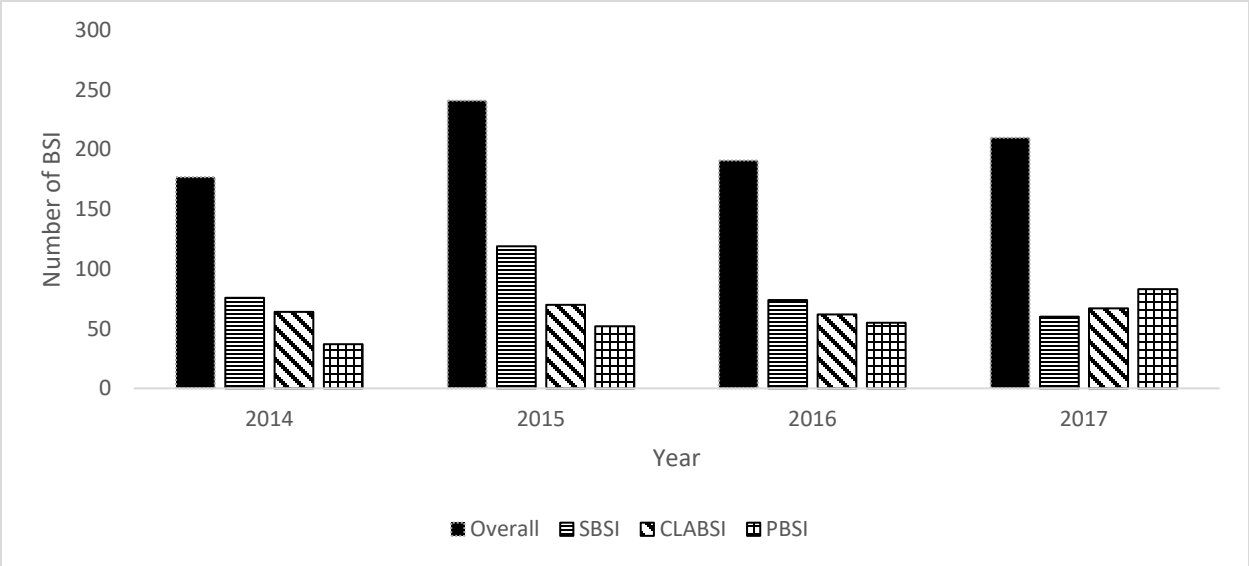


Figure 2. Yearly Bloodstream Infection Rates, 2014-2017

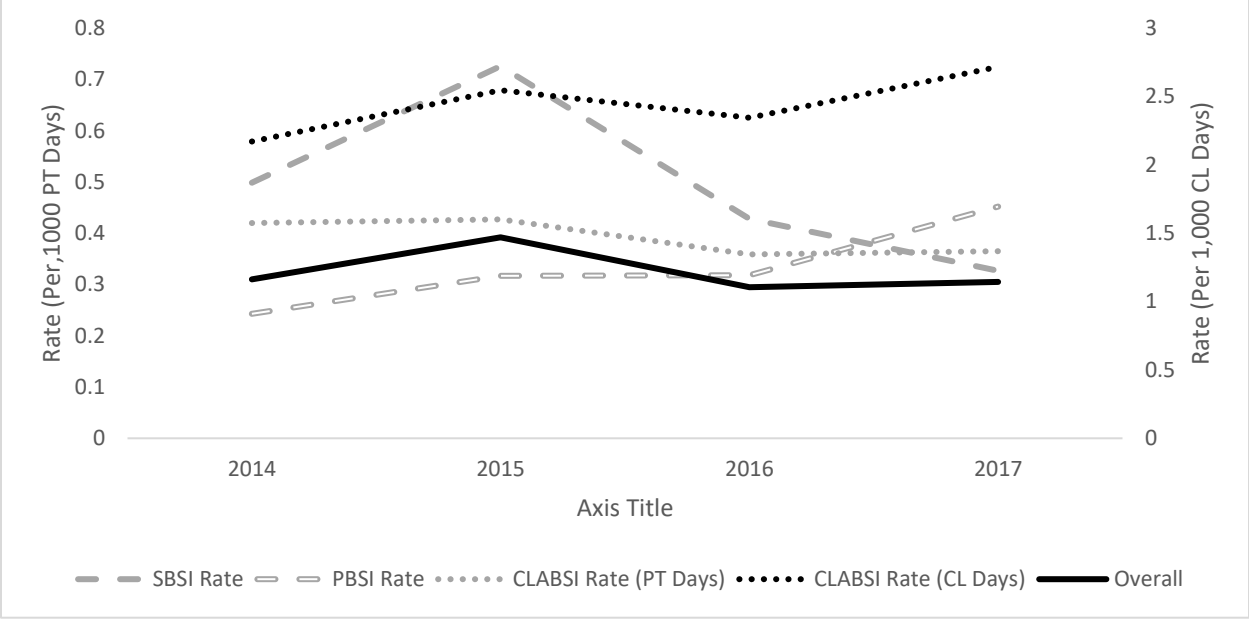


Figure 3. Quarterly Rate of BSI Type in ICU Locations at Grady Memorial Hospital, 2014-2017.

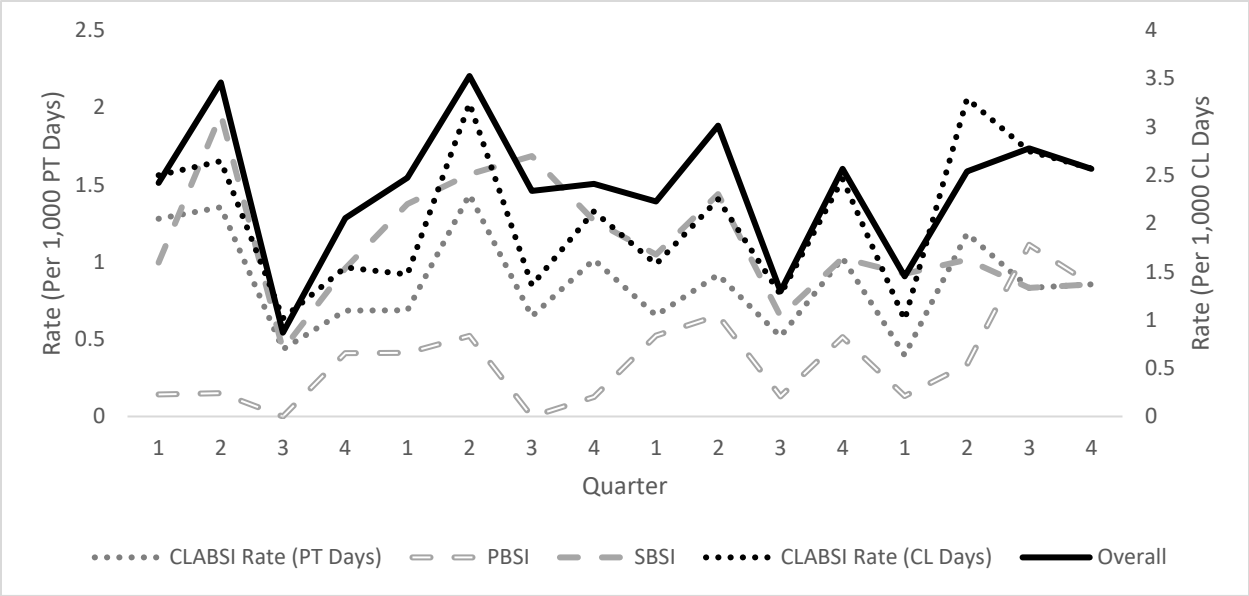


Figure 4. Quarterly Rate of BSI Type in Ward Locations at Grady Memorial Hospital, 2014-2017

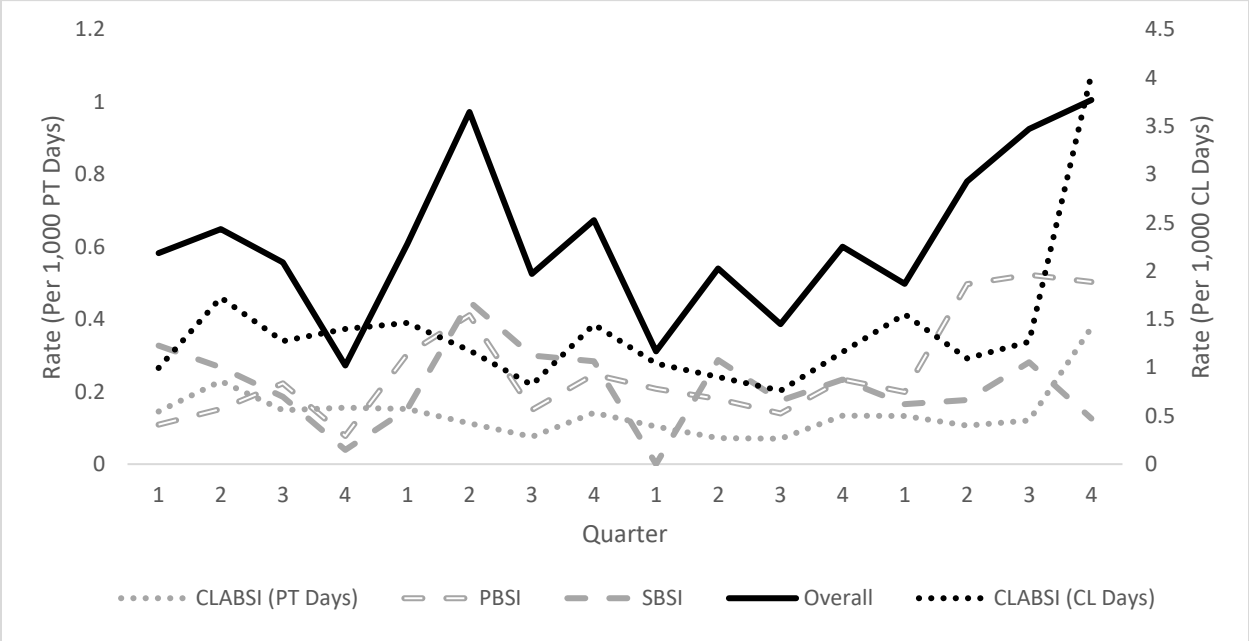


Figure 5. Device Utilization Hospital Wide in Grady Memorial Hospital, 2014-2017

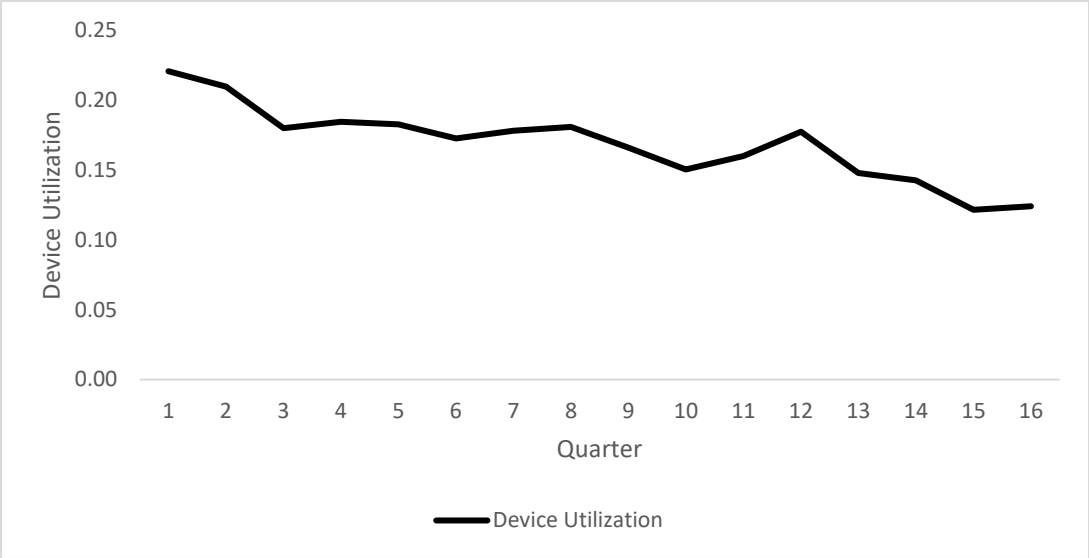


Figure 6. Device Utilization in ICU Locations in Grady Memorial Hospital, 2014-2017

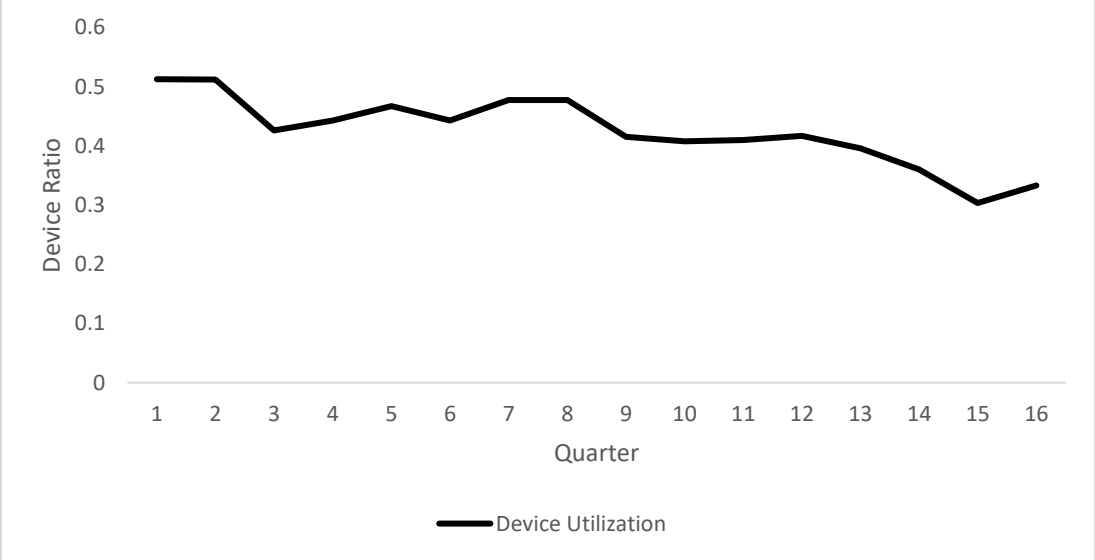


Figure 7. Device Utilization in Ward Locations in Grady Memorial Hospital, 2014-2017

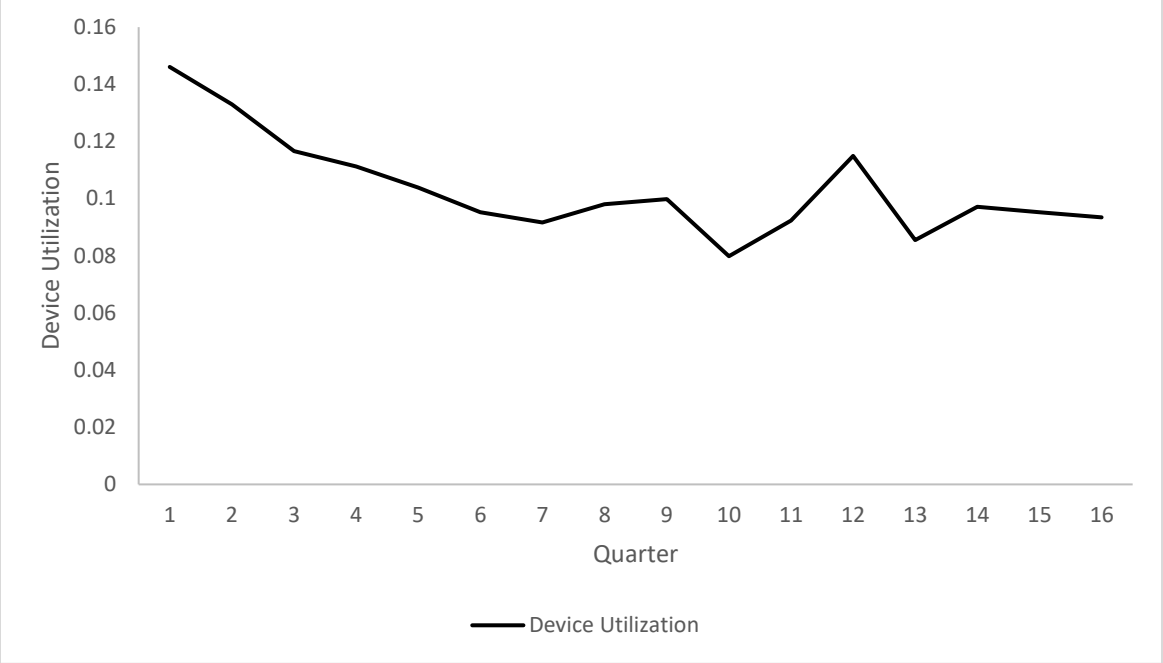


Figure 8. Yearly Ward BSI Rates by Pathogen Group at Grady Memorial Hospital, 2014-2017

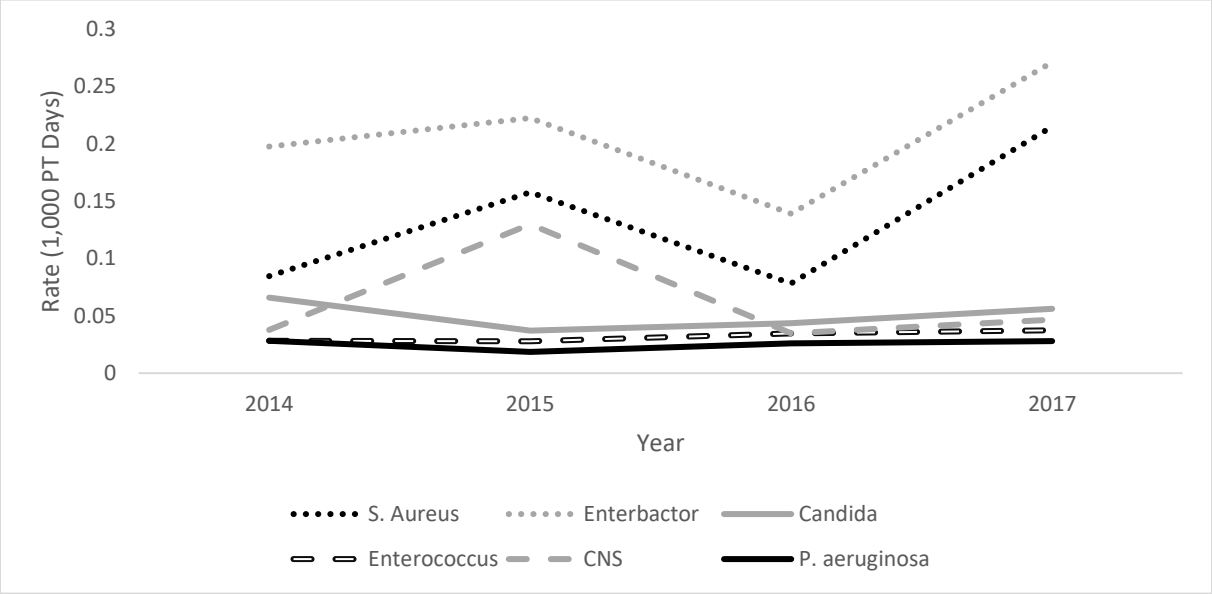
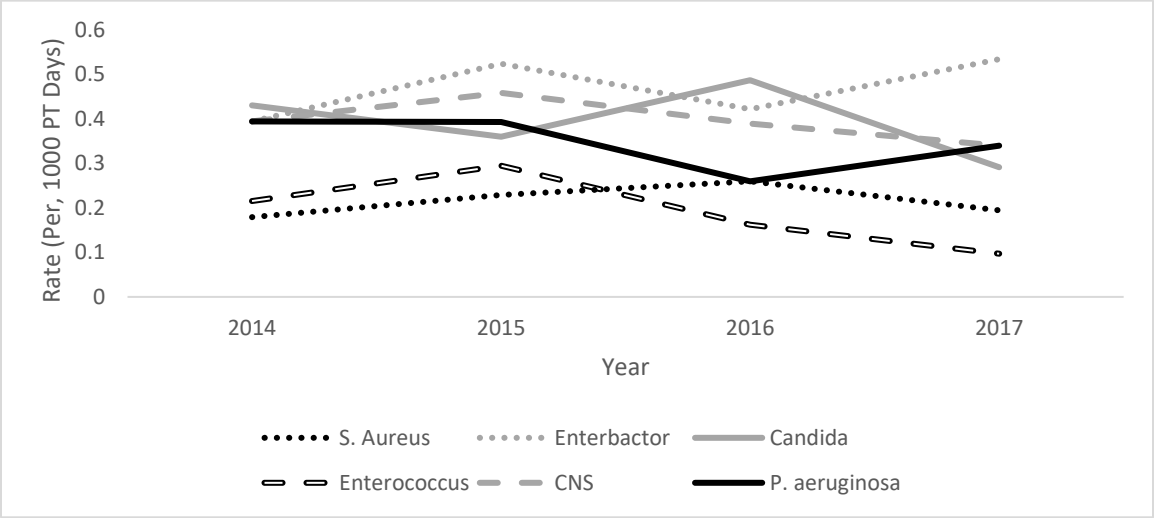


Figure 9. Yearly ICU BSI Rates by Pathogen Group at Grady Memorial Hospital, 2014-2017



Reference

1. “Healthcare-Associated Infections.” Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 1 Mar. 2016, www.cdc.gov/hai/bsi/bsi.html.

2. “Reduction in Central Line–Associated Bloodstream Infections Among Patients in Intensive Care Units—Pennsylvania, April 2001–March 2005.” *Jama*, vol. 295, no. 3, 2006, p. 269., doi:10.1001/jama.295.3.269.

3. “Vital Signs: Central Line–Associated Blood Stream Infections—United States, 2001, 2008, and 2009.” *Annals of Emergency Medicine*, vol. 58, no. 5, 2011, pp. 447–450., doi:10.1016/j.annemergmed.2011.07.035.

4. “HAC-Reduction-Program.” *CMS.gov Centers for Medicare & Medicaid Services*, 30 July 2018, www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/HAC-Reduction-Program.html.

5. Centers for Disease Control and Prevention (CDC). *Central Line-Associated Bloodstream Infection (CLABSI) Event*. Atlanta: CDC, 2011.http://www.cdc.gov/nhsn/PDFs/pscManual/4PSC_CLABScurrent.pdf. Accessed March 14, 2019

6. Fagan, Ryan P., et al. “Incidence Trends in Pathogen-Specific Central Line–Associated Bloodstream Infections in US Intensive Care Units, 1990–2010.” Infection Control

& Hospital Epidemiology, vol. 34, no. 09, 2013, pp. 893–899., doi:10.1086/671724.

7. Hadaway, Lynn. "Short Peripheral Intravenous Catheters and Infections." *Journal of Infusion Nursing*, vol. 35, no. 4, 2012, pp. 230–240., doi:10.1097/nan.0b013e31825af099.

8. Leonard A Mermel; Short-term Peripheral Venous Catheter–Related Bloodstream Infections: A Systematic Review, *Clinical Infectious Diseases*, Volume 65, Issue 10, 30 October 2017, Pages 1757–1762, https://doi.org/10.1093/cid/cix562

9. Bouza E , Muñoz P , López-Rodríguez J et al. "A needleless closed system device (CLAVE) protects from intravascular catheter tip and hub colonization: a prospective randomized study". *J Hosp Infect* 2003; 54:279–87.

10. Collignon PJ , Kimber FJ , Beckingham WD , Roberts JL . "Prevention of peripheral intravenous catheter-related bloodstream infections: the need for routine replacement." Med J Aust 2013; 199:750–1.

11. Delgado-Capel M , Gabillo A , Elías L , Yébenes JC , Sauca G , Capdevila JA . "Características de la bacteriemia relacionada con catéter venoso periférico en un hospital general". *Rev Esp Quimioter* 2012; 25:129–133.

12. Pujol M , Hornero A , Saballs M et al. "Clinical epidemiology and outcomes of peripheral venous catheter-related bloodstream infections at a university-affiliated hospital". *J Hosp Infect* 2007; 67:22–9.

13. Ana del Rio, Carlos Cervera, Asunción Moreno, Phillipe Moreillon, José M. Miró; Patients at Risk of Complications of *Staphylococcus aureus* Bloodstream Infection, *Clinical Infectious Diseases*, Volume 48, Issue Supplement_4, 15 May 2009, Pages S246–S253, https://doi.org/10.1086/598187

14. "Infective Endocarditis." *Practice Essentials, Background, Pathophysiology*, 2 Feb. 2019, emedicine.medscape.com/article/216650-overview.

15. Gasch, Oriol, et al. "Epidemiology of Methicillin-Resistant Staphylococcus Aureus (MRSA) Bloodstream Infection." *Medicine*, vol. 90, no. 5, 2011, pp. 319–327., doi:10.1097/md.0b013e31822f0b54.

16. Burton DC, Edwards JR, Horan TC, Jernigan JA, Fridkin SK. Methicillin-Resistant *Staphylococcus aureus* Central Line–Associated Bloodstream Infections in US Intensive Care Units, 1997-2007. *JAMA.*2009;301(7):727–736. doi:10.1001/jama.2009.153

17. (CDC), C.f.D.C.a.P., *Bloodstream Infection Event (Central Line-Associated Bloodstream Infection and Non-central Line Associated Bloodstream Infection)*. 2018.

18. Trick, W. E. "Decision Making During Healthcare-Associated Infection Surveillance: A Rationale for Automation." *Clinical Infectious Diseases*, vol. 57, no. 3, 2013, pp. 434–440., doi:10.1093/cid/cit249.