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The Effect of Chlorhexidine Gluconate Bathing on Central Line-Associated Bloodstream Infections and Mucosal Barrier Injury-Associated Bloodstream Infections on the Bone Marrow Transplant Unit at Emory University Hospital

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Abstract

The Effect of Chlorhexidine Gluconate Bathing on Central Line-Associated Bloodstream Infections and Mucosal Barrier Injury-Associated Bloodstream Infections on the Bone Marrow Transplant Unit at Emory University Hospital

By Kailey Freeman

Background: Central line-associated bloodstream infections (CLABSI) and mucosal barrier injury-associated bloodstream infections (MBI) are major complications for immunocompromised patients, particularly in bone marrow transplant (BMT) units. CLABSI prevention strategies often involve a bundled approach that includes chlorhexidine gluconate (CHG) bathing, but these strategies should not have an impact on MBI rates. Our study is an attempt to estimate the impact of the specific addition of CHG bathing on CLABSI and MBI rates on the BMT unit at Emory University Hospital.

Methods: This retrospective observational cohort study analyzed CLABSI and MBI events using prospectively collected surveillance data from January 2013-June 2022. Infection rates were calculated per 1,000 central line-days and interrupted time series (ITS) analyses using segmented regression models were performed on monthly rate data to evaluate changes before and after the July 2016 implementation of CHG bathing.

Results: A total of 346 bloodstream infections (187 MBIs and 159 CLABSIs) were identified. ITS analyses revealed a 44% immediate level decrease in CLABSI rates following CHG bathing implementation, though not statistically significant. The monthly trend in CLABSI rates showed a post-intervention decrease, though it lacked statistical significance. MBI rates also declined post-intervention with a statistically significant downward trend (-1.37% per month, $p=0.00015$). Infections associated with gram-positive bacteria showed a 34% immediate level decrease post-CHG bathing implementation, and a significant decline in monthly trend (-3.29% per month, $p=0.0061$). Gram-negative bacteria infections showed a similar trend.

Conclusion: CHG bathing was associated with decreased CLABSI and MBI rates, with the greatest impact observed in CLABSI reduction. Continued CHG bathing use is recommended in high-risk units. Future studies should explore compliance, patient education, and implementation across diverse healthcare facilities.

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Introduction

Central-lines (also known as a central venous catheter, or CVC) are catheters that access a major vein close to the heart and are used to administer medications and fluids or to draw blood.[1] Compared to peripheral catheters, central-lines tend to stay in place longer, often more than a week, and in some patients (e.g., organ transplant patients) for months, which makes them more prone to infection.[1] Infections of the bloodstream (BSI) that have no obvious primary source and are associated with a central-line are called central line-associated bloodstream infections (CLABSI). The cause of these infections are multifactorial but involve bacteria or fungi entering the bloodstream through the insertion site around a CVC, through contaminated fluids or materials, or through transient bacteria in the blood adhering (and propagating) to the CVC (1). In 2023, over 20,000 CLABSIs were reported across 3,707 general acute care hospitals in the United States.[2] Although this seems like a high burden, these values do represent progress on reductions in CLABSIs over the past decade. The CDC tracks progress through the National standardized infection ratio (SIR) for CLABSI across these hospitals, reported at 0.72 in 2023, representing a 28% reduction in CLABSI occurrence compared to the baseline period of 2015.[2] In Georgia, 711 CLABSIs were reported from 104 general acute care hospitals in 2023.[3] Georgia's CLABSI SIR was similar to the national SIR in 2023 (0.73 vs. 0.72), and only 10% of reporting hospitals in the state had an SIR above the national SIR overall.[3] In the United States, CLABSIs result in billions of dollars in added costs to the healthcare system, with an average cost of $46,000 per case.[4] A mucosal barrier injury-associated bloodstream infection (MBI) is a type of bloodstream infection (BSI), but the bacteria causing the infection stem from the gut and enter the bloodstream, rather than from the skin or environment into the bloodstream, like seen with a CLABSI.[5] Unlike CLABSIs, MBI reporting is not required, so there is very little public

data available about the prevalence of these infections in the United States and Georgia. The value for the infection prevention team in identifying MBIs is to ensure they are differentiated from CLABSIs as a cause of BSI and not reported to the National Healthcare Safety Network (NSHN) as CLABSIs in error, avoiding the appearance of excessively high CLABSI rates in their reports. The rationale for this is because MBIs are presumed to not be related to infection prevention practice in place to prevent CLABSIs.

CLABSI risk factors include prolonged hospitalization, duration of catheter use, and immunosuppression, but are directly related to lapses in best practice of catheter care.[6] MBI risk factors include neutropenia, graft vs. host disease, prolonged hospitalization, immunosuppression, and any factors that promote migration of bacteria from the enteric system (i.e., the gut) through a damaged mucosal surface, into the bloodstream.[7] Bone marrow transplant patients have a heightened risk for developing a CLABSI (through prolonged CVC use) or a MBI (through mucosal surfaces damaged by chemotherapy). Compared to other hospitalized patients, these patients often suffer from severe immunosuppression, have longer hospital stays than other patients (averaging about 1-month long stays post-transplant), and are more likely to have a CVC in place than other patients, therefore heightening their risk for infection.[8] Additionally, the chemotherapy and radiation treatments that these patients often undergo damages the mucosal lining of the GI tract, which allows the gut bacteria to translocate into the bloodstream, which increases the risk of developing an MBI.[8]

All CLABSIs are targeted for prevention and prevention often includes multiple interventions within a bundle.[9] An insertion bundle typically includes performing proper hand hygiene, using maximal barrier precautions, adhering to aseptic technique, choosing the best insertion site, and chlorhexidine gluconate (CHG) bathing.[10] Central-line maintenance bundles

typically include proper hand hygiene, daily assessments for necessity, replacing wet, soiled, or dislodged dressings, and the use of aseptic technique when handling the line.[10] Other CLABSI prevention practices include promptly removing unnecessary central lines, staff education and training, and audit and feedback programs or checklists to monitor compliance with various aspects of these practices.[10] Because the bacteria causing MBIs typically originates from the gut, CLABSI prevention mechanisms should not have an impact on MBI rates. Instead, MBI prevention tends to focus on optimizing gastrointestinal health, including by avoiding unnecessary antibiotic prescriptions that may disrupt the gut microbiota and implementing rapid diagnostic testing for early pathogen detection.[11] CHG is a skin disinfectant and the practice of CHG bathing involves bathing the entire body with CHG once per day, often in the form of a wipe or cloth.[12] The goal of CHG bathing is to decrease the bioburden of bacteria on the skin, thereby reducing the risk of CLABSIs in patients, particularly in high-risk patients.[12]

Since CLABSI and MBI prevention commonly involves implementing multiple interventions at once, also known as a bundled approach, it is often difficult to determine the effect of a specific intervention. Our study is an attempt to estimate the impact of the specific addition of CHG bathing on CLABSI and MBI rates on the bone-marrow transplant (BMT) unit at Emory University Hospital (EUH).

Methods

Study Design

We conducted a retrospective observational cohort study of all patients receiving care on the inpatient BMT at EUH from January 2013 through June 2022.

Primary Data Source

Data were extracted from the EUH Infection Prevention database. This database is populated with surveillance data extracted and maintained by the EUH Infection Prevention team, which performs prospective surveillance for BSIs using standardized National Healthcare Safety Network (NHSN) methodology. An infection is classified as a CLABSI if it is "a laboratory confirmed bloodstream infection (LCBI) where an eligible bloodstream infection organism is identified, and an eligible central line is present on the LCBI date of event or the day before."[13] An infection is classified as a MBI when it meets the criteria for a CLABSI, and the patient is neutropenic or has gastrointestinal signs of graft versus host disease, and either commensal organisms or organisms from the MBI NHSN organism list are present."[13] An infection was counted as a BSI if it was classified as either a CLABSI or an MBI for the purposes of this study. In addition to the MBI and CLABSI stratification, infections were also stratified into a gram-positive bacteria (GPB) group and/or a gram-negative bacteria (GNB) group. An infection was classified as a GPB if at least one of the organisms associated with the infection was gram-positive. An infection was classified as a GNB if at least one of the organisms associated with the infection was gram-negative. Infections could fall under both of these categories if multiple organisms were associated with the infection. The denominator of patient-days was defined as the number of calendar days all patients spent on the BMT unit at EUH during the month, regardless of infection status. The denominator of central line-days was defined as the number of calendar days patients on the BMT unit at EUH had central lines in place during the month, regardless of infection status.

Through review of minutes and interviews with staff, we compiled a list of practice changes and interventions that were implemented during the study period. The primary

intervention of interest in our study is a change in CHG bathing practices (use of SAGE cloth for bathing), which was implemented in July 2016. Secondary interventions of interest include a change in hand hygiene practices (implemented quarter 2 of 2019) and improved blood culture techniques (implemented quarter 4 of 2020).

Statistical Analysis

Statistical analysis began with conducting chi square tests between categorical variables, like device type (permanent central line, temporary central line, etc.), and three different infection classes: MBI, CLABSI, and all BSIs (MBI + CLABSI). Wilcoxon signed rank tests were run on continuous variables including: days from hospital admission to presence of an infection. These analyses were conducted using per-event data, rather than a monthly, quarterly, or yearly dataset. These analyses were conducted using SAS 9.4 (Cary Institute, Cary, NC).

The event data was then transformed into monthly, quarterly, and yearly datasets and rates were calculated for all BSIs, MBIs, CLABSIs, GPBs, and GNBs per 1000 patient-days and 1000 central line-days. Rates were also calculated for MBIs associated with a permanent central line, MBIs associated with a temporary central line, CLABSIs associated with a permanent central line, and CLABSIs associated with a temporary central line per 1000 patient-days and per 1000 central line-days. Figures were created to compare count and rate data across each of the categories, as well as compare data across categories (i.e., comparing MBI and CLABSI rates per 1000 central line-days, comparing MBIs with a permanent central line vs. MBIs with a temporary central line, etc.). Each figure includes a vertical line at the time point when CHG bathing was introduced. Vertical lines for the introduction of new hand hygiene protocols and improved blood culture techniques were also included. A fourth vertical line was included,

showing the point in time when the BMT unit was moved to a new building, which doubled the number of beds in the BMT unit. This change of location occurred in quarter 4 of 2017. All data transformations, rate calculations, and figures were created using Microsoft Excel.

A series of interrupted time-series (ITS) analyses were conducted on 114 observations, each observation representing one month of data during the study period, for which were varied between the different infection rates. The ITS focused primarily on the CHG bathing intervention, which was implemented in July 2016. Five ITS models were run, looking at the effect of CHG bathing on BSIs MBIs, CLABSIs, events associated with gram-positive bacteria (GPB), and events associated with gram-negative bacteria (GNB) per 1,000 central line-days. The intervention month was defined as the month CHG bathing was started, which was implemented on the BMT unit at EUH in July 2016, during month 43 of the study period. We chose not to define any wash-in period, as reportedly the intervention was implemented as a required nursing step early in this month. Originally, these models were run using a Poisson distribution, but the dispersion statistics were all much greater than 1, suggesting overdispersion. To account for the overdispersion, the models were rerun using a negative binomial distribution, which brought the dispersion statistic closer to 1 for all 5 models. All five of the analyses that were conducted used the monthly dataset, which included 42 data points before CHG bathing was implemented and 72 data points after CHG bathing was implemented. All five of the analyses were conducted using a similar model, with the outcome changing for each model. The following model was used in the analyses:

$$ln(rate\ of\ outcome) = \beta_0 + \beta_1 Month + \beta_2 Intervention + \beta_3 Month\ after\ intervention$$

Where:

- **Rate of outcome** is the primary outcome for the model that is currently being run. The five outcomes analyzed were: rate of total BSI per 1000 central line-days, rate of MBI per 1000 central line-days, rate of CLABSI per 1000 central line-days, rate of GPB per 1000 central line-days, and rate of GNB per 1000 central line-days.
- β_0 estimates the baseline level of the outcome at month 0.
- β_1 estimates the slope of the outcome over time before CHG bathing was implemented.
- **Month** is a continuous variable that indicates the number of the month since the study period began in January 2013 (January 2013 is 1, February 2013 is 2, etc.).
- β_2 estimates the change in level directly after the intervention was introduced.
- **Intervention** is the binary indicator for the CHG bathing intervention, which is coded as 0 for when the intervention was not in place and 1 for when the intervention was in place.
- β_3 estimates how the trend changes (slope changes) before and after CHG bathing was implemented. The sum of $\beta_1 + \beta_3$ estimates the slope after CHG bathing was introduced.
- **Month after intervention** is a continuous variable that is coded as 0 when the intervention was not implemented (January 2013-June 2016), and then indicates the number of months after July 2016 (coded as 0 before July 2016, then coded as 1 for July 2016, 2 for August 2016, etc.).

There was no need to account for seasonality in our ITS analyses because it is not part of the biologic plausibility of these types of infections. Additionally, we did not account for autocorrelation in our analyses because monthly data is less likely to be autocorrelated than weekly or daily data. Lastly, we did not include an offset for central line-days because the ITS analysis was conducted on a single value of the rate of infections for each month and the rate value already includes the central line-days data in the denominator. A p-value of less than 0.05

was considered statistically significant. SAS version 9.4 (Cary Institute, Cary, NC) was used to conduct all ITS analyses and Microsoft Excel was used to create all figures.

Lastly, the segmented regression models that were used compare trends before and after an intervention is implemented over time. The main goal of this type of regression is to determine if there is an immediate level change in the regression lines before and after the intervention has been implemented and/or to determine if there has been a change in slope before and after the intervention has been implemented.[14] The beta values from our ITS equation explain the effect of the intervention on the logarithmic scale of the outcome, so in order to determine the pre and post-intervention slopes, the level change, and the slope change, we must exponentiate the beta values, which produces rate ratios. By exponentiating the beta values, the effect of the intervention translates back to the original scale of the outcome, in this case, the rate per 1000 central line-days. Because of this, when running the ITS analysis in SAS 9.4 (Cary Institute, Cary, NC), we included code that automatically exponentiated all of the beta values, as well as the sum of $\beta_1 + \beta_3$ (which gives us the post-intervention slope).

Results

Summary Statistics

A total of 346 BSIs (sum of CLABSIs and MBIs) occurred on the EUH BMT unit during the study period (Table 1): 187 MBIS and 159 CLABSIs. MBIs were less likely to have multiple pathogens, to have a GPB associated with the infection, and to have temporary (indwelling) central venous catheters compared to CLABSIs (Table 1). A majority of devices in place on EUH BMT during the study period were permanent (implanted) (68.12)%. All infections associated with a dialysis device were classified as a CLABSI. The median time from admission

to infection was the same for MBIs and CLABSIs at 13 days. Both infections shared the same 25% quartile (10 days), but the 75% quartile was higher for CLABSIs than MBIs (MBI: 16 days vs. CLABSI: 18 days). The number of days from hospital admission to infection was deemed statistically significant, with the p-value<0.0001.

Data Exploration

As shown in Figure 1, the yearly rate of BSIs per 1000 central line-days and per 1000 patient-days followed a similar trend. Similarly to Figure 1, Figure 2 shows that the yearly rate of MBIs per 1000 central line-days and per 1000 patient-days followed a similar trend. The highest MBI rate per 1000 central line-days was 3.31 and the highest rate per 1000 patient-days was 3.07, both of which occurred in 2016. Like Figures 1 and 2, Figure 3 shows a similar trend with the CLABSI rate per 1000 central line-days. The highest CLABSI rates per 1000 central-line days and 1000 patient-days occurred in different years. The highest CLABSI rate per 1000 central line-days was 2.49 and occurred during 2021, while the highest CLABSI rate per 1000 patient-days was 2.27 and occurred in 2016. Noticeably, in the later years, there is some discordance in the trends with CLABSI rates increasing in 2021 while MBI rates steadily decreased.

Figures 4, 5, and 6 all show that the rate per 1000 central line-days is higher than the rate per 1000 patient-days, however, these values tend to overlap/have a very small gap in between them. Generally, compared to annual rates (Figures 1-3), quarterly rates have greater variability between quarters. Figure 4 shows the highest quarterly BSI rate per 1000 central line-days was 8.19, which occurred in quarter 14, and the highest quarterly BSI rate per 1000 patient-days also occurred in quarter 14, but was 7.78 BSIs per 1000 patient-days. Quarterly MBI rates per 1000

central line-days peaked at 5.67 in quarter 19 and the rate per 1000 patient-days also peaked in quarter 19, but at the slightly lower rate of 4.98 MBIs per 1000 patient-days, as seen in figure 5. Figure 6 highlights the quarterly CLABSI rates per 1000 central line-days and per 1000 patient-days, with the rate per 1000 central line-days peaking at 4.80 and the rate per 1000 patient-days peaking at 4.35, both of which occurred in quarter 11.

Figure 7 shows the quarterly BSI case count, GPB rate per 1000 central line-days, and GNB rate per 1000 central line-days. The rate of infections associated with at least 1 GPB per 1000 central line-days peaks at 4.34 during quarter 14. The rate of infections associated with at least 1 GNB per 1000 central line-days also peaks in quarter 14, but at 3.86 infections associated with at least 1 GNB per 1000 central line-days.

Interrupted Time Series Analysis

Results of the interrupted time series analysis using a segmented regression model for BSIs are displayed in Figure 8 and Table 2. Before the implementation of CHG bathing, the rate of BSIs per 1000 central line-days increased by 3.3% per month (p-value<0.0001). Immediately after the intervention was implemented, the rate of BSIs per 1000 central line-days was 78.42% of the rate before CHG bathing was implemented. This indicates a decrease of 21.58% in the monthly rate of BSIs per 1000 central line-days immediately after CHG bathing was introduced, however, this finding was not statistically significant (p-value=0.2742). After CHG bathing was implemented, the rate of BSIs per 1000 central line-days decreased by 0.82% per month (p-value=0.0197). The change in trend before and after the introduction of CHG bathing decreased by 4% (p-value<0.0001).

Results of the interrupted time series analysis using a segmented regression model for MBIs are displayed in Figure 9 and Table 3. The rate of MBIs per 1000 central line-days increased by 5.41% per month before the implementation of CHG bathing (p-value<0.0001). Immediately after the introduction of CHG bathing, the rate of MBIs per 1000 central line-days was 93.29% of the rate before the intervention was implemented, which indicates a decrease of 6.71%, however, this was not a statistically significant reduction in the monthly rate of MBIs per 1000 central line-days (p-value=0.8000). The rate of MBIs per 1000 central line-days decreased by 1.37% per month after the introduction of CHG bathing on EUH BMT (p-value=0.0015). The change in trend before and after the introduction of CHG bathing decreased by 6.43% per month (p-value<0.0001).

Results of the interrupted time series analysis using a segmented regression model for CLABSIs are displayed in Figure 10 and Table 4. The model run on the rate of CLABSIs per 1000 central line-days shows an increase of 1.98% per month before CHG bathing was implemented, but this was not found to be statistically significant (p-value=0.0873). Immediately after the introduction of CHG bathing, the rate of CLABSIs per 1000 central line-days was 55.55% of the rate before the intervention was implemented. This indicates a decrease of 44.45% in the monthly rate of CLABSIs per 1000 central line-days immediately after CHG bathing was introduced, however, this finding was not statistically significant (p-value=0.0876). After CHG bathing was implemented, the rate of CLABSIs per 1000 central line-days decreased by 0.09% per month, however, this was not a statistically significant finding (p-value=0.8721). The change in trend for the rate of CLABSIs per 1000 central line-days before and after the introduction of CHG bathing decreased by 2.03% per month, but this was not a statistically significant finding (p-value=0.1066).

Results of the interrupted time series analysis using a segmented regression model for GPBs are displayed in Figure 11 and Table 5. Before the implementation of CHG bathing, the rate of infections associated with at least 1 GPB per 1000 central line-days increased by 3.1% per month (p-value=0.0065). Directly after CHG bathing was implemented, the rate of infections associated with at least 1 GPB per 1000 central line-days was 65.85% of the rate before CHG bathing was implemented. This shows a decrease of 34.15% in the monthly rate of infections associated with at least 1 GPB per 1000 central line-days immediately after CHG bathing was introduced, but this finding was not considered statistically significant (p-value=0.1740). After the implementation of CHG bathing, the rate of infections associated with at least 1 GPB per 1000 central line-days decreased by 0.29% per month, but this finding was also not statistically significant (p-value=0.5407). The change in trend for the rate of infections associated with at least 1 GPB per 1000 central line-days before and after CHG bathing was introduced decreased by 3.29% per month (p-value=0.0061).

Results of the interrupted time series analysis using a segmented regression model for GNBs are displayed in Figure 12 and Table 6. The rate of infections associated with at least 1 GNB per 1000 central line-days increased 3.01% per month prior to CHG bathing implementation on EUH BMT (p-value=0.0049). Immediately after the introduction of CHG bathing, the rate of infections associated with at least 1 GNB per 1000 central line-days was 96.75% of the rate before CHG bathing was implemented. This indicates a decrease of 3.25% in the monthly rate of infections associated with at least 1 GNB per 1000 central line-days, however this finding was not statistically significant (p-value=0.9044). After CHG bathing was introduced, the rate of infections associated with at least 1 GNB per 1000 central line-days decreased by 1.12% per month (p-value=0.0103). The change in trend for the rate of infections

associated with at least 1 GNB per 1000 central line-days before and after CHG bathing was introduced decreased by 4.01% per month (p-value=0.0003).

Discussion

Unfortunately, we did not see a statistically significant immediate level change for any of the five ITS analyses that were conducted. Despite this, the biggest effect of CHG bathing was seen on CLABSI rates, with a decrease of 44% immediately following the intervention introduction, compared to the 7% decrease that was seen for MBIs. This finding is consistent with the goal of CHG bathing and other evidence.[15-17] When looking at the rate of BSIs overall, we saw an immediate decrease of 22% following the introduction of CHG bathing, which is half of the decrease that was seen with CLABSI rates. This finding shows the importance of stratifying BSIs by CLABSIs and MBIs when assessing the impact of CHG bathing. Additionally, we were surprised to learn that CHG bathing had an effect on the monthly MBI rates at all. This is because MBI pathogens originate from the gut and CHG is a skin disinfectant, so one would hypothesize that CHG bathing only impacts CLABSI rates and not MBI rates.[18] However, other interventions were implemented during the study period, like improved blood culture techniques, which could have impacted this. Additionally, when comparing the immediate effect of CHG bathing on GPB and GNB, we see a much larger decrease for GPB (35%) compared to GNB (3%). CLABSIs are more likely to be associated with GPB compared to GNB and MBIs are more often associated with GNB instead of GPB, so these findings are consistent with the goal of CHG bathing and our findings for CLABSI and MBI rates.[19]

Each ITS analysis showed a statistically significant change in slope, which went from positive to negative (excluding CLABSI, which was not a statistically significant change). With

ongoing quality improvement overall, as well as quality improvement regarding proper training on and compliance with CHG bathing guidelines, a downward slope was expected. Additionally, the post-intervention trend of each ITS analysis shows a consistent and statistically significant decrease in the monthly rates of infection over time (CLABSI and GPB show the same phenomena, though the findings were not statistically significant). CHG bathing is an intervention that we would expect to get better over time as employees adopt the intervention, become more compliant with the protocols, and get better at working with the patients, which is consistent with our findings.[20]

This study has several limitations. One limitation is that we did not include a lag period directly after the introduction of CHG bathing in the ITS analyses to account for the practice change. If a lag period was included, we may have seen a statistically significant immediate level change in the rates of infections across all 5 analyses. Another limitation is that there was no adjustment for autocorrelation in the ITS analyses, which could have led to more statistically significant findings for each analysis. The lack of statistically significant findings were likely not caused by a power issue within the study, since 114 data points were used for the analysis. One cause of this could be a lack of data on compliance with CHG bathing, meaning we do not know if it took one month to ensure compliance, several months before the practice was successfully initiated, or if everyone providing catheter care complied with protocols in the same manner or as often as one another. If compliance data was available, we likely would have seen more statistically significant findings and could have determined if the observed effect on MBI rates was due to improved compliance over time or other, unmeasured quality improvement initiatives. In 2014, the NHSN case definition for a CLABSI was updated to include distinctions for MBIs. Because of this, research staff reviewed the data from 2013 and determined if the

infection was a CLABSI or an MBI based on the new case definition and the medical records. Over time, reporting of BSIs to the infection prevention team may have changed, with fewer cases being reported over time, related to negative consequences of publicly reported CLABSI rates, making it a fourth limitation.

In conclusion, the implementation of CHG bathing led to a decrease in monthly CLABSI rates per 1000 central line-days and monthly MBI rates per 1000 central line-days, with a larger decrease seen in the CLABSI rates. Based on this finding, CHG bathing should continue to be used on the BMT unit and additional units should adopt this intervention, especially if the unit has high CLABSI rates. To better assess the impact of CHG bathing as an intervention, compliance should be measured via random audits of CHG bathing practices, ensuring staff complete a CHG application checklist, or reviewing medical records for indication of CHG bathing. In the BMT unit, the patients are typically self-bathing and are able to move around freely, so patient education should also be provided, as this can impact the likelihood of infection. In the future, more studies should be conducted in different types and sizes of healthcare facilities and on different types of units in order to gain a better understanding of the impact of CHG bathing on CLABSI and MBI rates.

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Tables and Figures

Table 1. Summary statistics.

Variable	Total BSI (N=346)	MBI (N=187)	CLABSI (N=159)	p-value
Multiple Organisms Identified – N (%)	57 (16.47)	21 (11.23)	36 (22.64)	0.0043
GPB – N (%)	172 (49.71)	68 (36.36)	104 (65.41)	<0.0001
GNB – N (%)	184 (53.18)	123 (65.78)	61 (38.36)	<0.0001
Both GPB and GNB Identified – N (%)	27 (7.80)	10 (5.35)	17 (10.69)	0.0647
Device Type – N (%)				0.0025
Permanent/Implanted	235 (68.12)	139 (74.33)	96 (60.76)	
Temporary/Indwelling	99 (28.70)	46 (24.60)	53 (33.54)	
Dialysis	8 (2.32)	0 (0.00)	8 (5.06)	
Other/Unspecified	3 (0.87)	2 (1.07)	1 (0.63)	
Days to Infection – median (IQR)	13 (10-17)	13 (10-16)	13 (10-18)	<0.0001

*All p-values were determined with a chi square test, except for Days to Infection, which was determined with a Wilcoxon Signed Rank test.
*For Device Type, N=345 for Total BSI, not 346.

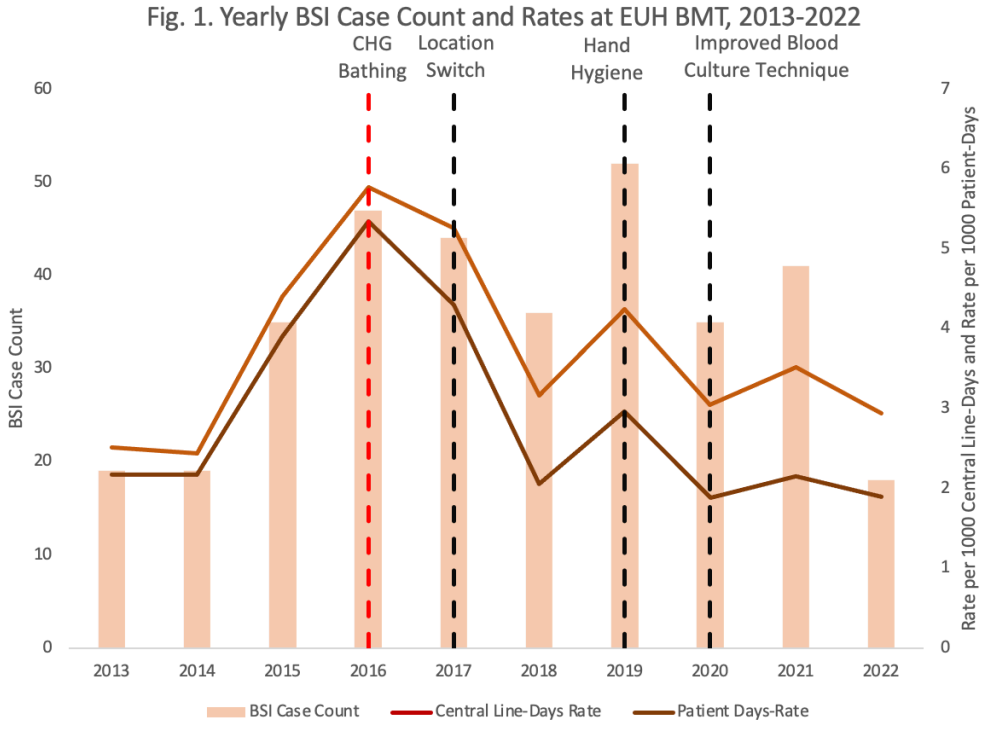

Figure 1. Yearly BSI case counts and rates at EUH BMT, 2013-2022

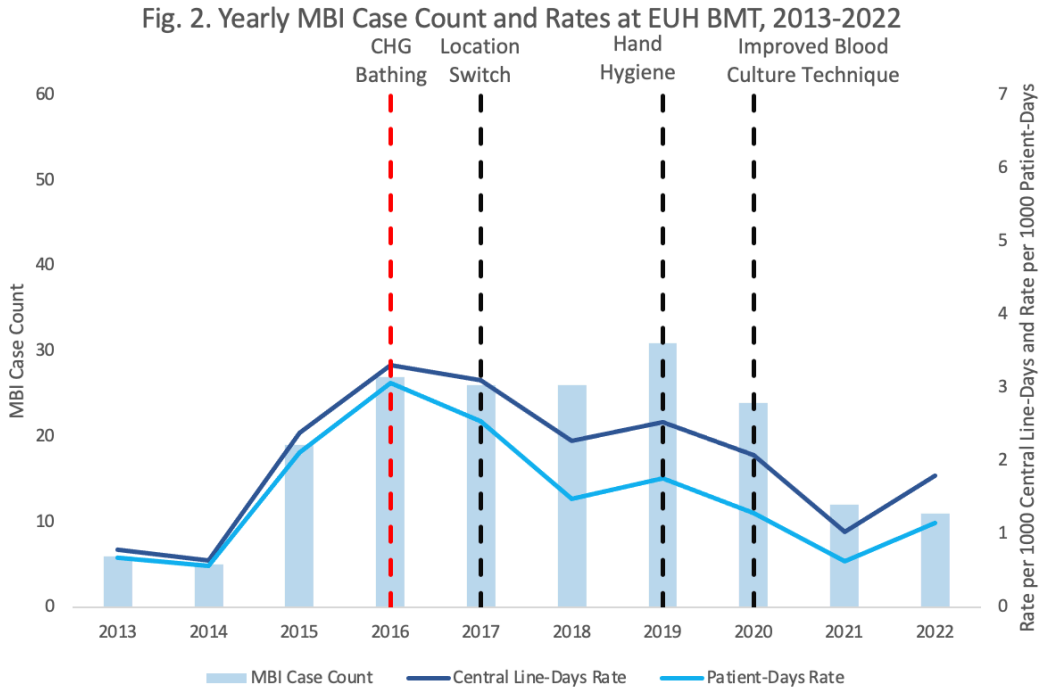

Figure 2. Yearly MBI case counts and rates at EUH BMT, 2013-2022

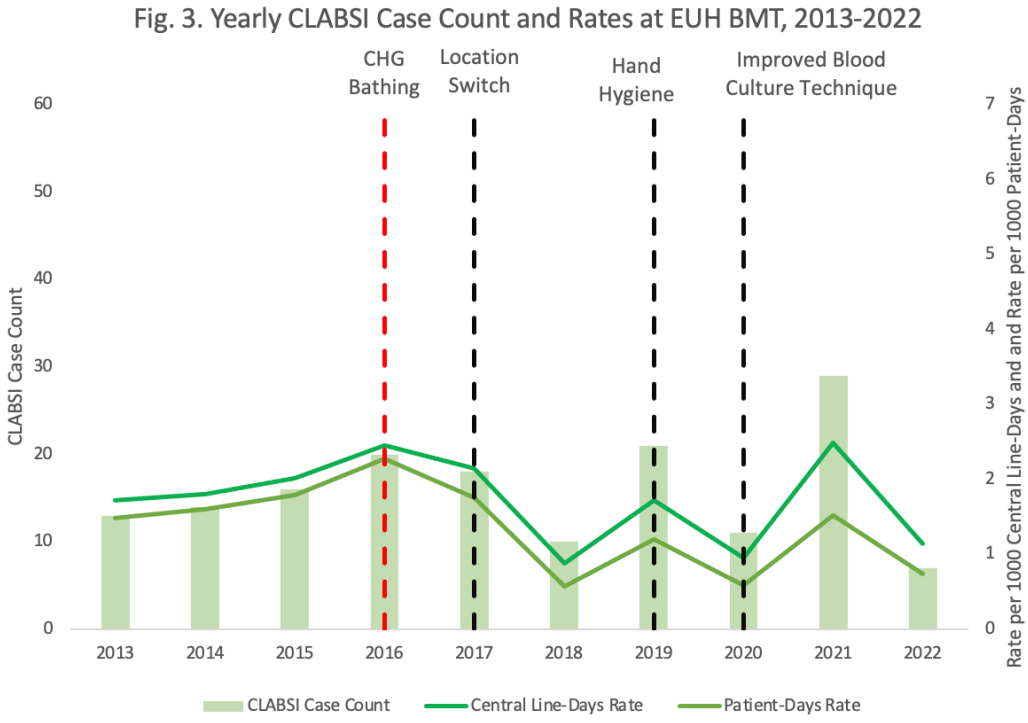

Figure 3. Yearly CLABSI case counts and rates at EUH BMT, 2013-2022

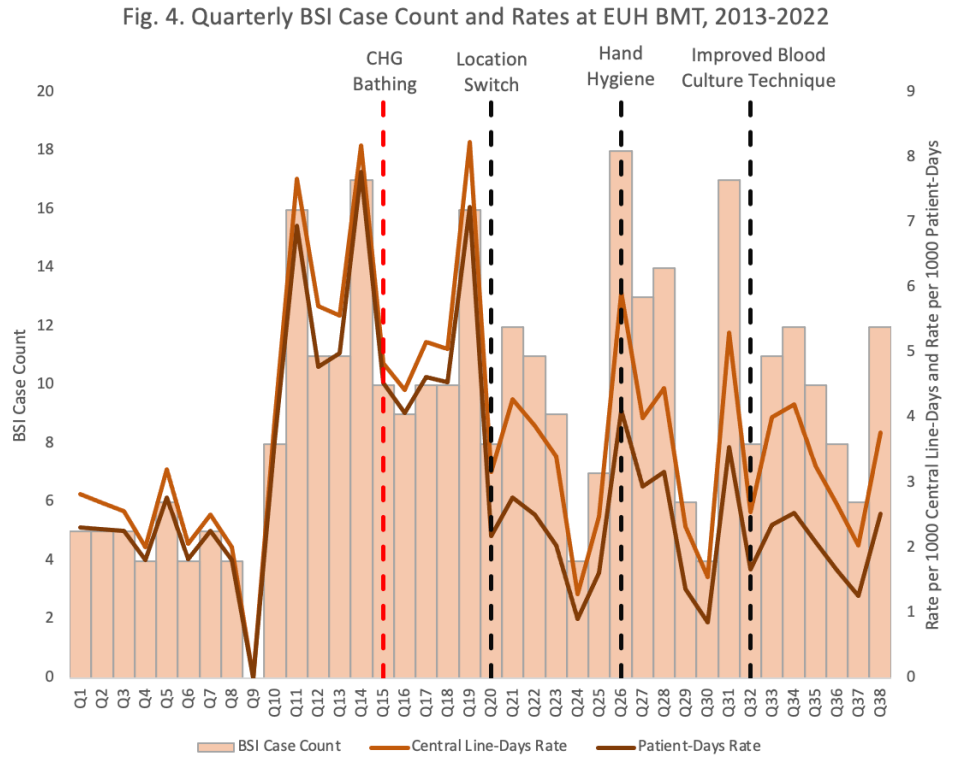

Figure 4. Quarterly BSI case counts and rates at EUH BMT, 2013-2022

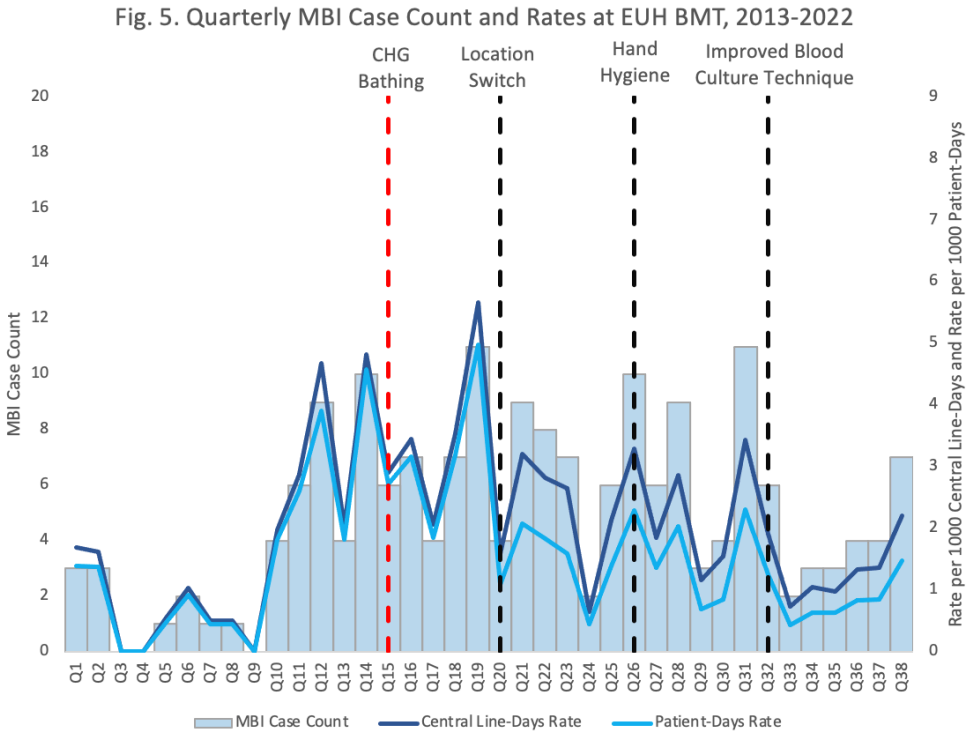

Figure 5. Quarterly MBI case counts and rates at EUH BMT, 2013-2022

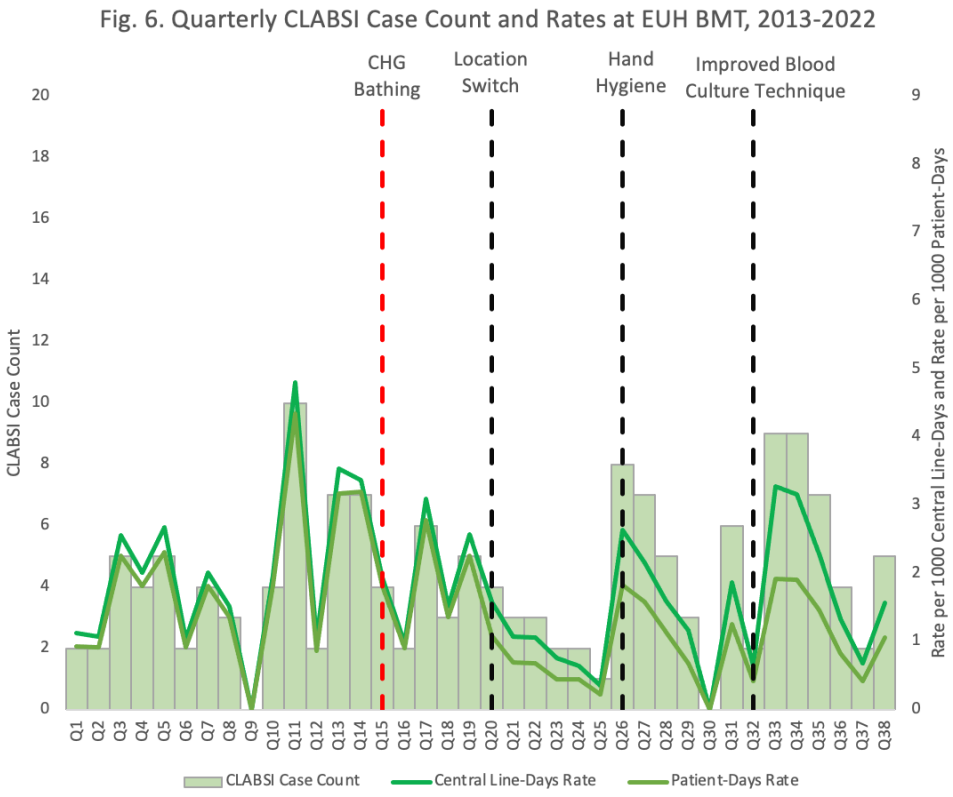

Figure 6. Quarterly CLABSI case counts and rates at EUH BMT, 2013-2022

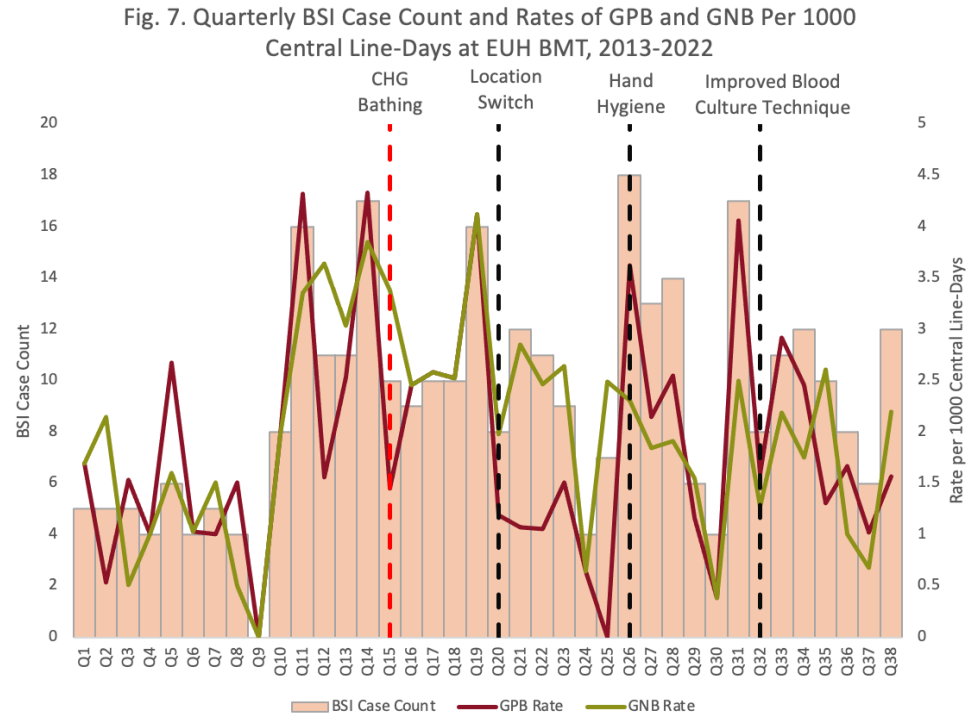

Figure 7. Quarterly BSI case count and GPB and GNB rates per 1000 central line-days.

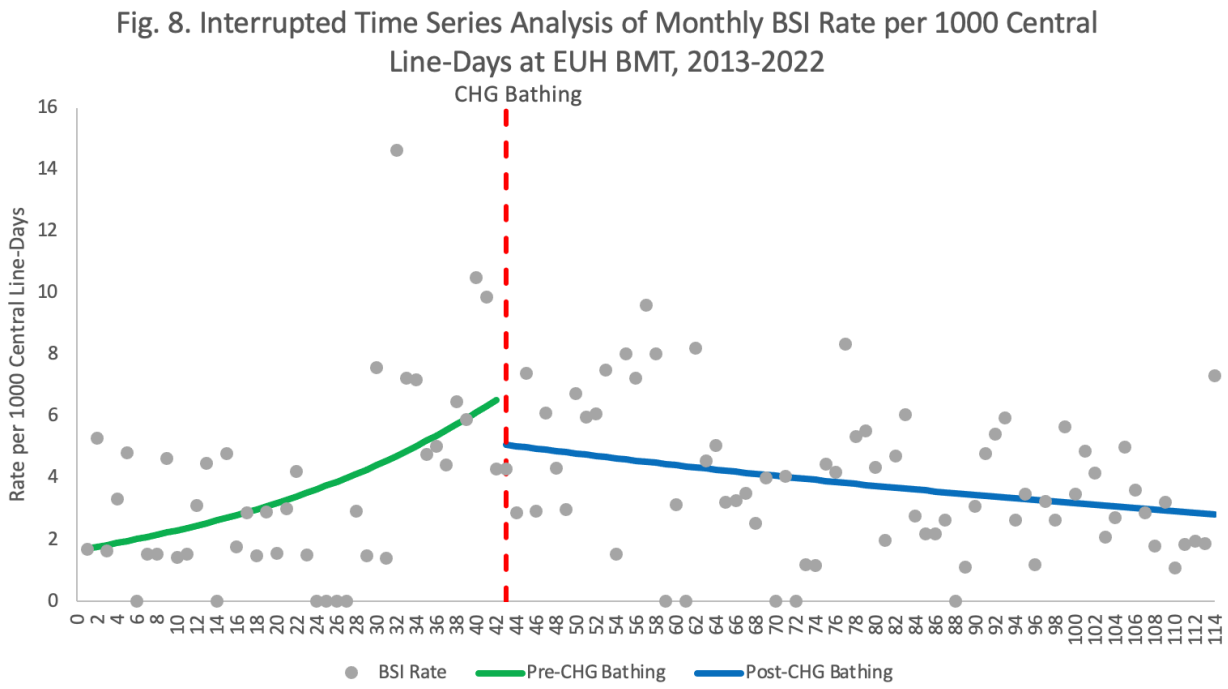

Figure 8. Interrupted time series analysis of monthly BSI rates per 1000 central line-days.

Table 2. Interrupted time series analysis of monthly BSI rates per 1000 central line-days.

Outcome	Parameter Estimate	Rate Ratio (RR)	95% Confidence Interval for RR	p-value
BSI Rate per 1000 Central Line-Days				
Pre-Intervention Slope (β_1)	0.0326	1.0331	1.0166, 1.0499	<0.0001
Immediate Level Change (β_2)	-0.2431	0.7842	0.5073, 1.2124	0.2742
Post-Intervention Slope ($\beta_1+\beta_3$)	-0.0082	0.9918	0.9850, 0.9987	0.0197
Slope Change (β_3)	-0.0408	0.9600	0.9433, 0.9770	<0.0001

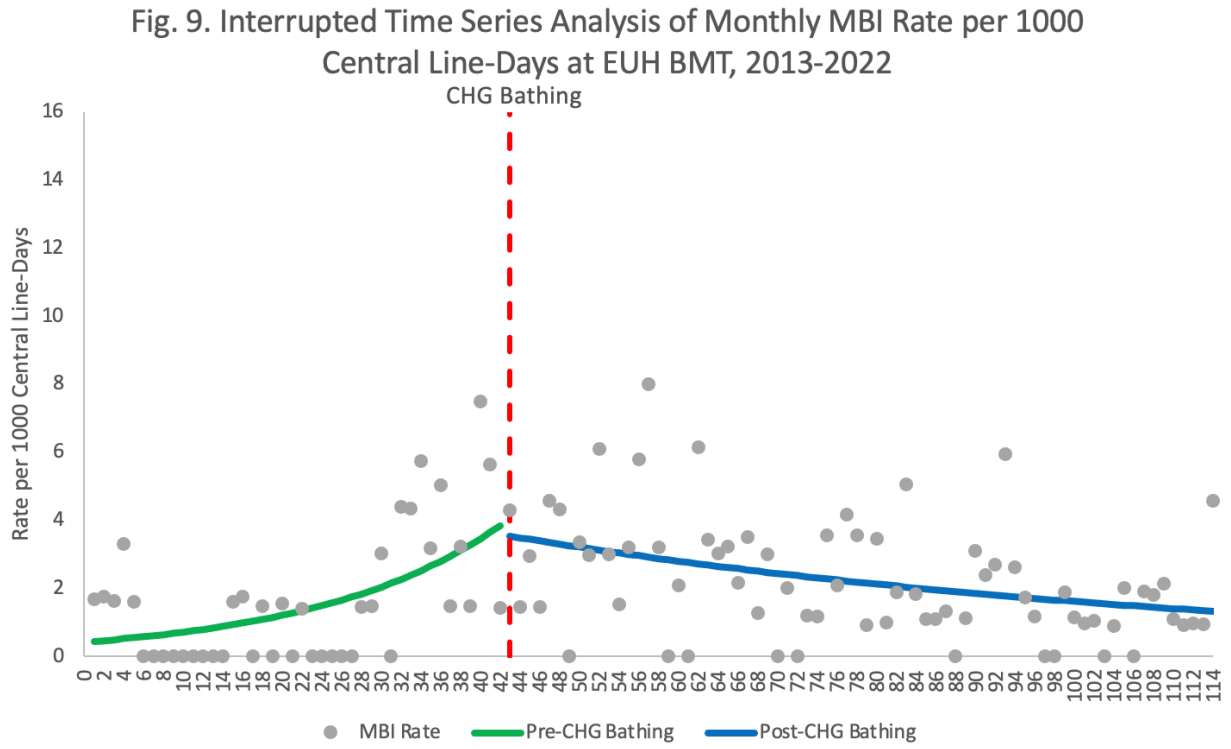

Figure 9. Interrupted time series analysis of monthly MBI rates per 1000 central line-days.

Table 3. Interrupted time series analysis of monthly MBI rates per 1000 central line-days.

Outcome	Parameter Estimate	Rate Ratio (RR)	95% Confidence Interval for RR	p-value
MBI Rate per 1000 Central Line-Days				
Pre-Intervention Slope (β_1)	0.0527	1.0541	1.0291, 1.0798	<0.0001
Immediate Level Change ($\beta 2$)	-0.0694	0.9329	0.5453, 1.5961	0.8000
Post-Intervention Slope ($\beta_1+\beta_3$)	-0.0138	0.9863	0.9780, 0.9947	0.0015
Slope Change (β_3)	-0.0665	0.9357	0.9121, 0.9598	<0.0001

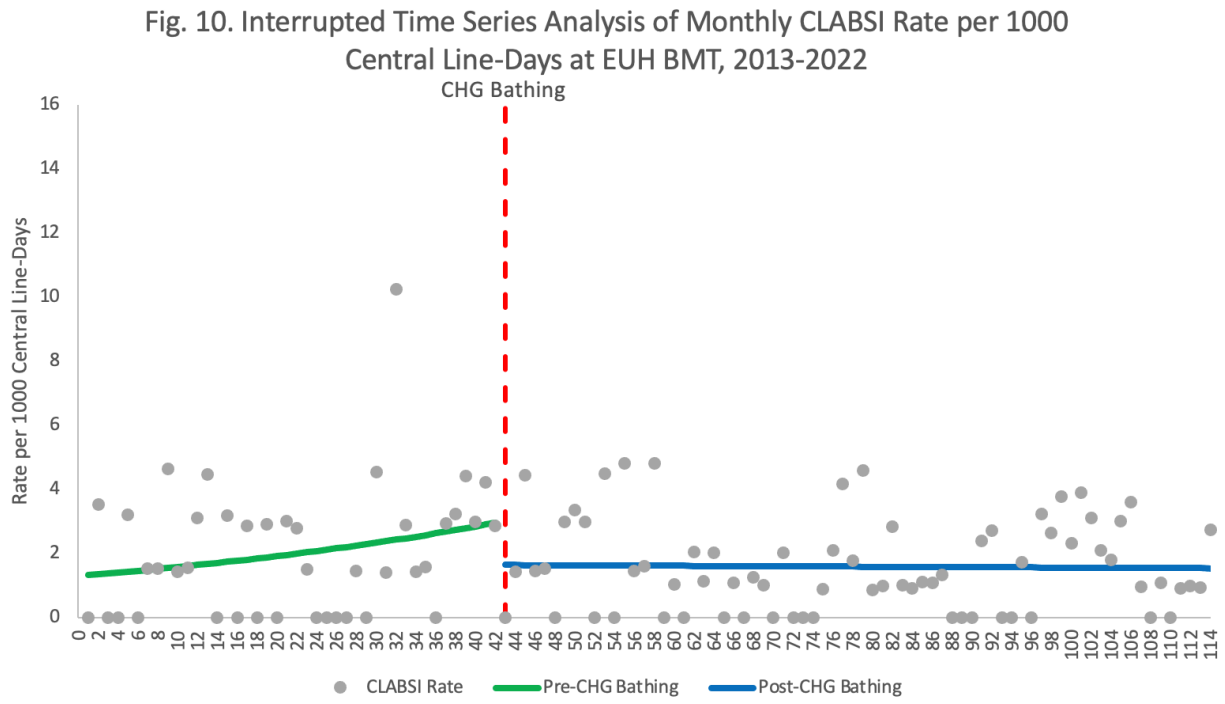

Figure 10. Interrupted time series analysis of monthly CLABSI rates per 1000 central line-days.

Table 4. Interrupted time series analysis of monthly CLABSI rates per 1000 central line-days.

Outcome	Parameter Estimate	Rate Ratio (RR)	95% Confidence Interval for RR	p-value
CLABSI Rate per 1000 Central Line-Days				
Pre-Intervention Slope (β_1)	0.0196	1.0198	0.9971, 1.0431	0.0873
Immediate Level Change ($\beta 2$)	-0.5879	0.5555	0.2830, 1.0904	0.0876
Post-Intervention Slope ($\beta_1+\beta_3$)	-0.0009	0.9991	0.9885, 1.0099	0.8721
Slope Change (β_3)	-0.0205	0.9797	0.9556, 1.0099	0.1066

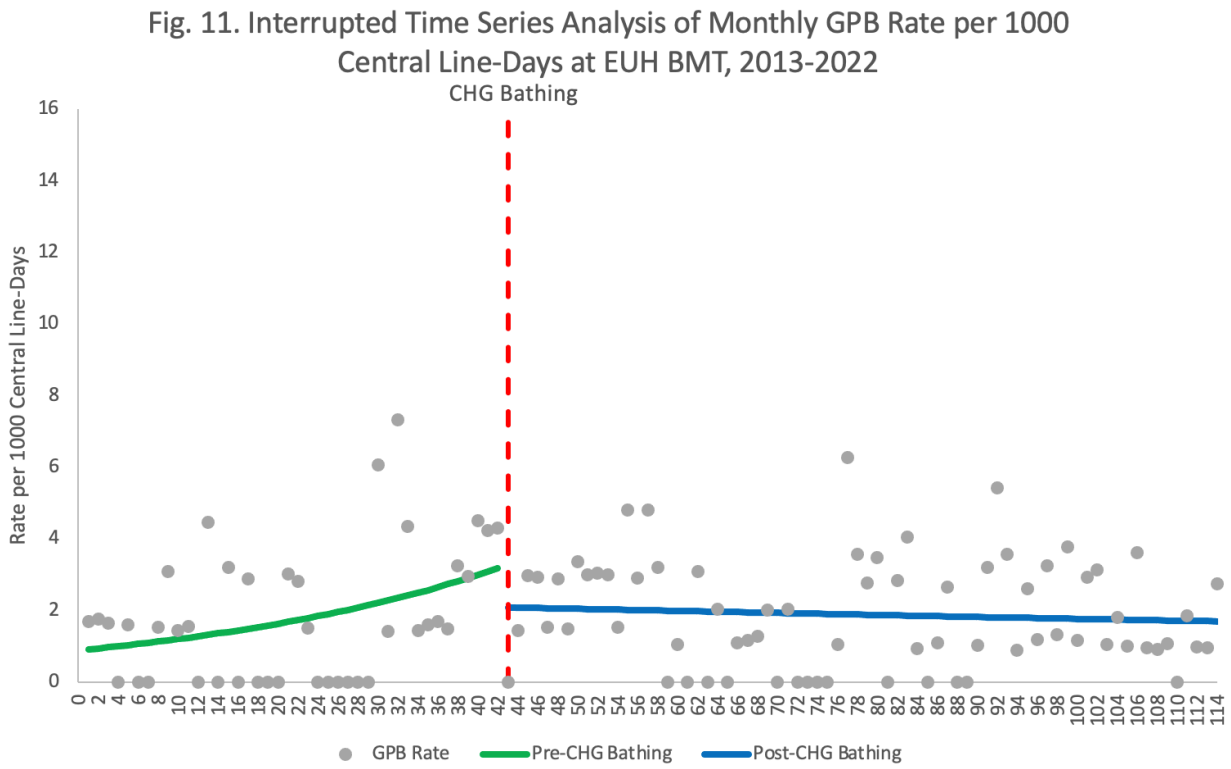

Figure 11. Interrupted time series analysis of monthly GPB rates per 1000 central line-days.

Table 5. Interrupted time series analysis of monthly GPB rates per 1000 central line-days.

Outcome	Parameter Estimate	Rate Ratio (RR)	95% Confidence Interval for RR	p-value
GPB Rate per 1000 Central Line Days				
Pre-Intervention Slope (β_1)	0.0305	1.0310	1.0086, 1.0538	0.0065
Immediate Level Change ($\beta 2$)	-0.4179	0.6585	0.3605, 1.2027	0.1740
Post-Intervention Slope ($\beta_1+\beta_3$)	-0.0030	0.9971	0.9877, 1.0065	0.5407
Slope Change (β_3)	-0.0334	0.9671	0.9443, 0.9950	0.0061

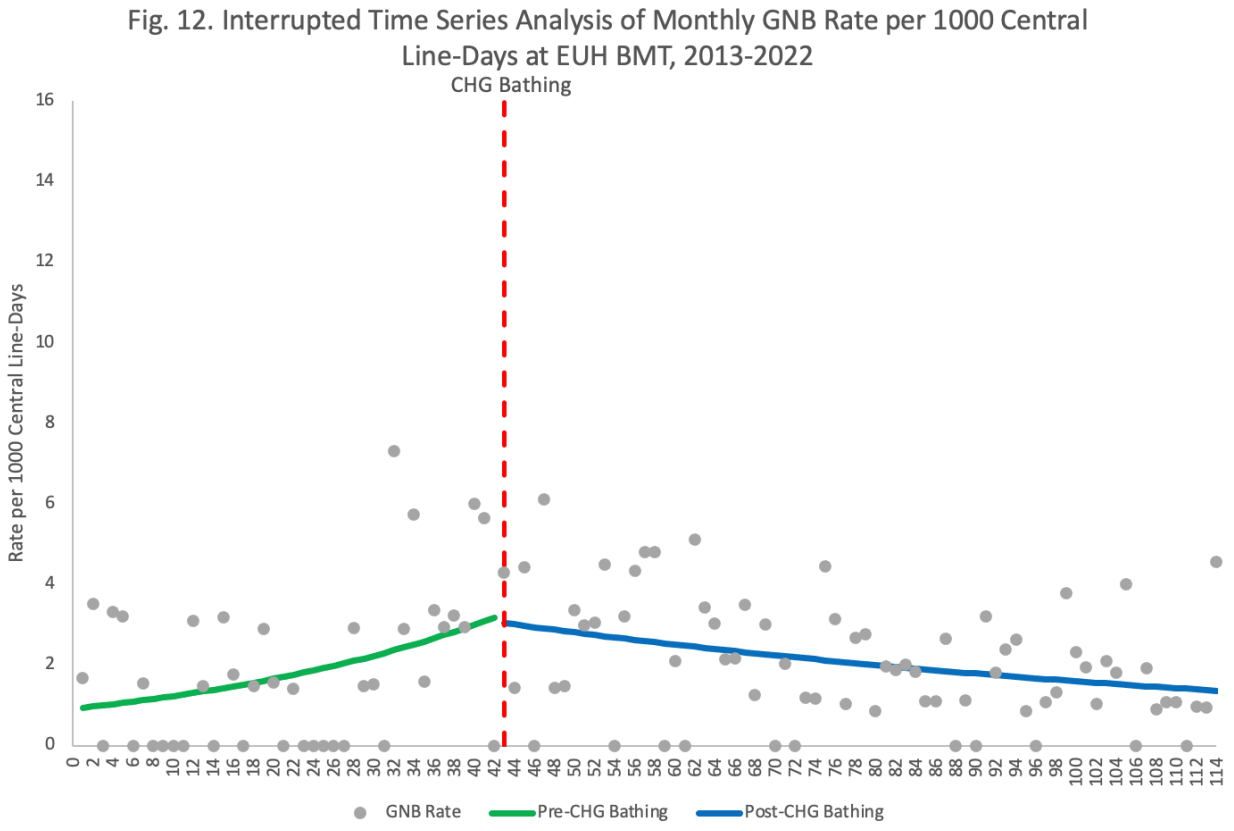

Figure 12. Interrupted time series analysis of monthly GNB rates per 1000 central line-days.

Table 6. Interrupted time series analysis of monthly GNB rates per 1000 central line-days.

Outcome	Parameter Estimate	Rate Ratio (RR)	95% Confidence Interval for RR	p-value
GNB Rate per 1000 Central Line Days				
Pre-Intervention Slope (β_1)	0.0296	1.0301	1.0090, 1.0516	0.0049
Immediate Level Change ($\beta 2$)	-0.0301	0.9675	0.5638, 1.6600	0.9044
Post-Intervention Slope ($\beta_1+\beta_3$)	-0.0113	0.9888	0.9803, 0.9973	0.0103
Slope Change (β_3)	-0.0409	0.9599	0.9386, 0.9816	0.0003