Eliminating CLABSI, A National Patient Safety Imperative

A Companion Guide to the National *On the CUSP: Stop BSI* Project Final Report

A Project of:

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Preface

"Eliminating CLABSI, A National Patient Safety Imperative: Final Report on the National *On the CUSP: Stop BSI* Project" presents key findings of the *On the CUSP: Stop BSI* initiative. This report discusses project background, implementation, impact, and lessons learned and provides data on rates, costs, and survey instruments administered throughout the course of the project with an emphasis on adult intensive care units (ICUs). The following document serves as a companion guide to the primary *On the CUSP: Stop BSI* final report.

This companion guide provides supporting documentation for the *On the CUSP: Stop BSI* Final Report. This document is broken into four primary sections: Methods, Participation, Outcomes, and Moderating Factors. In addition, a number of appendices supplement the text.

Within the Methods section, a data collection schedule and details on calculations can be found. The Participation section highlights characteristics of participants at both the hospital and unit levels. In addition, data submission through the course of the project is examined as is project penetration. The Outcomes section is comprised of four sub-sections: adult ICUs; adult non-ICUs; pediatric units; and infections avoided, excess costs averted, and changes in mortality rate. While the majority of registered units are adult ICUs and are the focus of the final report, any units that could benefit from the initiative were encouraged to register. As such, data on non-ICUs can be found in detail within these sections.

The section "Infections Avoided, Excess Costs Averted, and Changes in Mortality Rate," analyzes the change in the CLABSI rate over time to infer project impact. The project undertook a systematic review of the literature on attributable cost of CLABSI among adults in the United States health care system and details about this search are highlighted in this section. In addition, assumptions used in calculating excess costs averted and changes in mortality can be found in this section. Finally, the Moderating Factors section examines variation in CLABSI rates found in the project. Moderators of interest include hospital characteristics, findings in the baseline and follow-up Hospital Survey on Patient Safety Culture (HSOPS) at the unit level, utilization of the Team Checkup Tool among units as well as performance on the Readiness Assessment.

Methods

Data Collection

This report uses data stored in the Care Counts database created and maintained by the Michigan Health & Hospital Association (MHA) Keystone Center in Lansing, Michigan. Each month, the number of central line days and the number of CLABSIs observed in the participating hospital units were submitted to this database. Some facilities submitted infection rate data directly into this database, while others contributed data through the Centers for Disease Control and Prevention's (CDC's) National Healthcare Safety Network (NHSN). All participants used CDC definitions to count central line days and to determine the number of CLABSIs observed.

All analyses are based on data extracted from Care Counts on October 15, 2012. The baseline period consisted of 12 consecutive data collection months and post-baseline data collection periods consisted of 3 consecutive months, referred to as quarters. One should note that quarters are in reference to project quarters, not calendar quarters. Since cohorts entered the project at different times, not all cohorts have completed data entry for all six post-baseline project quarters. The October 2012 data extract included data submitted for all periods through August 2012. The project quarters by cohort included in the October 2012 data extract, and used for this report, are detailed in Table 1. For cohort 6, only two of the three months of its sixth project quarter were available.

Table 1. Project data by cohort

Cohort	Baseline	Q1	Q2	Q3	Q4	Q5	Q6
1	May 08 – Apr 09	May – Jul 09	Aug – Oct 09	Nov 09 – Jan 10	Feb – Apr 10	May – Jul 10	Aug – Oct 10
2	Sep 08 – Aug 09	Sep – Nov 09	Dec 09 – Feb 10	Mar – May 10	Jun – Aug 10	Sep – Nov 10	Dec 10 – Feb 11
3	Feb 09 – Jan 10	Feb – Apr 10	May – Jul 10	Aug – Oct 10	Nov 10 – Jan 11	Feb – Apr 11	May – Jul 11
4	Jul 09 – Jun 10	Jul – Sep 10	Oct – Dec 10	Jan – Mar 11	Apr – Jun 11	Jul – Sep 11	Oct – Dec 11
5	Nov 09 – Oct 10	Nov 10 – Jan 11	Feb – Apr 11	May – Jul 11	Aug – Oct 11	Nov 11 – Jan 12	Feb – Apr 12
6	Apr 10 – Mar 11	Apr – Jun 11	Jul – Sep 11	Oct – Dec 11	Jan – Mar 12	Apr – Jun 12	Jul – Sep 12

Calculations

The project calculated central line days as the sum of all reported central line days during the reporting period, while the number of CLABSIs equaled the sum of all CLABSIs reported during the period. The unit level CLABSI rate equals the ratio of CLABSIs to central line days multiplied by 1,000. Relative reduction is calculated as baseline rate for the sample, minus the quarter of interest rate for the sample, divided by the baseline rate. All analyses were conducted using SAS version 9.3 (SAS Institute, Cary, North Carolina).

Participation

Section Summary

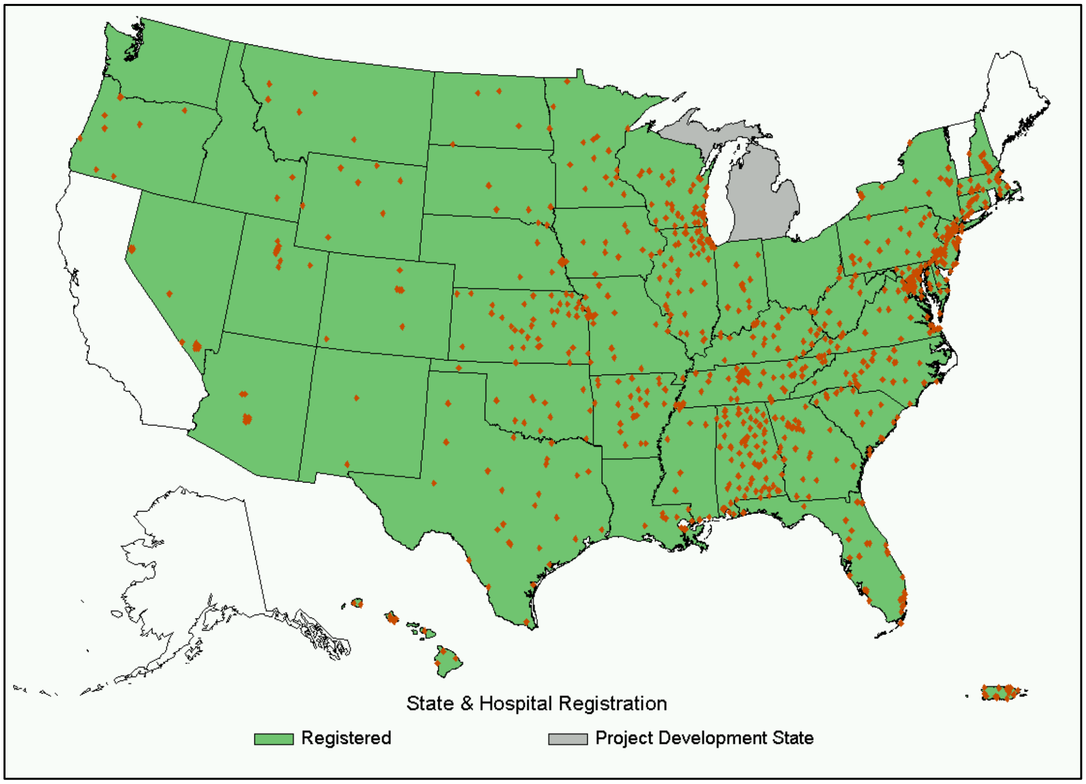
- Over 1,000 hospitals registered for participation in the study, with over 1,800 total units represented.
- Over 71 percent of registrants were adult ICUs. However adult non-ICUs (24 percent) and pediatric units (5 percent) also registered.
- Almost 30 percent of hospitals with an ICU in the United States participated in the initiative.

A total of 1,081 unique hospitals registered for the improvement project comprised of 1,821 total registered units (see Figure 1). Forty-four States, the District of Columbia, and Puerto Rico registered hospitals and units in at least one of the six cohorts. Although Michigan is not depicted as a formal project participant, Michigan hospitals continue to work with the MHA Keystone Center on sustaining the exceptionally low CLABSI rates they achieved in the initial Keystone Project.[1, 2] Because we want to recognize as many of the hospitals that have chosen to participate as possible, a complete list of hospitals that have contributed to the national database can be found at the project website at www.onthecuspstophai.org.

[1] Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 2006 Dec 28;355(26):2725–32.

[2] Pronovost P, Goeschel CA, Colantuoni E, et al. Sustaining reductions in catheter-related bloodstream infections in Michigan intensive care units: an observational study. *BMJ* 2010 Feb 4;340:c309.

Figure 1. State and Hospital Participation



Hospital Characteristics

In order to be included in the examination of hospital characteristics, registered hospitals had to have completed the 2010 American Hospital Association (AHA) Annual Survey, and hospitals had to respond to variables of interest. A total of 934 hospitals could be matched to their AHA Annual Survey results (86 percent). Among hospitals matched, the average total bed size was 254 (±229) with the majority classified as having between 0-100 beds (27 percent) followed by 101-175 (20 percent) and greater than 400 beds (19 percent). The majority of registered hospitals were non-government, not-for-profit (57 percent). Furthermore, the vast majority of hospitals identified as general medical and surgical hospitals. Approximately 39 percent of registered hospitals were classified as teaching hospitals, and only 28 percent of hospitals were considered rural by AHA Annual Survey definitions. Finally, approximately 18 percent of registered hospitals were located in one of the 100 largest cities in the United States, and 21 percent of registrants were classified as being critical access hospitals.

Unit Characteristics

The majority of registered units were adult ICUs although some adult non-ICUs and pediatric units did participate (see Figure 2). A total of 237 units formally withdrew from the initiative (101 ICU, 130 Non-ICU, 6 pediatric). A statistically significant larger proportion of non-ICUs withdrew from the project than ICUs or pediatric units ($p<0.001$). One possible explanation for this finding is that the initiative was geared towards the ICU setting. Further breakdown of unit type composition can be found in Figure 3 through Figure 5.

Figure 2. Percent of registered unit by unit type

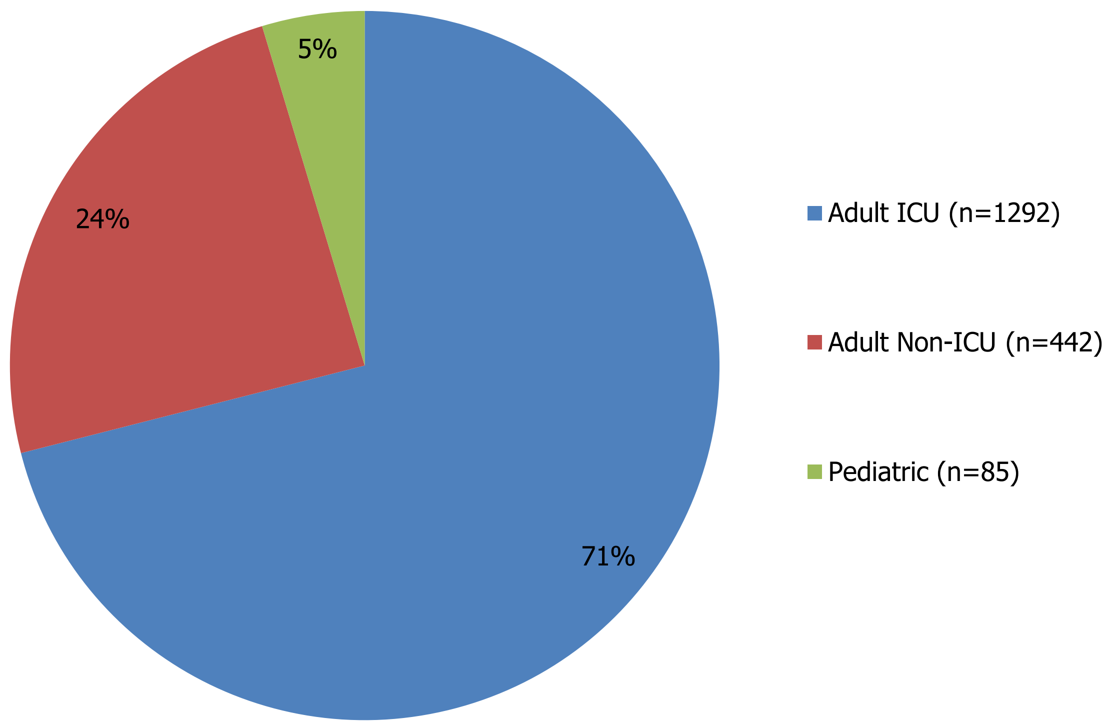


Figure 3. Types of registered adult ICUs

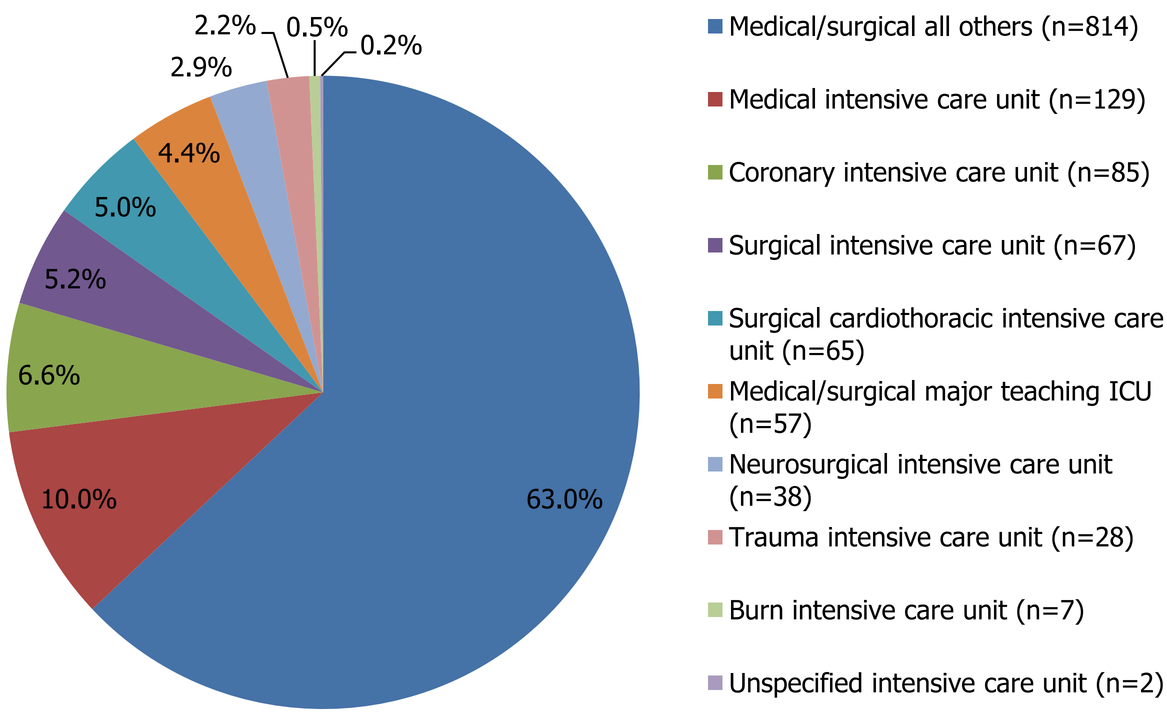


Figure 4. Types of registered adult non-ICUs

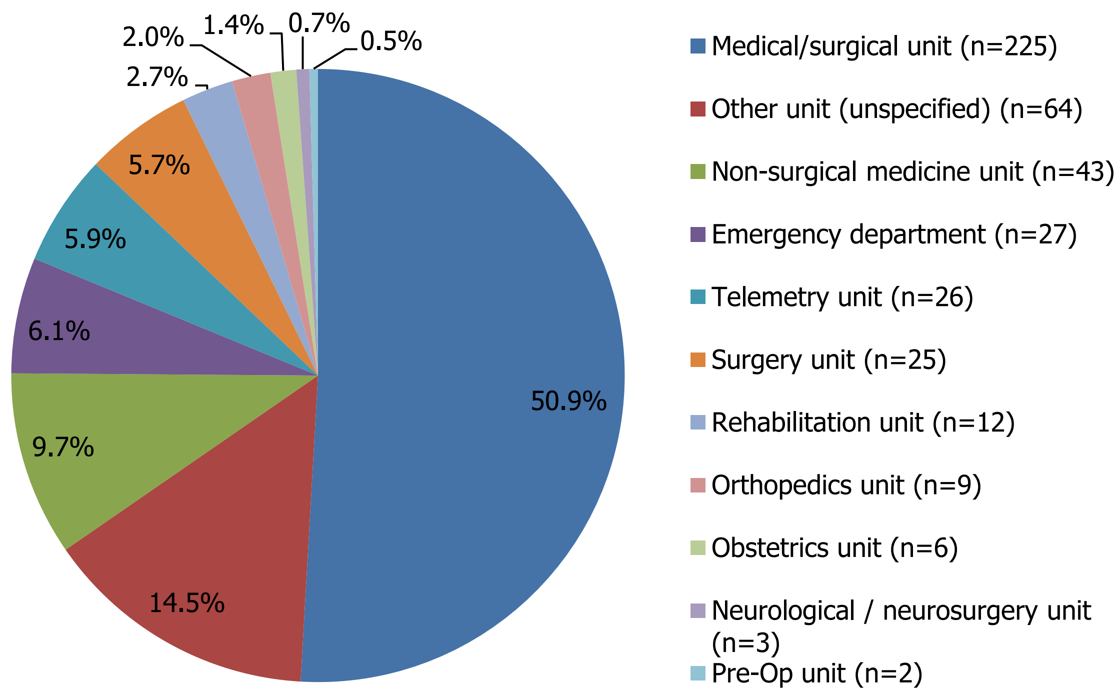
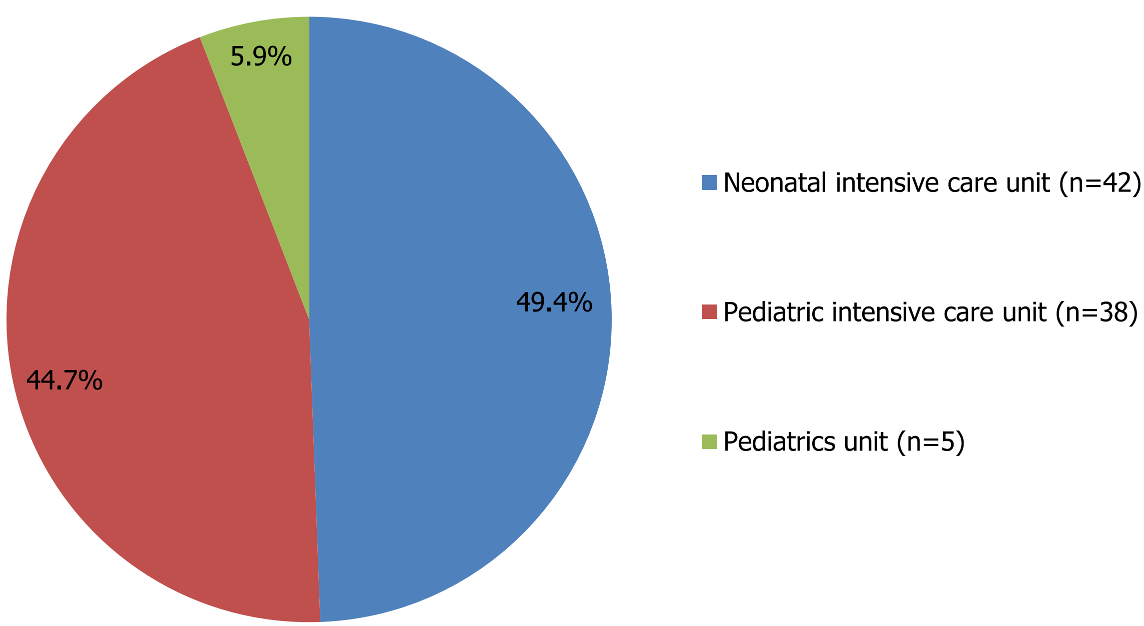


Figure 5. Types of registered pediatric units



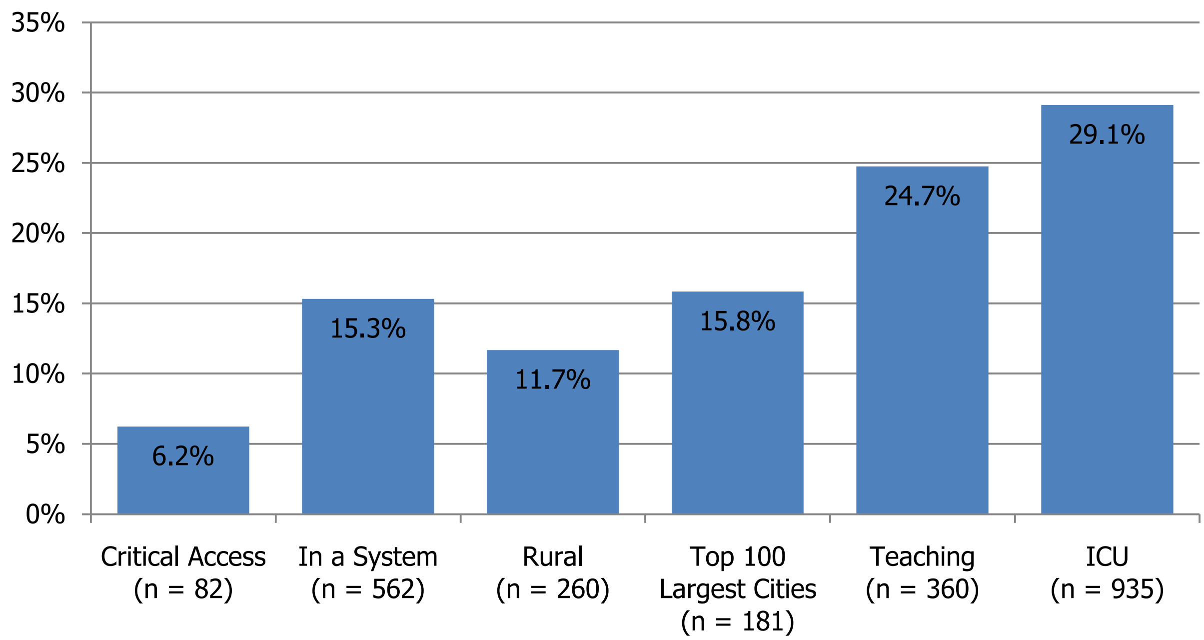
Data Submission

Participating units were requested to submit 12 consecutive months of baseline CLABSI data prior to their cohort start date and 18 consecutive months post-baseline for a total of 30 data points. On average, units submitted 76 percent of the CLABSI data requested. Submission rates were higher in the post-baseline period (84 percent) than in the baseline period (65 percent). Variability was found when assessing data submission rates by unit classification with adult ICUs and pediatric units having statistically significantly greater data submission (80 percent and 78 percent respectively) than adult non-ICUs (59 percent; $p<0.05$).

Project Penetration

A total of 935 hospitals participating self-identified as having an ICU (data obtained from project registration, not AHA Annual Survey). This represents approximately 29 percent of hospitals with ICUs in the country (approximately 3,200 hospitals with ICUs nationally based on the 2010 AHA Annual Survey). For additional hospital characteristics, hospitals were next directly linked to their 2010 AHA Annual Survey (86 percent match) and these characteristics as a proportion of U.S. hospitals can be found in Figure 6 and Figure 7.

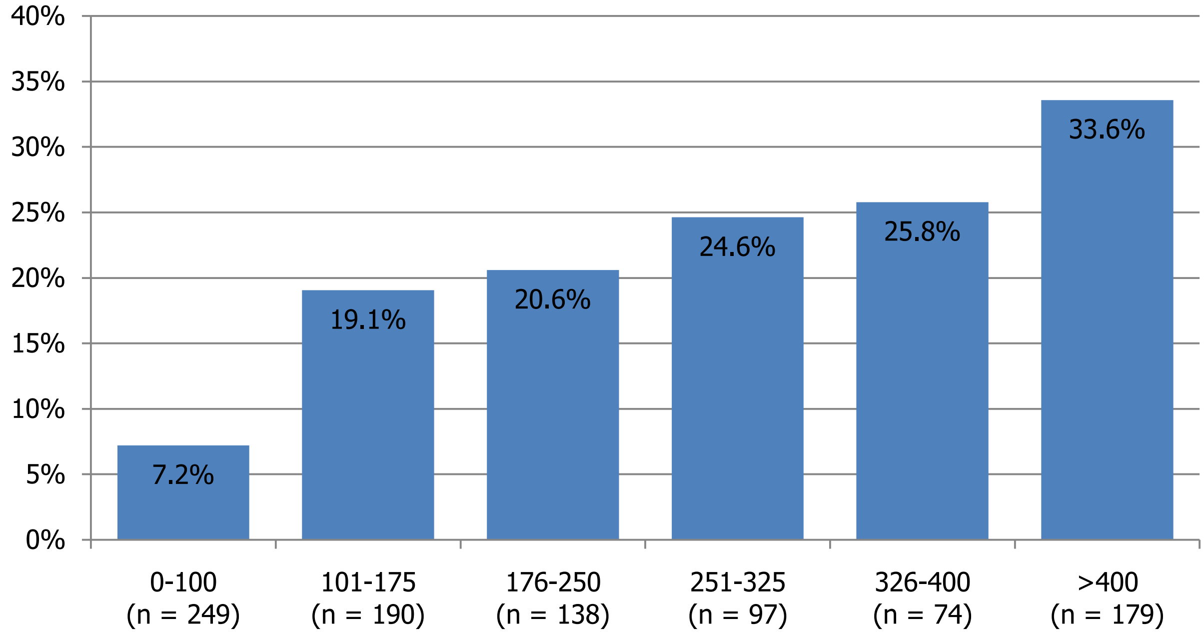
Figure 6. Percentage of U.S. Hospitals registered by characteristic*†



*Hospitals can have characteristics that are not mutually exclusive. For example, a hospital can be identified as both rural and critical access.

†Prior interim reports presented hospital characteristics of only hospitals with adult ICUs in the nation. As such, percentages differ from previous reports.

Figure 7. Percentage of U.S. Hospitals registered by characteristic*†



*Total hospital bed size was unknown for seven registered hospitals.

†Prior interim reports presented hospital bed size of only hospitals with adult ICUs in the nation. As such, percentages differ from previous reports.

In 2010, hospitals reported having over 81,300 total ICU beds. Participating CUSP hospitals represented approximately 34,400 ICU beds. As such, over 42 percent of U.S. ICU beds were potentially impacted by the CUSP project. Further, there were approximately 28 million hospital admissions in 2010 with slightly over 10 million occurring in hospitals where the CUSP intervention was implemented. Although the majority of units participating were ICUs, and not all admissions will be treated on a floor where CUSP was implemented, approximately 36 percent of hospital admissions were potentially affected by the project.

Outcomes

Adult ICUs

Section Summary

- Data from over 1,100 adult ICUs were examined.
- CLABSI rates were reduced from 1.915 at baseline to 1.133 at quarter six, a relative reduction of over 40 percent.
- Variability in relative reduction was found by cohort and hospital characteristics.

A total of 1,185 adult ICUs reported at least one data point. Units that formally withdrew were excluded (n=50)[3], and units that never reported post-baseline data were excluded (n=11), resulting in a final analytic sample of 1,124 units. One unit did not report data between quarter one and quarter six but did report during quarters seven and eight. On average, units had less than one missing post-baseline quarter worth of data (mean=0.36; stdev=0.96; median=0).

Overall

Overall CLABSI rates over time can be found in Figure 8. Table 2 illustrates the number of units reporting for each time period. Figure 9 illustrates the percentage of units reporting a rate of zero (shown in dark blue) or less than one (shown in light blue) during each time period. At baseline 30 percent of units reported a rate of zero. At quarter six, this percentage more than doubled with 68 percent of units reporting a rate of zero. Summary results for all adult ICUs can be found in Table 3.

[3] This number does not reflect units that formally withdrew but had not submitted any data. For details regarding project withdrawal see Participation section.

Figure 8. Adult ICU CLABSI rate overall over time

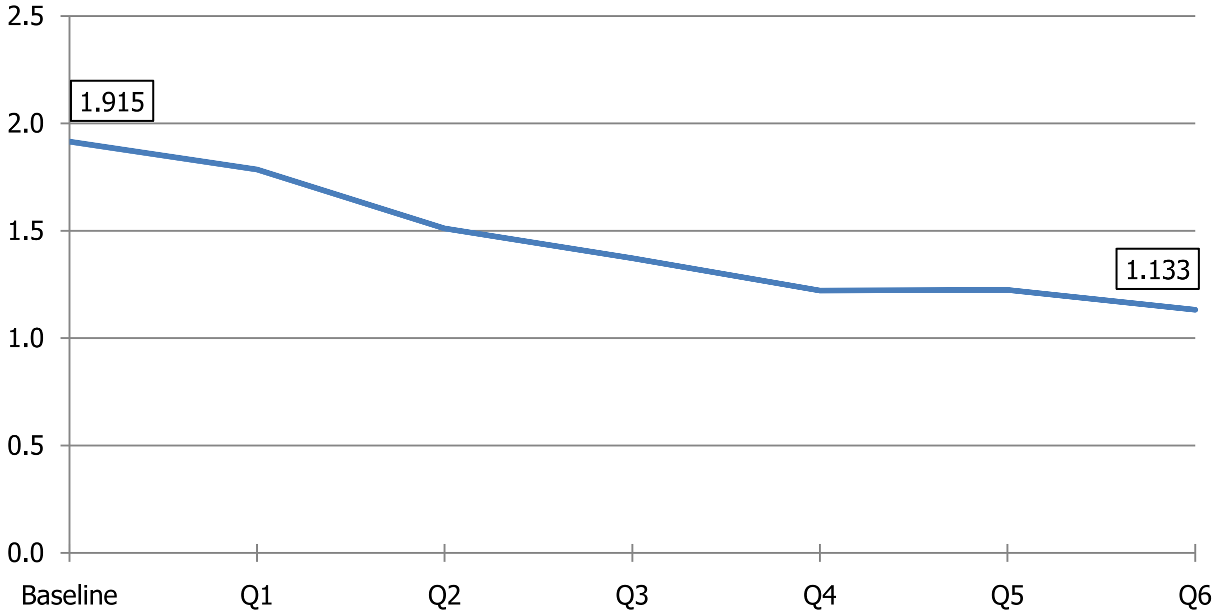
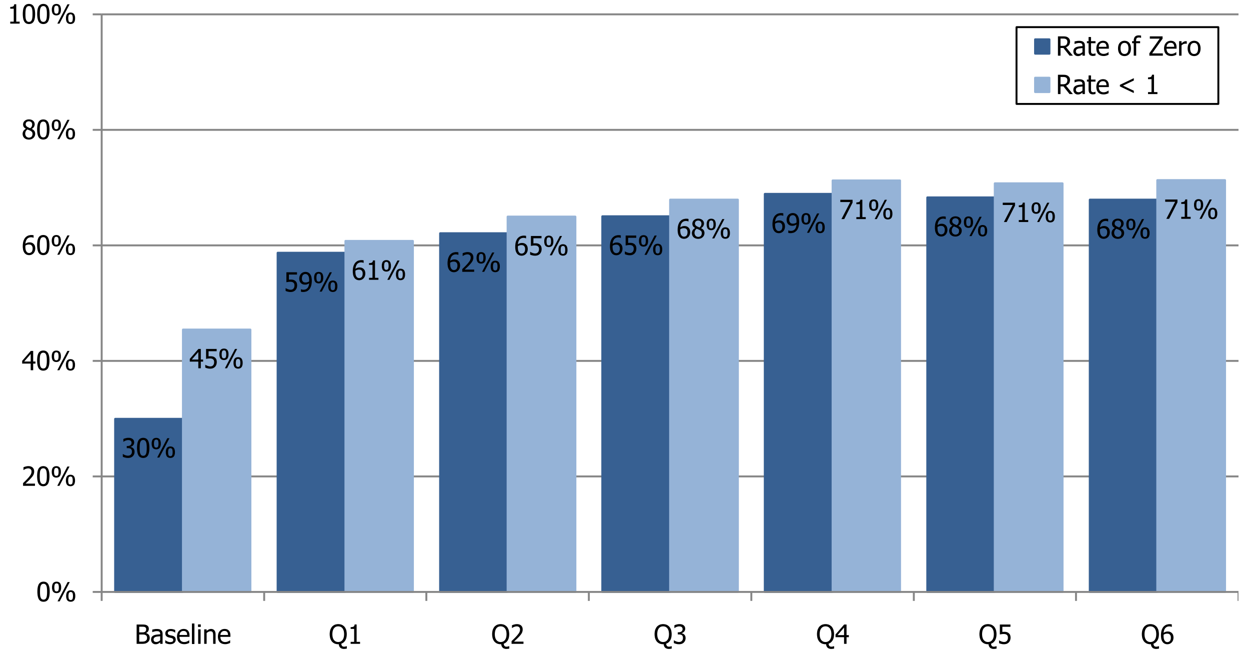


Table 2. Number of ICUs reporting data at each time point

Baseline	Q1	Q2	Q3	Q4	Q5	Q6
977	1,078	1,083	1,088	1,058	1,026	1,004

Figure 9. Percent of reporting ICU units with CLABSI rate of zero or less than one, all cohorts



*Percentage of units calculated as number of units with a rate of zero or less than one divided by the total number of units reporting during the time period.

Table 3. Summary for adult ICU cohorts 1-6 through quarter 6

	Pre-Intervention	Post-Intervention					
	Baseline	Q1	Q2	Q3	Q4	Q5	Q6
	12 Months	Months 1-3	Months 4-6	Months 7-9	Months 10-12	Months 13-15	Months 16-18
Number of States Reporting	46	45	46	46	46	45	44
Number of Units Reporting	977	1,078	1,083	1,088	1,058	1,026	1,004
Average CLABSIs/Unit	3.318	0.870	0.729	0.669	0.571	0.562	0.518
Average CL Days/Unit	1,733	487	483	488	467	459	457
Rate: (Infections/Days)x1,000	1.915	1.785	1.511	1.372	1.221	1.225	1.133
Relative Reduction	n/a	-7%	-21%	-28%	-36%	-36%	-41%

By Cohort

Figure 10. CLABSI rate by cohort over time for adult ICUs

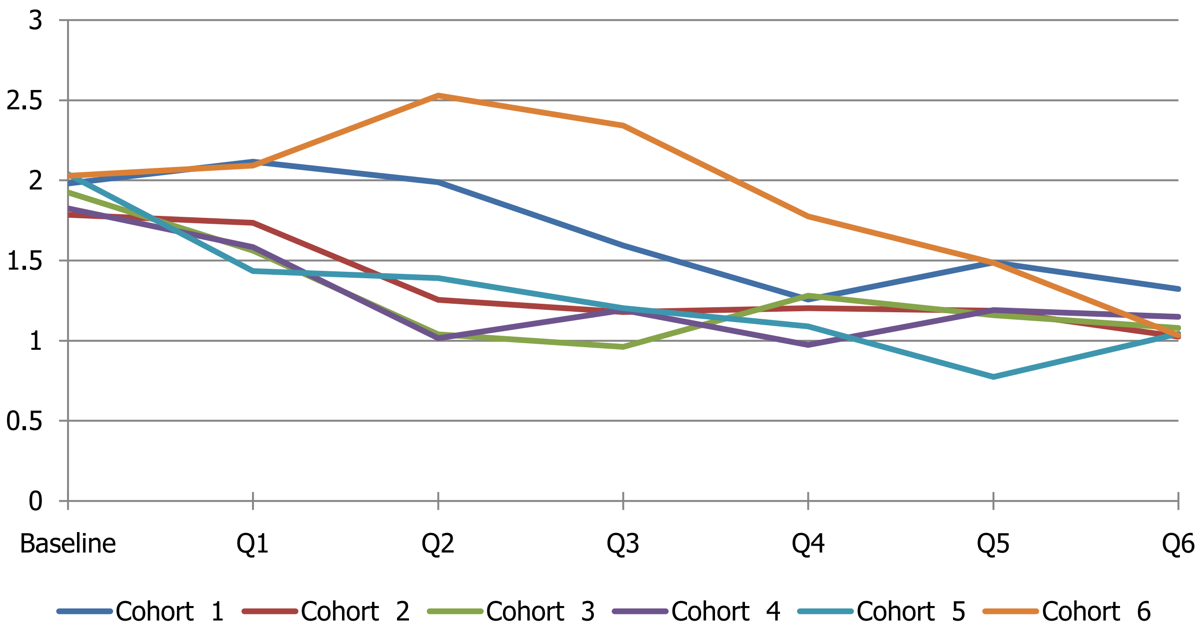


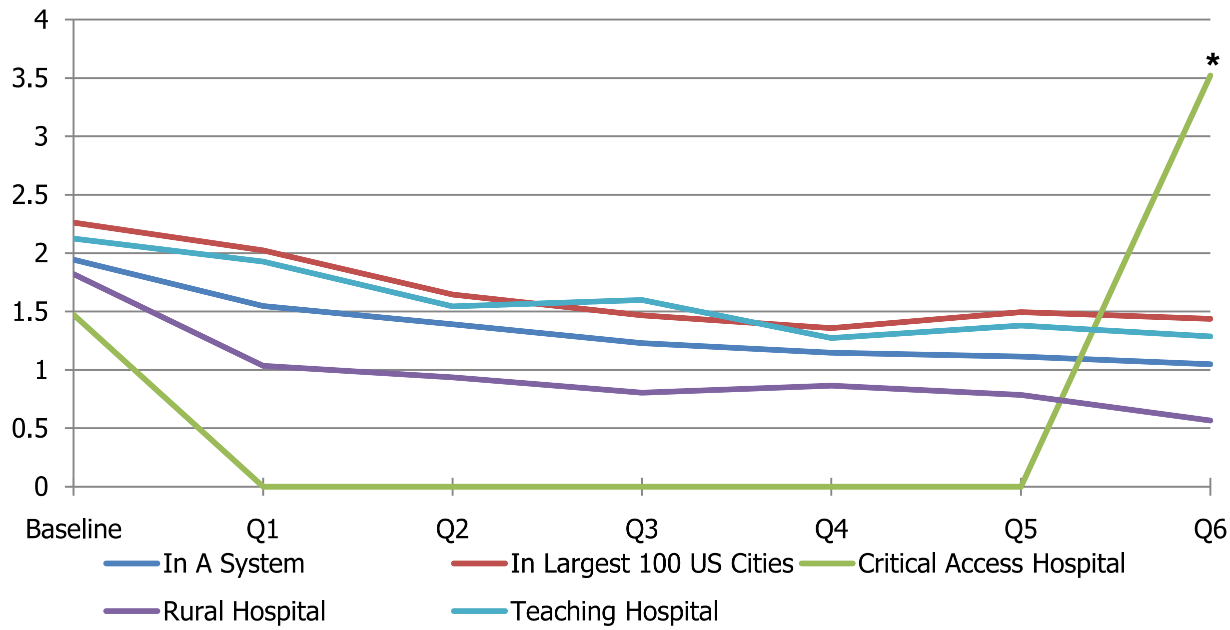
Table 4. Number of ICUs reporting data at each time point by cohort*

	Baseline	Q1	Q2	Q3	Q4	Q5	Q6
Cohort 1	275	280	281	290	285	291	288
Cohort 2	244	290	290	292	282	267	282
Cohort 3	80	80	80	78	78	77	73
Cohort 4	152	183	187	186	185	183	178
Cohort 5	129	145	146	145	141	131	126
Cohort 6	97	100	99	97	87	77	57

*Note: As of the October 15, 2012 extract, the sixth project quarter for cohort 6 had not concluded.

By Hospital Characteristics

Figure 11. Adult ICU CLABSI rate overall over time by hospital characteristic



*Critical access hospitals (n=23) experienced one infection in 284 central line days (the lowest number of central line days reported during any quarter for critical access hospitals) resulting in a rate of 3.52 for quarter six.

Table 5. Number of ICUs reporting data at each time point by hospital characteristics

	Baseline	Q1	Q2	Q3	Q4	Q5	Q6
In A System	584	622	624	624	609	594	575
In Largest 100 US Cities	220	229	230	228	226	228	212
Critical Access Hospital	19	21	21	22	22	22	19
Rural Hospital	155	180	183	183	178	172	165
Teaching Hospital	447	462	463	464	451	441	424

By Bed Size

Figure 12. Adult ICU CLABSI rate overall over time by hospital bed size

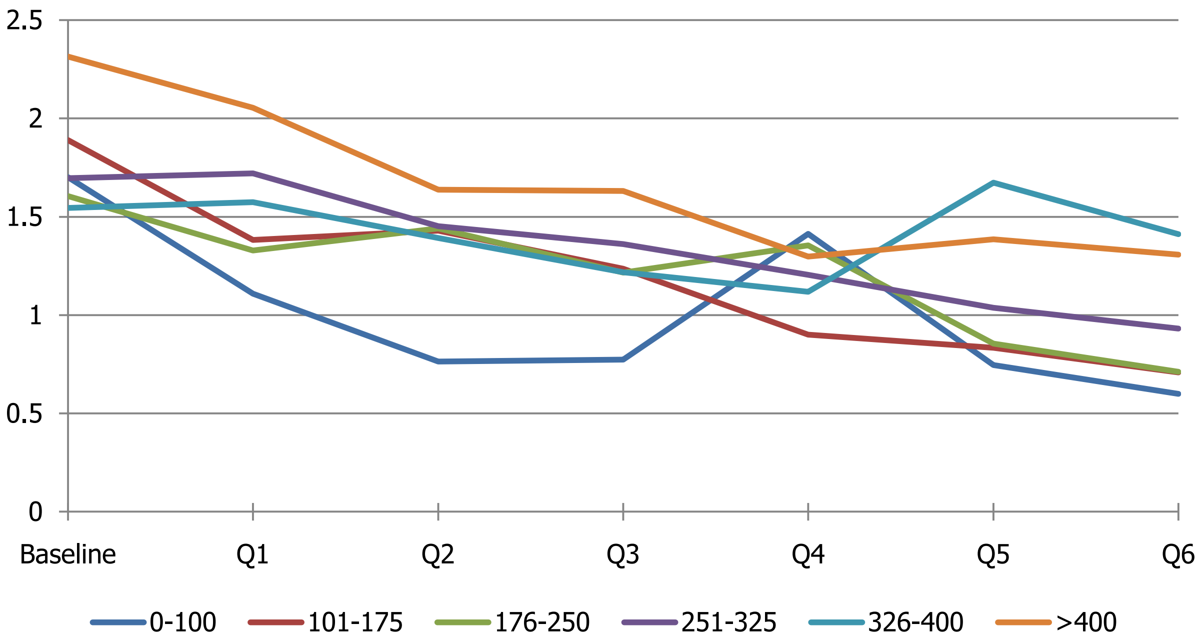


Table 6. Number of ICUs reporting data at each time point by hospital bed size

	Baseline	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
0-100	116	138	140	141	141	139	133	121	106
101-175	135	148	151	148	144	137	134	113	96
176-250	132	137	137	133	127	122	111	93	80
251-325	113	119	119	119	113	109	104	98	89
326-400	99	102	102	106	99	96	94	86	68
>400	278	286	286	288	285	283	270	250	233

Adult Non-ICUs

Section Summary

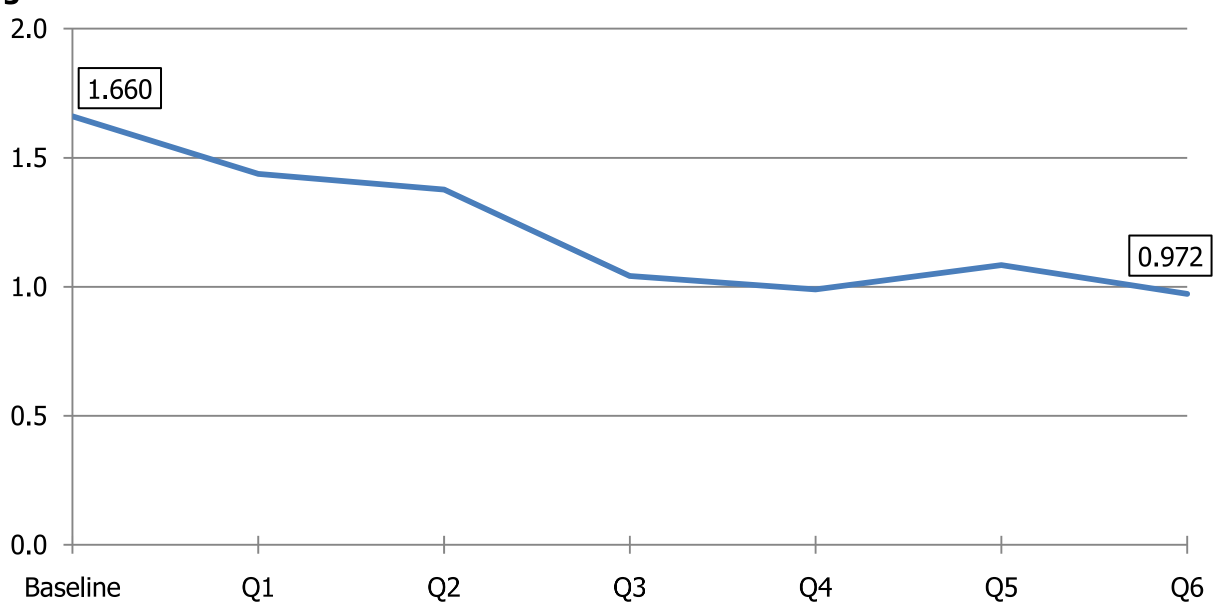
- Data from 260 adult non-ICUs were examined.
- CLABSI rates reduced from 1.660 at baseline to 0.972 at quarter six, a relative reduction of 41 percent.

Although the intervention was tailored to adult ICUs, other hospital units that stood to benefit from participating in the intervention were encouraged to register. A total of 303 adult non-ICUs reported at least one data point. Units that formally withdrew were excluded (n=41)[4], and units that never reported post-baseline data were excluded (n=2), resulting in a final analytic sample of 260 units. One unit did not report data between quarter one and quarter six but did report during quarter seven and eight. On average, units had less than one missing post-baseline quarter worth of data (mean=0.68; stdev=1.37; median=0).

Overall

Overall CLABSI rates over time can be found in Figure 13. Table 7 illustrates the number of units reporting for each time period. Figure 14 illustrates the percentage of units reporting a rate of zero (shown in dark blue) or less than one (shown in light blue) during each time period. At baseline 61 percent of units reported a rate of zero. By quarter six, this percentage had increased to 81 percent of units reporting a rate of zero. Summary results for all adult non-ICUs can be found in Table 8.

Figure 13. Adult non-ICU CLABSI rate overall over time

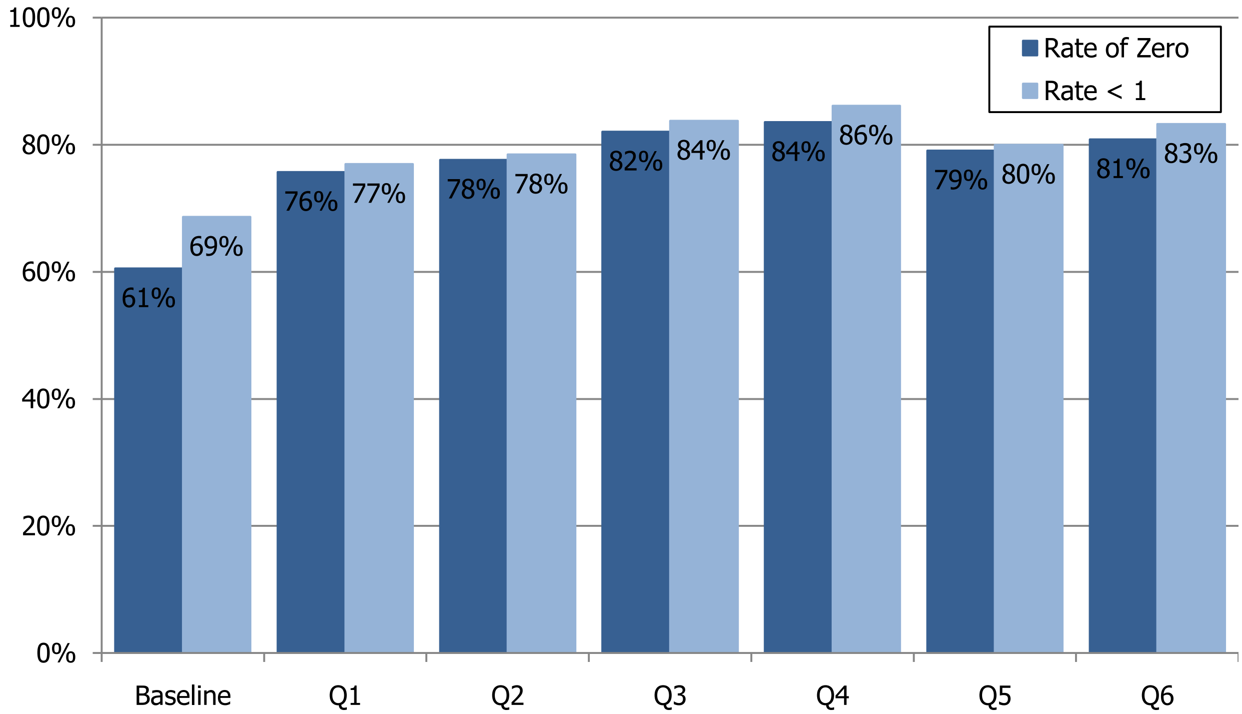


[4] This number does not reflect units that formally withdrew but had not submitted any data. For details regarding project withdrawal see Participation section.

Table 7. Number of non-ICUs reporting data at each time point

Baseline	Q1	Q2	Q3	Q4	Q5	Q6
185	243	246	234	231	220	209

Figure 14. Percent of reporting non-ICU units with CLABSI rate of zero or less than one



*Percentage of units calculated as number of units with a rate of zero or less than one divided by the total number of units reporting during the time period.

Table 8. Summary for non-ICUs, cohorts 1-6 through quarter 6

	Pre-Intervention	Post-Intervention					
	Baseline	Q1	Q2	Q3	Q4	Q5	Q6
	12 Months	Months 1-3	Months 4-6	Months 7-9	Months 10-12	Months 13-15	Months 16-18
Number of States Reporting	34	37	37	38	34	33	30
Number of Units Reporting	185	243	246	234	231	220	209
Average CLABSIs/Unit	1.935	0.481	0.496	0.359	0.329	0.364	0.316
Average CL Days/Unit	1,165	335	360	345	332	335	325
Rate: (Infections/Days) x 1,000	1.660	1.437	1.376	1.041	0.990	1.084	0.972
Relative Reduction	n/a	-13%	-17%	-37%	-40%	-35%	-41%

Pediatric Units

Section Summary

- Data from 72 pediatric units were examined.
- CLABSI rates reduced from 2.742 at baseline to 1.702 at quarter six, a relative reduction of 38 percent.

Although the intervention was tailored to adult ICUs, other hospital units that stood to benefit from participating in the intervention were encouraged to register. A total of 76 pediatric units reported at least one data point. Units that formally withdrew were excluded (n=4)[5], and all other units reported at least one post-baseline data point, resulting in a final analytic sample of 72 units. On average, units had less than one missing post-baseline quarter worth of data (mean=0.35; stdev=0.98; median=0).

Overall

Overall CLABSI rates over time can be found in Figure 15. Table 9 illustrates the number of units reporting for each time period. Figure 16 illustrates the percentage of units reporting a rate of zero (shown in dark blue) or less than one (shown in light blue) during each time period. At baseline 28 percent of units reported a rate of zero. At quarter six, this percentage increased to 59 percent of units reporting a rate of zero. Summary results for all pediatric units can be found in Table 10.

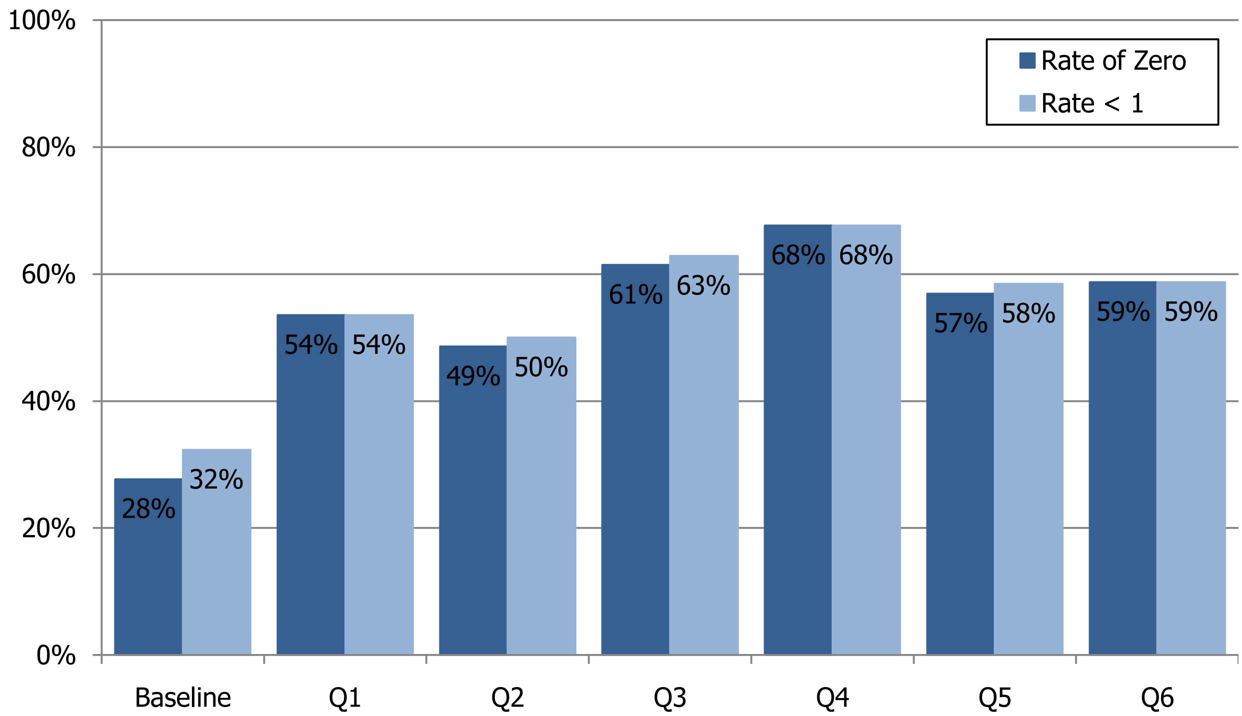
Figure 15. Pediatric CLABSI rate overall over time

[5] This number does not reflect units that formally withdrew but had not submitted any data. For details regarding project withdrawal see Participation section.

Table 9. Number of pediatric units reporting data at each time point

Baseline	Q1	Q2	Q3	Q4	Q5	Q6
65	71	70	70	68	65	63

Figure 16. Percent of reporting pediatric units with CLABSI rate of zero or less than one



*Percentage of units calculated as number of units with a rate of zero or less than one divided by the total number of units reporting during the time period.

Table 10. Summary for pediatric units cohorts 1-6 through quarter 6

	Pre-Intervention	Post-Intervention					
	Baseline	Q1	Q2	Q3	Q4	Q5	Q6
	12 Months	Months 1-3	Months 4-6	Months 7-9	Months 10-12	Months 13-15	Months 16-18
Number of States Reporting	24	25	25	26	26	25	25
Number of Units Reporting	65	71	70	70	68	65	63
Average CLABSIs/Unit	4.477	0.887	1.143	0.714	0.485	0.677	0.762
Average CL Days/Unit	1633	426	489	443	465	462	448
Rate: (Infections/Days) x 1,000	2.742	2.082	2.339	1.613	1.043	1.466	1.702
Relative Reduction	n/a	-24%	-15%	-41%	-62%	-47%	-38%

Infections Avoided, Excess Costs Averted, and Changes in Mortality Rate

Section Summary

- The project carried out a systematic review of the cost of CLABSI. After reviewing almost 850 abstracts and over 150 articles in full, 6 articles met inclusion criteria.
- After weighting and adjusting to 2012 dollars, the average CLABSI cost reported in the literature was $70,696 with a range (± two standard deviations) of $40,412–$100,980.
- Assuming baseline rates would have remained stable without the study intervention, an estimated total of 2,187–2,419 CLABSIs were prevented over the course of the project.
- An estimated 290–605 deaths were prevented during the course of the project assuming a 12–25 percent mortality rate.
- An estimated $97,756,628–$244,270,620 in excess costs were averted during the course of the project.

Prior versions of this analysis reported the excess cost per CLABSI at $16,550, an estimate used by the CDC.[6] However, to better assess the estimated excess costs averted as a result of the improvement project, a systematic review of the literature was conducted. Although prior systematic reviews have been conducted, this review differed in that it focused solely on the U.S. experience. As such, studies conducted outside of the United States were excluded. In addition, we assumed that the cost of treating adult versus pediatric CLABSIs differs and as such did not include studies solely examining NICU, PICU, or pediatric units.

Literature Review - Methods

PubMed, EconLit, Biological Abstract and Science Direct were searched. First, articles were reviewed at the abstract level. Abstracts believed to have appropriate CLABSI cost calculations were retrieved to be reviewed in full. Retrieved articles were then reviewed against inclusion criteria and included articles were abstracted (for a full list of *a priori* inclusion criteria, see Appendix A). Costs identified in included studies were adjusted to reflect May 2012 dollars using the consumer price index (CPI) inpatient hospital services index.[7] When authors did not indicate what dollar year their estimates were based upon, the year of publication was assumed. A clear consensus does not exist for cost adjustment.[8] As such, both the all urban CPI (CPI-U) and CPI inpatient adjustments were calculated and reflected in the summary table. After adjusting to 2012 dollars, a weighted mean was calculated. The number of patients with a CLABSI (i.e.

[6] Morbidity and Mortality Weekly Report (MMWR) March 2011. Vital Signs: Central Line-Associated Blood Stream Infections – United States, 2001, 2008, and 2009. Accessed on: October 18, 2012. Access at: http://www.cdc.gov/mmwr/pdf/wk/mm6008.pdf

[7] Bureau of Labor Statistics, Consumer Price Indexes. Accessed on: October 18, 2012. Access at: http://www.bls.gov/cpi/

[8] Scott RD. The Direct Medical Costs of Healthcare-Associated Infections in U.S. Hospitals and the Benefits of Prevention - Centers for Disease Control and Prevention. 2009 Accessed on: October 18, 2012. Access at: http://www.cdc.gov/hai/pdfs/hai/scott_costpaper.pdf

cases) was used to weight the final mean. Although more robust methodologies exist, we were limited by the detail of statistical data reported by authors. This limitation resulted in the use of two standard deviations (plus/minus) to estimate the range of costs based upon the estimated mean.

Literature Review - Results

A total of 841 unique abstracts were identified. Forty-nine articles were retrieved after being deemed relevant at the abstract level, and 109 additional articles were retrieved after conducting a reference review. A total of six articles satisfied inclusion criteria and can be found in Table 11. A flowchart of the article review process can be found in Appendix B, and all excluded articles and reason for exclusion can be found in Appendix C.

Table 11. Articles satisfying inclusion criteria

Author	Year	Title
Al-Rawajfah et al.	2012	Length of stay and charges associated with health care acquired bloodstream infections
Butler et al.	2010	Attributable costs of enterococcal bloodstream infections in a nonsurgical hospital cohort
Cohen et al.	2010	Cost saving from reduced catheter-related bloodstream infection after simulation-based education for residents in a medical intensive care unit
Kilgore et al.	2008	Cost of bloodstream infections
Shannon et al.	2006	Economics of central line-associated bloodstream infections
Warren et al.	2006	Attributable costs of catheter-associated bloodstream infections among intensive care patients in a nonteaching hospital

Although stringent inclusion/exclusion criteria were applied, the six included articles differed significantly in both estimated costs as well as the methods utilized to derive the costs. Variation can be attributed to factors such as sample size (range: 12-100,851 cases), setting (single hospital site estimate in four studies vs. multi-site estimate), costs considered (e.g. costs billed, actual costs, etc.), and estimation model utilized (e.g. matching procedure). Although a weighted mean was calculated, only one study utilized a large, national administrative database, thereby resulting in greater cases and a larger weight in the averaging process.[9]

[9] Al-Rawajfah OM, et al. Length of stay and charges associated with health care-acquired bloodstream infections. *Amer J Infec Contr* 2012;40:227-232.

Average costs per CLABSI in each study as well as relevant CPI adjustment weights and adjusted costs can be found in Table 12. The average cost per CLABSI after using the weight and May 2012 CPI inpatient hospital service index adjustment was estimated at $70,696 with a range (plus/minus two standard deviations) of $40,412 to $100,980. This range is similar to that found on the Johns Hopkins CLABSI Opportunity Estimator website (range of $40,000 to $117,000 per infection).[10]

[10] Johns Hopkins CLABSI Opportunity Estimator. Accessed on October 18, 2012. Access at: http://www.hopkinsmedicine.org/quality_safety_research_group/our_projects/stop_bsi/toolkits_resources/clabsi_estimator.html

Table 12. Cost per CLABSI of studies meeting inclusion criteria*

Author	Cases[†]	Study Mean	Cost in Year	CPI-U Weight	CPI-U Adjusted Cost	CPI IP Weight	CPI I Adjusted Cost
Al-Rawajfah et al. (2012)	100,851	$ 68,067.00	2010	1.05	$ 71,326.16	1.12	$ 76,093.08
Butler et al. (2010)	276	$ 2,858.87	2007	1.10	$ 3,150.94	1.39	$ 3,976.12
Cohen et al. (2010)	12	$ 82,005.00	2008	1.06	$ 87,061.12	1.30	$ 106,443.30
Kilgore et al. (2008)	12,578	$ 19,643.00	2006	1.13	$ 22,271.25	1.48	$ 29,041.85
Shannon et al. (2006)	54	$ 40,179.00	2006	1.13	$ 45,554.98	1.48	$ 59,404.01
Warren et al. (2006)	41	$ 11,971.00	2000	1.33	$ 15,887.51	2.18	$ 26,050.71

*All consumer price indexes utilized May 2012 tables.

[†]Cases reflect the number of observed CLABSIs utilized in the study's cost estimate.

CPI-U = all urban consumer price index; CPI IP = consumer price index inpatient hospital services index

Estimation Method

To estimate the deaths prevented, a range in mortality was assumed (12-25 percent).[11] For each 100 CLABSIs prevented, 12-25 deaths are prevented. To estimate the excess costs averted, the mean cost per CLABSI (using CPI inpatient hospital service adjustment) was utilized: $70,696. Thus, for each CLABSI prevented, $70,696 in treatment costs were averted. To estimate the number of CLABSIs prevented, the number of actual CLABSIs reported was compared with the number of CLABSIs that would have occurred if the pre-intervention ("baseline") rate of CLABSIs per 1,000 line days had persisted:

CLABSIs prevented = (baseline rate – observed rate) * (#central line days)

These calculations were done on a quarterly basis and totaled over all quarters.

The project quarters considered were eight quarters post-intervention, or 24 months. Not all units reported data for all 24 months (to be distinguished from units that reported zero central line days). Thus, it is useful to calculate savings based not only on months of reported data, but under the assumption that for each unit, non-reported months were similar to reported months. In order to estimate the total number of central line days (CLDs) and CLABSIs over the project quarter, these were interpolated for each unit using the available reported data. Mean interpolation was used. For example, if one unit did not report data for the eighth month, the numbers of CLDs and CLABSIs for that month were estimated as the average of the numbers for the seventh and ninth months. If the month with missing data was at the end of the project quarter (i.e. month 24), the numbers of the last available month were carried forward, and if at the beginning of the project quarter (i.e. month 1), the numbers of the first available month were carried back (see Appendix D for an example). Since CLABSI rates declined over the course of the intervention, using the study average would underestimate projected savings. Thus, data from quarters five and six were used to estimate monthly costs and lives saved over time after the project. Estimates are based on all adult ICU units that participated in the project and had not formally withdrawn. Units that never submitted data but did not formally withdraw were excluded.

Results

Table 13 presents estimated CLABSIs and deaths prevented and excess costs averted using all available data as well as missing data imputation. An estimated total of 2,187 CLABSIs were prevented over the course of the study with a projected continuation of 114 CLABSIs prevented monthly moving forward. After missing values were imputed, this number increased to an estimated total of 2,419 CLABSIs prevented over the course of the study with a projected continuation of 121 CLABSIs prevented monthly.

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[11] Morbidity and Mortality Weekly Report (MMWR) March 2011. Vital Signs: Central Line-Associated Blood Stream Infections – United States, 2001, 2008, and 2009. Accessed on: October 18, 2012. Accessed at: http://www.cdc.gov/mmwr/pdf/wk/mm60e0301.pdf

Estimates of deaths prevented varied as a function of the underlying assumption: 12 percent mortality rate to 25 percent mortality rate. Using all available data, an estimated range of 262–547 deaths were prevented over the course of the study with 14–28 deaths prevented monthly moving forward. After missing value imputation, this number increased to an estimated range of 290–605 deaths prevented over the course of the study with 14–30 deaths prevented monthly moving forward.

A range of estimates for excess costs averted can be found in Table 14. Using all available data and the CPI inpatient hospital service adjusted weighted cost, an estimated $154,612,152 in excess costs were averted with an estimated $8,057,594 in excess costs averted monthly moving forward. After missing value imputation, this number increased to $171,013,624 in excess costs averted with an estimated $8,533,375 in excess costs averted monthly moving forward. In previous reports, using the estimate of $16,550 per CLABSI the estimated excess costs averted would range from $36,194,850 to $40,034,450 (see Table 13).

Since the cost estimate is based on an estimated mean, a more conservative approach would be to consider a range of costs. Using all available data and a range that is two standard deviations from the mean, excess costs averted are estimated at between $88,381,044 and $220,540,320. Every month moving forward this translates into an estimated cost savings range of $4,606,015 to $11,509,172. After imputing missing values the total range estimate becomes $97,756,628 to $244,270,620 with every month moving forward estimated at averting $4,877,989 to $12,188,760 in costs.

It should be noted that the finalized estimate of costs is from the hospital perspective, not the patient. As such, excess costs averted such as wages lost were not considered. In addition, estimates do not include costs of death in terms of the value of statistical life which would increase the overall economic impact of the project (see the National Center for Environmental Economics for more information[12]). Finally, estimated costs do not reflect reductions in CLABSI rates found in non-ICU and pediatric units participating in the project.

[12] National Center for Environmental Economics: http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/homepage

Table 13. Estimation of infections and deaths prevented and excess costs averted among participating adult ICUs using all data ("reported") and data after missing value imputation ("estimated") using CDC estimates

	CLABSIs Prevented†	Deaths Prevented		Excess Costs Averted‡
		Mortality Rate 12%	Mortality Rate 25%	
Reported	2,187	262	547	$36,194,850
Estimated	2,419	290	605	$40,034,450

†CLABSI Prevented represents the sum of Q1 to Q8 and does not include savings outside the timeframe

‡ Center of Disease Control and Prevention Morbidity and Mortality Weekly Report (see: http://www.cdc.gov/mmwr/pdf/wk/mm60e0301.pdf)

Table 14. Estimation of excess costs averted among participating adult ICUs using all data ("reported") and data after missing value imputation ("estimated")

	Assumed Cost		Excess Costs Averted			
	Mean	Two Standard Deviations	Total: Mean†	Total: Range†‡	Projected Monthly Mean*	Projected Monthly Range*‡
Reported (2,187 CLABSIs)	$70,696	$30,284	$154,612,152	$88,381,044 - $220,540,320	$8,057,594	$4,606,015 - $11,509,172
Estimated (2,419 CLABSIs)	$70,696	$30,284	$171,013,624	$97,756,628 - $244,270,620	$8,533,375	$4,877,989 - $12,188,760

†Total represents the sum of Q1 to Q8 and does not include savings outside the timeframe

*Calculated based upon data from Q5 to Q6

‡Range estimates utilize ± two standard deviation from the mean

Moderating Factors

Hospital Characteristics

Section Summary

- Characteristics of the hospital in which a unit resides may serve as a predictor of how well a unit performs in quality improvement initiatives.
- A statistically significant reduction in CLABSI rate was found over time among adult ICUs with baseline rates greater than zero ($p<0.01$).
- Greater improvement was found among teaching hospitals, within a health care system and typically registering after cohort 1. A significant interaction between rural areas and time was also found and results suggest non-government, not-for-profit hospitals may have greater improvement in the initiative.

There are a number of hospital-level characteristics that may contribute to the ability of an ICU to reduce its CLABSI rate. By better understanding how ICUs perform based on the type of hospital in which they are situated, future improvement projects can more appropriately target units that may lag as well as allocate the appropriate amount of resources (i.e. coaching sessions, site visits, etc.).

Methods

Sample

To be included in the model, units had to be an adult ICU and have baseline data and at least one post-baseline data point. In addition, units with an outlier baseline rate were excluded from analyses (defined as a value of greater than 25; n=3 units). Post baseline data rates greater than 25 were re-coded to missing (n=11 data points). However, the unit overall was not excluded. Data through quarter eight were included in the model. Finally, units were categorized as having a baseline rate of zero (n=293 units) or a baseline rate greater than zero (n=681 units), and the final model was restricted to only units with a baseline rate greater than zero. A flowchart documenting inclusion/exclusion criteria can be found in Appendix E.

Model Selection and Covariates

To examine the relationship between the change in CLABSI rates and hospital characteristics, a mixed effects regression model with random intercept and random trend was utilized with rate over time as the outcome of interest. To assess change in rates over time, an empty model of rate over time was first fitted. Although the slopes in both the linear and quadratic model were significant, the quadratic model fit was statistically significantly better than the linear model ($\chi^2(1)=34.5$, $p<0.01$).

Hospital characteristics of interest were added to the model simultaneously. Hospital characteristics were derived from the 2010 AHA Annual Survey. Characteristics of hospitals that did not participate in the AHA Annual Survey were coded as missing. The following *a priori* hospital characteristics were considered for inclusion in the model: cohort status (cohorts 1–6), control status (i.e. government, investor owned, etc.), primary service provided, teaching status, rurality, critical access status, part of a health care system, and bed size (<100, 101-75, 176-250, 251-325, 326-400, >400). Next, hospital characteristics that were not statistically significant were removed from the model and an additional interaction term (time) was created for each of these variables. Hospital characteristics and interaction terms that were not statistically significant were then removed resulting in the final, parsimonious model.

Confirmatory Analysis

As a confirmatory analysis, a count model was also utilized with number of CLABSIs per time period serving as the outcome of interest and number of central line days serving as the offset variable. Poisson, negative binomial, and zero inflated distributions were examined with a negative binomial distribution resulting in the best fit due to significant over-dispersion. Characteristics that were statistically significant in the mixed model were included in the confirmatory analysis.

Results

CLABSI rates over time of the final sample can be found in Figure 17. Since adult ICUs included in the model were required to have a baseline rate greater than zero, the overall baseline measure of 2.147 is slightly higher than that found among all adult ICUs (1.915; see Adult ICU Outcomes section above for overall adult ICU outcomes details). Characteristics of included units can be found in Table 15.

Figure 17. CLABSI rates over time among adult ICUs by baseline rate

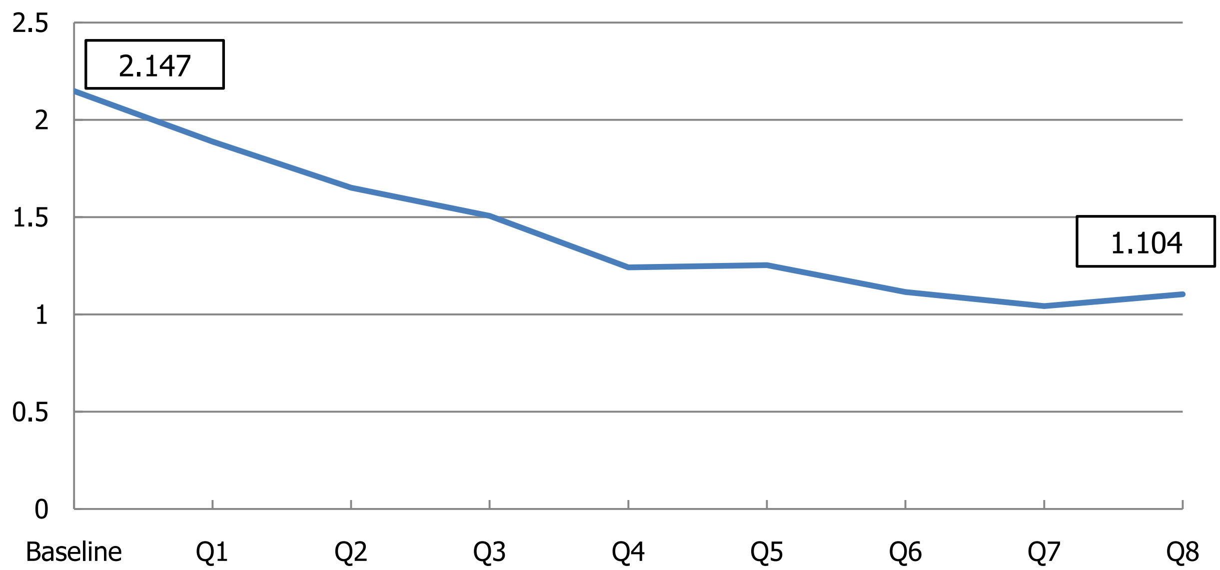


Table 15. Characteristics of adult ICUs included in dataset with baseline rate greater than zero

Hospital Characteristics	Unit (n=681)	Percent
Cohort		
1	189	28%
2	172	25%
3	58	9%
4	104	15%
5	94	14%
6	64	9%
Control Status		
Non-Government, Not-For-Profit	426	63%
Government, Not-For-Profit	86	13%
Investor Owner, For-Profit	81	12%
Missing	88	13%
Primary Service Provided		
General Medical and Surgical	582	85%
Others	11	2%
Missing	88	13%
Teaching Status		
Non-Teaching	244	36%
Teaching	349	51%
Missing	88	13%
Rurality		
Non-Rural	528	78%
Rural	65	10%
Missing	88	13%
Critical Access		
Not Critical Access	593	87%
Critical Access	0	0%
Missing	88	13%
Health Care System		
Not in a System	349	51%
In a System	88	13%
Missing	244	36%
Bed Size		
<100	65	10%
101-175	88	13%
176-250	593	87%
251-325	88	13%
326-400	77	11%
>400	229	34%
Missing	528	78%

Baseline Rate Greater Than Zero

Results of the parsimonious model can be found in Table 16. A significant effect of time was found with significant reductions in CLABSI rates as the study advanced. This reduction, however, is dampened by the significant quadratic term (β=0.0297, p<0.01) indicating a slowing or "leveling-off" of the decreasing rate at later time periods. Cohort assignment was found to be significant with cohort 2 having a lower rate than cohort 1. Comparison between cohort 1 and cohort 6 was also significant; however, the rate for cohort 6 was significantly higher. There was no statistically significant difference in rate comparing cohort 1 to cohorts 2, 3, or 4. Rurality independently was not statistically significant, but the interaction between rurality and time was significant. Specifically, rural hospitals improved over time more than non-rural hospitals (β=0.117, p<0.01). Hospital teaching status was significant with non-teaching hospitals having a lower rate than teaching hospitals. Hospital control was also significant with investor-owned, for-profit hospitals having higher rates than non-government, not-for-profit facilities. Finally, health care system was significant whereby units residing in hospitals not associated with a system had a higher rate than units in hospitals associated with a system.

Table 16. Mixed regression of hospital characteristics on CLABSI rates over time among adult ICUs with a baseline rate greater than zero (n=681)

	Coef	p-value	Wald-p
Intercept	2.778		**<.0001**
Time (quarter)	-0.5049		**<.0001**
Quadratic	0.0297		**<.0001**
Cohort			**0.0016**
1	ref		
2	-0.3147	0.0169	
3	0.2032	0.2601	
4	-0.09515	0.5288	
5	-0.2782	0.0772	
6	0.5404	0.0129	
Rurality			0.328
Rural	ref		
Non-rural	-0.2779	0.328	
Teaching Status			**0.0058**
Teaching	ref		
Non-Teaching	-0.2978	0.0058	
Health Care System			**0.0059**
In a System	ref		
Not in a System	0.3099	0.0059	
Control Status			**0.0194**
Non-Government, Not-For-Profit	ref		
Government, Not-For-Profit	0.2312	0.1047	
Investor Owned, For-Profit	0.3874	0.0128	
Rurality x Time			**0.0351**
Rural	ref		
Non-Rural	0.117	0.0098	

Confirmatory Analysis

Results of the confirmatory count model (negative binomial) were almost identical to the mixed model. Differences were found for the covariate cohorts (all cohorts were significantly lower than cohort 1 with the exception of cohort 6 which was significantly higher than cohort 1) and control status (no significant effect of control status). See Table 17 for details regarding the model.

Table 17. Negative binomial regression of hospital characteristics on CLABSI rates over time among adult ICUs with a baseline rate greater than zero (n=681)

	Coef	Wald-p
Intercept	-5.8688	**<.0001**
Time (quarter)	-0.2856	**<.0001**
Quadratic	0.0135	**<.0001**
Cohort		**0.0016**
1	ref	
2	-0.3137	**<.0001**
3	-0.2689	**<.0001**
4	-0.1891	**0.0007**
5	-0.2077	**0.0001**
6	0.1413	**0.0369**
Rurality		
Rural	ref	
Non-rural	-0.0725	0.4838
Teaching Status		
Teaching	ref	
Non-Teaching	-0.1299	**0.0009**
Health Care System		
In a System	ref	
Not in a System	0.2028	**<.0001**
Control Status		
Non-Government, Not-For-Profit	ref	
Government, Not-For-Profit	0.092	0.0668
Investor Owner, For-Profit	0.093	0.0929
Rurality x Time		
Rural	ref	
Non-Rural	0.0888	**0.0035**

HSOPS

Section Summary

- The Hospital Survey on Patient Safety Culture (HSOPS) was administered at baseline and at follow-up in all units.
- Among adult ICUs, a statistically significant improvement was found in two dimensions: "feedback and communication about error" and "teamwork within unit." No statistically significant differences were found among the remaining HSOPS dimensions.

The Hospital Survey on Patient Safety Culture (HSOPS) is a reliable and valid survey[13] designed to assess clinician and staff perceptions of the culture of safety within their unit and overall hospital. The instrument contains seven unit-level safety culture dimensions, four hospital-level dimensions, and four outcome variables.

Methods

HSOPS data were collected during two time periods: at the start of project participation and during a follow-up period near project completion. Participating units were invited to collect fresh HSOPS data from unit staff members or to upload previously collected survey data collected during annual safety culture surveys conducted by their organizations. To be included in analyses, units had to be an adult ICU and have a baseline and follow-up survey response rate between zero and 100 percent. Analyses were carried out to test the change in perceptions of safety culture and to mirror as closely as possible the methods used reported in the original Michigan Study and reported by Sexton et al. (2011).[14] It should be noted that the study published by Sexton et al. examined the Safety Attitude Questionnaire, an instrument containing a single "safety climate" dimension while the HSOPS measures 10 dimensions of the safety culture construct as well as 4 outcome variables. Analyses of baseline/follow-up changes in HSOPS dimension scores were assessed using a two-tailed, paired samples t-test with Bonferonni correction for multiple tests. Dimensions with a statistically significant change were further examined to assess the changes in the number of units classified as "needing improvement" (defined as a score of less than 50 percent, a threshold suggested within the HSOPS user's manual). Changes in classification were assessed using McNemar's test.

Results

Results among adult ICUs with baseline and follow-up response rates between zero and 100 percent (n=302) can be found in Table 18 and Figure 18. A statistically significant improvement was found for two dimensions: "feedback and communication about error" (38.9 percent at baseline versus 44.8 percent at follow-up; $p<0.01$) and "teamwork within unit" (75.1 percent

[13] Agency for Healthcare Research and Quality, HSOPS Safety Culture Dimensions and Reliabilities at: http://www.ahrq.gov/qual/patientsafetyculture/hospdim.htm

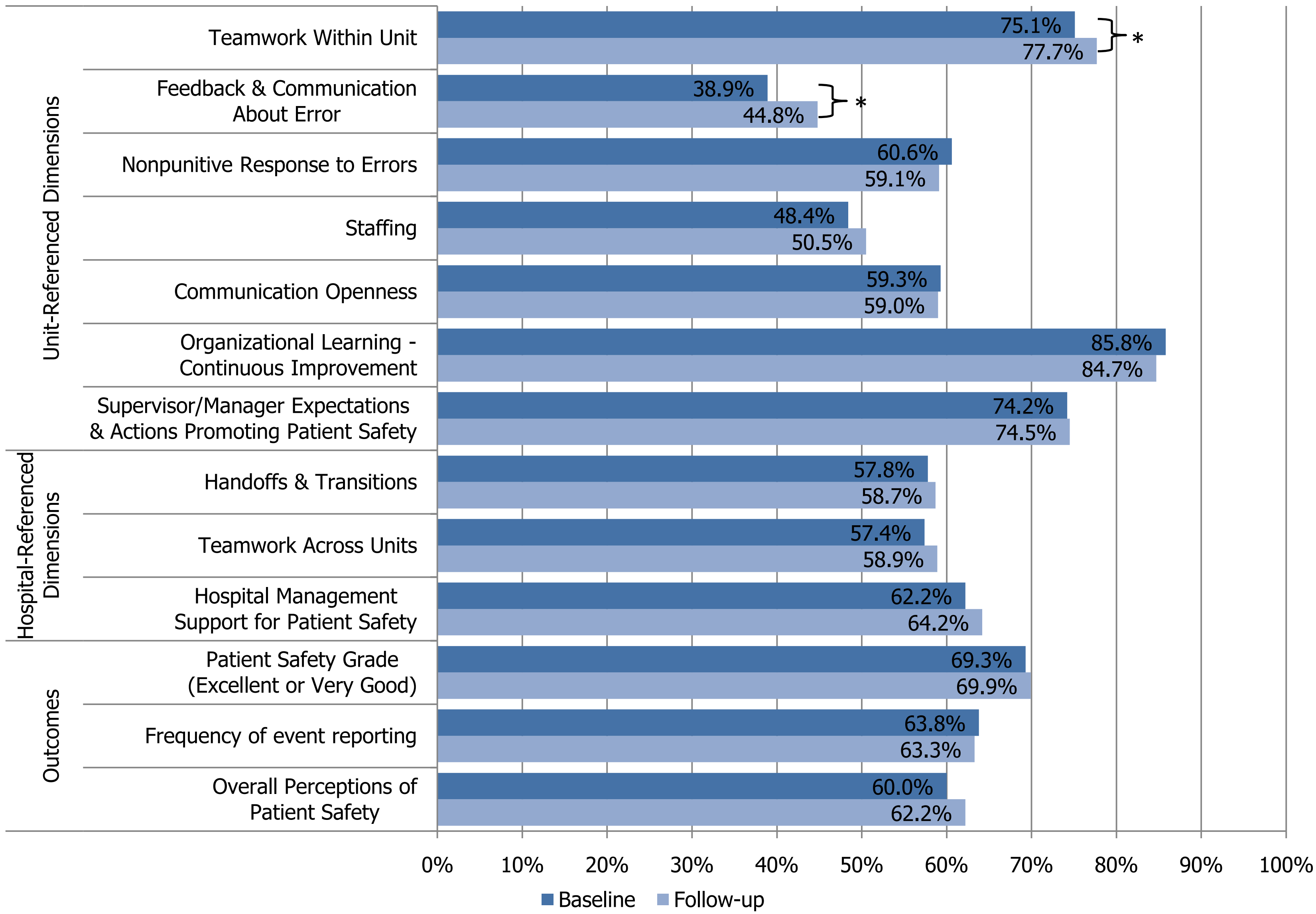
[14] Sexton JB, Berenholtz SM, Goeschel SR, et al. Assessing and improving safety climate in a large cohort of intensive care units. *Critical Care Medicine* 2011;39(5):934-999.

baseline versus 77.7 percent at follow-up; *p*<0.01). The number of units classified as "needing improvement" within the "feedback and communication about error" dimension was statistically significantly reduced by 22 percent (77.8 percent of units at baseline versus 63.9 percent of units at follow-up; *p*<.001). However, the number of units classified as "needing improvement" within the "teamwork within units" dimension did have a statistically significant change (4.3 percent of units at baseline versus 5.3 percent of units at follow-up). There were no statistically significant changes in other dimensions of the HSOPS.

Table 18. Baseline and follow-up HSOPS scores by dimension in adult ICUs (n=302)

	Mean Percent Positive Dimension Scores		Difference		
	Baseline	Follow-up	Mean	Stdev	p-value
Outcomes					
Overall Perceptions of Patient Safety	60.0%	62.2%	-0.023	0.168	0.019
Frequency of event reporting	63.8%	63.3%	0.004	0.170	0.663
Pt. Safety Grade (Excellent or Very Good)	69.3%	69.9%	-0.006	0.198	0.569
Hospital-Referenced Dimensions					
Hospital Management Support for Patient Safety	62.2%	64.2%	-0.019	0.152	0.027
Teamwork Across Units	57.4%	58.9%	-0.015	0.143	0.068
Handoffs and Transitions	57.8%	58.7%	-0.008	0.164	0.381
Unit-Referenced Dimensions					
Supervisor/Manager Expectations & Actions Promoting Patient Safety	74.2%	74.5%	-0.003	0.140	0.686
Organizational Learning—Continuous Improvement	85.8%	84.7%	0.012	0.114	0.080
Communication Openness	59.3%	59.0%	0.003	0.141	0.698
Staffing	48.4%	50.5%	-0.020	0.144	0.015
Nonpunitive Response to Errors	60.6%	59.1%	0.015	0.167	0.114
Feedback and Communication About Error	38.9%	44.8%	-0.059	0.183	**<0.001***
Teamwork Within Unit	75.1%	77.7%	-0.026	0.153	**0.003***

Figure 18. Baseline and follow-up HSOPS scores by dimension among adult ICUs (n=302)



*Statistically significant different, $p<0.01$.

Team Checkup Tool

Section Summary

- Units were requested to complete a Team Checkup Tool (TCT) assessing CUSP adoption, implementation, and barriers.
- The proportion of units using specific project steps (a.m. briefing, daily goals, observing rounds) increased over time.
- More than 80 percent of units consistently used the following CLABSI reduction steps over time: hand hygiene, chlorhexidine skin preparation, full-barrier precautions during line insertion, avoidance of femoral site for placement, and removal or review of unnecessary lines.
- At baseline, units identified the following as the top barriers to progress: 1) not enough time, 2) confusion about how to proceed with CUSP activities, and 3) not enough buy-in from other physician staff. Over time, the proportion of units perceiving these as barriers decreased.

Participating units were requested to complete a Team Checkup Tool (TCT) evaluating three primary domains: adoption of CUSP activities, implementation of CLABSI reduction steps, and progress barriers. Initially, cohorts were requested to complete the TCT on a monthly basis. Due to data collection burden, the collection schedule was modified in December of 2010 to quarterly, and the survey instrument was shortened. Both versions of the survey instrument can be found in Appendix F. Figure 19 and Figure 20 illustrate cohorts providing survey responses by instrument version over time. Results include data from all units regardless of ICU status due to low submission rates. Questions from domains were selected for presentation only if all cohorts were exposed to the question. For example, "Culture debriefing" is found in version one of the instrument but not version two, and therefore results for this domain are not shown below.

Although survey response was low (~18 percent completion), results found an increase in "adoption of CUSP activities" and "implementation of CLABSI reduction steps" domains over time and a decrease in "progress barriers" with time. Specifically, the proportion of units undertaking AM briefing, daily goals, and observing rounds increased over time. More than 80 percent of units consistently used hand hygiene, chlorhexidine skin preparation, full-barrier precautions during line insertion, and avoidance of femoral site for placement. Reported removal or review of unnecessary lines also increased over time. The top three unit progress barriers were 1) not enough time, 2) confusion about how to proceed with CUSP activities, and 3) not enough buy-in from other physician staff. Proportion of units perceiving these three areas as barriers decreased over time.

Figure 19. TCT completion by cohort - version one

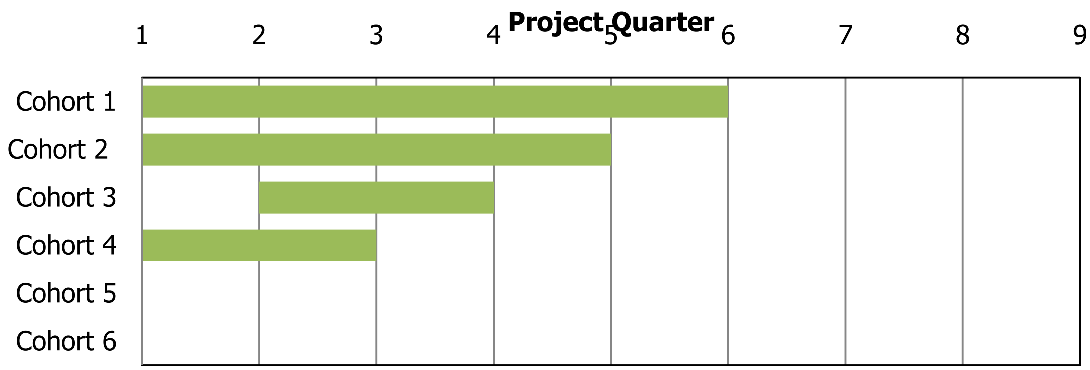


Figure 20. TCT completion by cohort - version two

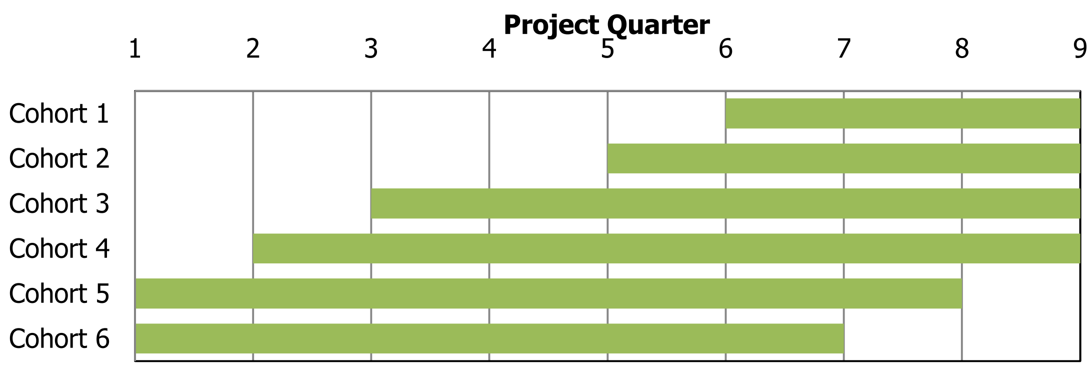
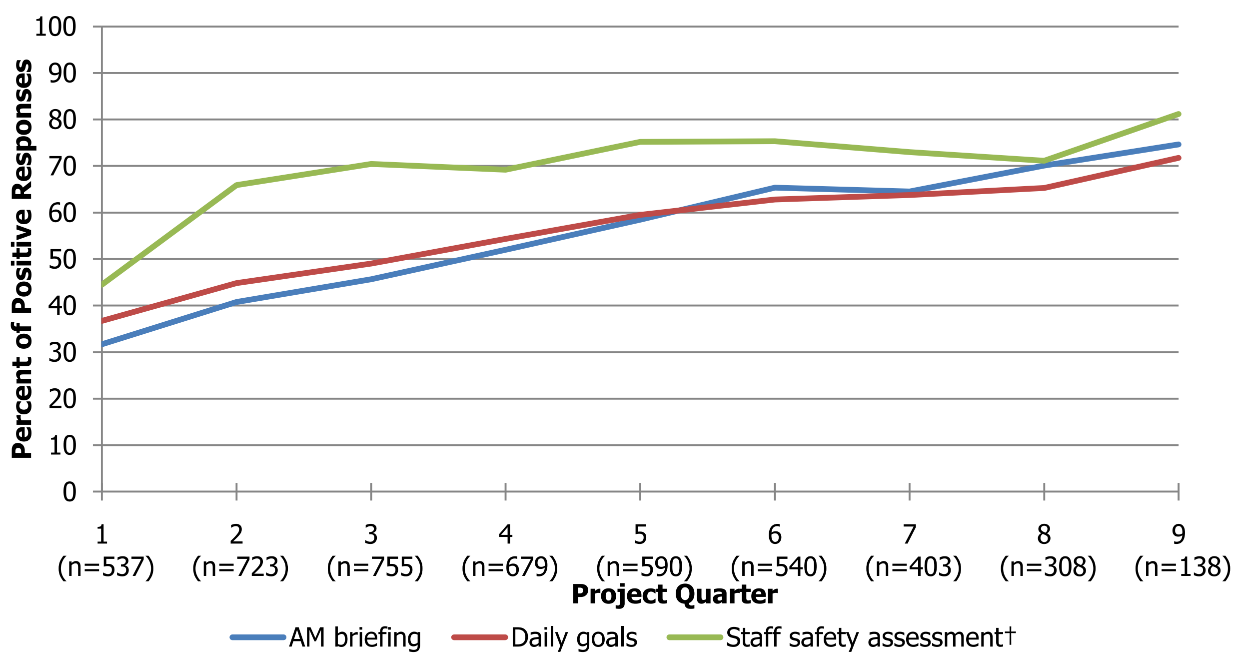
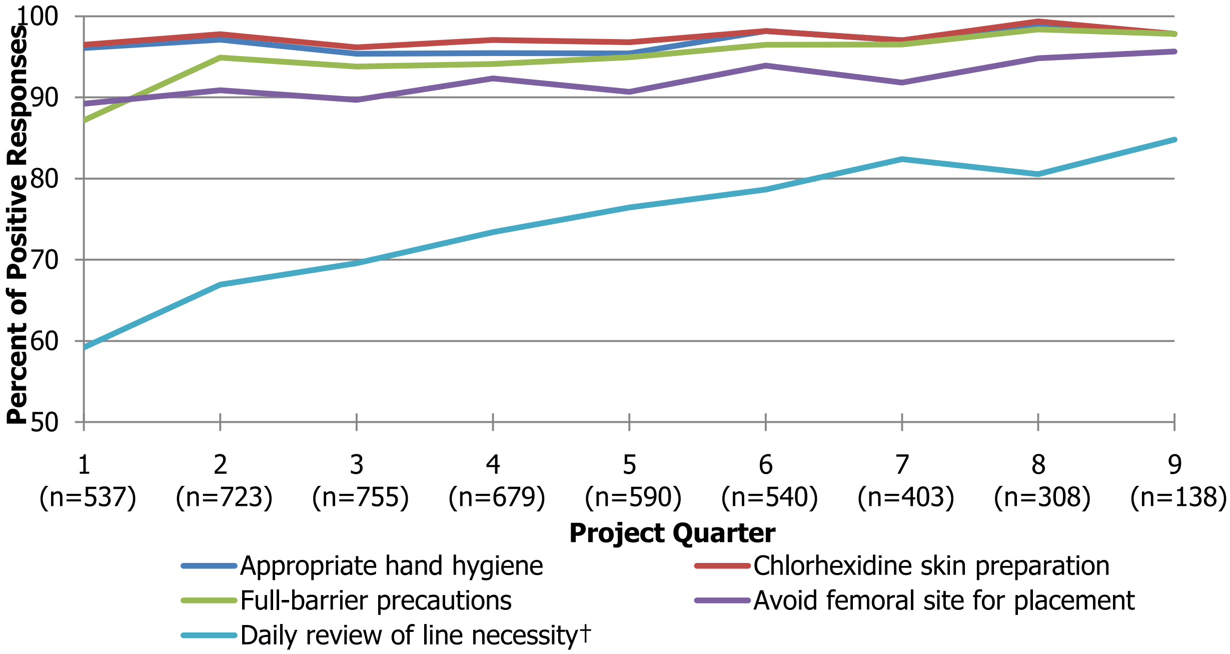


Figure 21. Adoption of CUSP activities



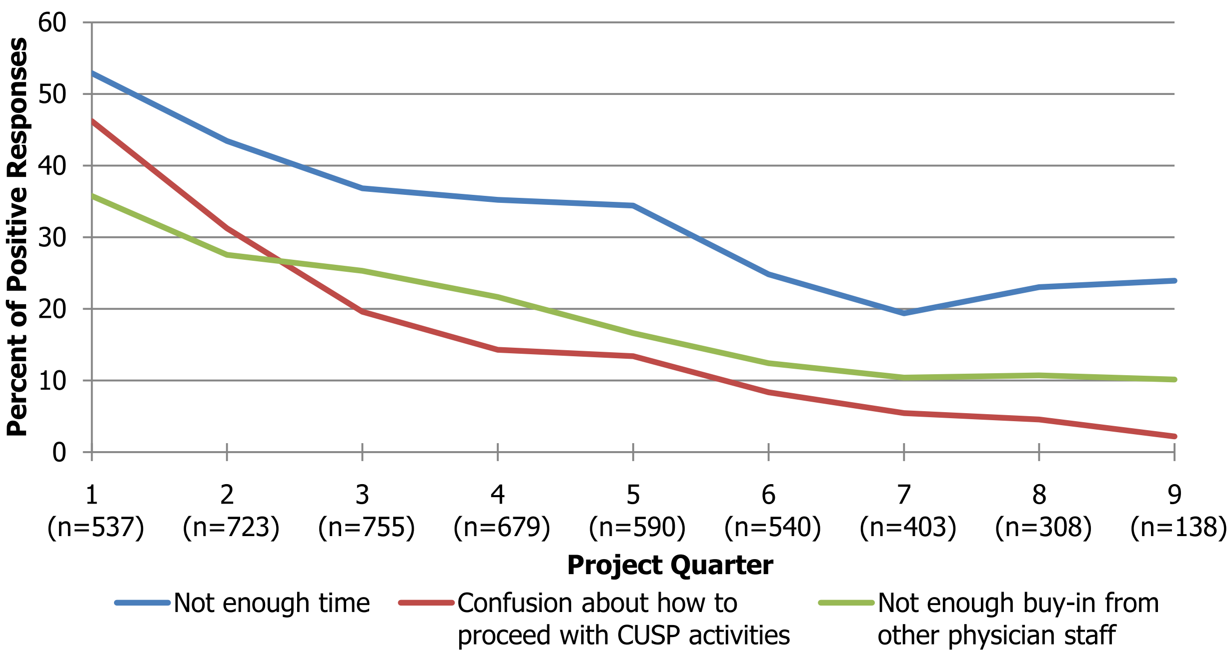
†Only data in the 2nd version of TCT were included

Figure 22. Implementation of CLABSI reduction steps



†Only data in the 2nd version of TCT were included

Figure 23. Top three unit progress barriers



Readiness Assessment

Section Summary

- A total of 342 Readiness Assessments were completed in adult ICUs.
- Units most frequently reported they had fully implemented inclusion of chlorhexidine in their central line kit (94.7 percent) followed by use of an independent line cart or kit stocked with essentials for placing a central line catheter (83.0 percent).
- Least frequently reported was the routine bathing of patients in clinical areas with chlorhexidine (20.7 percent) followed by use of an antiseptic or antibiotic impregnated or coated central catheter (43.6 percent).
- Units in teaching hospitals or hospitals with greater than the median number of beds were more likely to report to the CDC NHSN ($p<0.001$).

Units were requested to complete a Readiness Assessment at baseline (see Appendix G for complete instrument). The Readiness Assessment was designed to assess adoption of best clinical practices (e.g. frequency of bathing patients in clinical areas with chlorhexidine) and prior exposure to CUSP materials or participation in other CLABSI reduction efforts.

Results of Readiness Assessments presented below were restricted to adult ICUs and, when possible, matched to their hospital's 2010 AHA Annual Survey. Utilizing the AHA survey, units were classified as residing in teaching or non-teaching hospitals, and the median bed size of the sample was used to classify units as residing in hospitals with total bed size above or below the sample median. Readiness Assessment results that could not be matched to an AHA survey were classified as non-teaching and below the median bed size. Finally, for presentation purposes, results of the assessment were restricted to items considered most clinically relevant or pertinent to CUSP implementation. A total of 342 Readiness Assessments were completed among adult ICUs. Forty-five percent of units resided in teaching hospitals, and the median bed size was 230 (mean=311, stdev=256). Seven units could not be matched to their AHA surveys.

Survey responses can be found in Table 19. Most frequently, units reported they had fully implemented inclusion of chlorhexidine in their central line kit (94.7 percent). Least frequent was the routine bathing of patients in clinical areas with chlorhexidine (20.7 percent). Variability in responses was found based on teaching status and bed size. Units residing in either teaching hospitals or hospitals with greater than 230 beds were more likely to report to the CDC NHSN ($p<0.001$). Units residing in teaching hospitals were more likely to have participated in an organized multi-site effort to reduce CLABSI. Finally, units residing in hospitals with greater than 230 beds were more likely to, 1) use an independent line cart or kit stocked with essentials for placing a central line catheter, 2) use a line insertion checklist to ensure compliance with evidence-based practices, 3) use chlorhexidine impregnated patch for central venous line care and, 4) bathe patients in clinical care areas with chlorhexidine.

Table 19. Readiness Assessment results for adult ICUs

	Assessment Question*	All (n=342)	Teaching Status: Non-Teaching (n=187)	Teaching Status: Teaching (n=155)	Teaching Status: p value‡	Bed Size†: ≤230 beds (n=175)	Bed Size†: >230 Beds (n=167)	Bed Size†: p value‡
1	Participation in any organized multi-site effort to reduce bloodstream infections	43.9%	20.5%	23.4%	**0.009**	20.8%	23.1%	0.210
2	Partnership' with a Senior Executive for patient safety	49.4%	26.6%	22.8%	0.760	24.9%	24.6%	0.749
3	Systematic analysis and proactive learning from harmful events or events with potential harm as raised by front-line staff (other than M&Ms and official RCA)	52.3%	28.4%	24.0%	0.849	26.0%	26.3%	0.574
4	Use of an independent line cart or kit, stocked with essentials for placing a central-line catheter	83.0%	43.3%	39.8%	0.035	39.8%	43.3%	**0.007**
5	Inclusion of chlorhexidine in central line kit	94.7%	51.5%	43.3%	0.573	47.4%	47.4%	0.066
6	Use of a line-insertion checklist to ensure compliance with evidence-based practices	80.1%	41.2%	38.9%	0.016	37.7%	42.4%	**0.002**
7	Does your hospital participate in reporting to the CDC NHSN?	54.1%	24.9%	29.2%	**<0.001**	22.8%	31.3%	**<0.001**
8	Does your ICU/Clinical Care Area currently use a chlorhexidine impregnated patch for central venous line care?	67.5%	34.2%	33.3%	0.031	30.1%	37.4%	**<0.001**
9	Does your ICU/Clinical Care Area currently use antiseptic or antibiotic impregnated or coated central catheters?	43.6%	24.0%	19.6%	0.908	22.8%	20.8%	0.701
10	Do you bathe patients in this clinical care area with chlorhexidine?	20.7%	8.8%	12.0%	0.018	7.0%	13.7%	**0.001**

* Items 1-7 are considered a positive response if reported as "fully implemented" and items 8-10 are considered a positive response if reported as "Routinely"

† Total hospital beds median for sample used for stratification (median = 230, mean = 311, stdev = 256)

‡ Statistical significance considered at $p<0.01$ level.

Appendix A

Exclusion Criteria

To be included, publications had to be full articles, (abstracts were excluded) and CLABSIs had to occur in adult ICU or non-ICU settings. The following exclusion criteria were applied when considering articles to be included in the systematic review of CLABSI cost:

- Articles not pertaining to calculating attributable CLABSI cost estimates were excluded.
- Articles combining CLABSI cost estimates with other hospital-acquired infections were excluded.
- Articles in which hospitals were not within the United States were excluded.
- Cost estimates not in U.S. dollars were excluded.
- Articles pertaining to bloodstream infections that were not hospital-acquired were excluded.
- Articles related to dialysis-acquired CLABSI were excluded.
- Articles where CLABSI was assessed in persons younger than 18 years of age (i.e. pediatrics) were excluded.
- Simulated cost models were excluded.
- Articles published in a language other than English were excluded.
- Articles related to non-human subjects were excluded.
- Review and systematic review articles were excluded; however, articles were pulled and citations cross-checked.
- Articles published before 2002 were excluded.
- Articles not peer reviewed were excluded.
- Letters, case reports (n=1), historical articles, editorials, and commentaries were excluded.

Appendix B

Systematic Review Flowchart

Total search result abstracts
N=855

↓

Unique number of abstracts
n=841

Irrelevant by title and abstract
n=792

↓

Initial articles reviewed
n=49

Additional articles reviewed after reviewing references
n=109

↓

Total number of articles reviewed
n=158

Excluded (n=152):

- Prior to 2002 (59)
- Not calculating attributable CLABSI cost (39)
- Not pertaining to CLABSI specific hospital-acquired infections (17)
- Outside of the United States (17)
- Reviews, meta-analysis or systematic reviews (9)
- Combines CLABSI cost estimates with other infections (4)
- Articles not peer reviewed (4)
- Cost not in U.S. Dollars (2)
- Simulated cost model (1)

↓

Total number of included studies
n=6

Appendix C

Article Exclusion List with Reason for Exclusion

Author, Year	Title	Reason for Exclusion
Abramson MA, 2002	Nosocomial methicillin-resistant and methicillin-susceptible Staphylococcus aureus. Primary Bacteremia: At What Costs?	Does not pertain to calculated attributable CLABSI cost estimates
Al-Rawajfah OM, 2009	Incidence of and risk factors for nosocomial bloodstream infections in adults in the United States.	Does not pertain to calculated attributable CLABSI cost estimates
Armour AD, 2007	The impact of nosocomially-acquired resistant Pseudomonas aeruginosa infection in a burn unit.	Does not pertain to calculated attributable CLABSI cost estimates
Arnow PM, 1993	Consequences of intravascular catheter sepsis.	Published before 2002
Ben-David D, 2009	Are there differences in hospital cost between patients with nosocomial methicillin-resistant Staphylococcus aureus bloodstream infection and those with methicillin-susceptible S. aureus bloodstream infection?	Compares and/or combines CLABSI cost estimates with other HAI
Berenholtz SM, 2004	Eliminating catheter-related bloodstream infections in the intensive care unit.	Does not pertain to calculated attributable CLABSI cost estimates
Blot S, 2002	Clinical impact of nosocomial Klebsiella bacteremia in critically ill patients.	Does not pertain to calculated attributable CLABSI cost estimates
Blot S, 2005	Clinical and economic outcomes in critically ill patients with nosocomial catheterrelated bloodstream infection.	Pertains to hospital(s) not within the United States
Blot S, 2002	Effects of nosocomial candidemia on outcomes of critically ill patients.	Does not pertain to calculated attributable CLABSI cost estimates
Blot S, 2003	Reappraisal of attributable mortality in critically ill patients with nosocomial bacteraemia involving Pseudomonas aeruginosa.	Does not pertain to calculated attributable CLABSI cost estimates
Blot S, 2003	Evaluation of outcome in critically ill patients with nosocomial enterobacter bacteremia: results of a matched cohort study.	Does not pertain to calculated attributable CLABSI cost estimates
Blot S, 2003	Nosocomial bacteremia involving Acinetobacterbaumannii in critically ill patients: a matched cohort study.	Does not pertain to calculated attributable CLABSI cost estimates
Blot S, 2002	Nosocomial bacteremia caused by antibiotic-resistant gram-negative bacteria in critically ill patients: Clinical outcome and length of hospitalization.	Does not pertain to calculated attributable CLABSI cost estimates
Borschel DM, 2006	Are antiseptic-coated central venous catheters effective in a real-world setting?	Does not pertain to calculated attributable CLABSI cost estimates

Author, Year	Title	Reason for Exclusion
Brun-Buisson C, 2003	The costs of septic syndromes in the intensive care unit and influence of hospital-acquired sepsis.	Cost estimates not in U.S. dollars
Burke JP, 2003	Infection control - a problem for patient safety.	Does not pertain to calculated attributable CLABSI cost estimates
Burton DC, 2009	Methicillin-resistant Staphylococcus aureus central line-associated bloodstream infections in US intensive care units, 1997-2007.	Does not pertain to calculated attributable CLABSI cost estimates
Carbon C 1999	Costs of treating infections caused by methicillin-resistant staphylococci and vancomycin-resistant enterococci.	Published before 2002
Carmeli Y, 2002	Health and economic outcomes of vancomyecin resistant enterococci.	Does not pertain to CLABSI specific HAI
CDC, 2005	Reduction in central line-associated bloodstream infections among patients in intensive care units--Pennsylvania, April 2001-March 2005	Does not pertain to calculated attributable CLABSI cost estimates
CDC, 1992	Public health focus: surveillance, prevention, and control of nosocomial infections.	Published before 2002
CDC, 1998	National Nosocomial Infections Surveillance (NNIS) system report, data summary from October 1986- April 1998	Published before 2002
CDC, 2011	Vital signs: central line-associated blood stream infections--United States, 2001, 2008, and 2009.	Does not pertain to calculated attributable CLABSI cost estimates
Coopersmith CM, 2002	Effect of an education program on decreasing catheter-related bloodstream infections in the surgical intensive care unit.	Does not pertain to calculated attributable CLABSI cost estimates
Correa L, 2000	Problems and solutions in hospital-acquired bacteraemia.	Published before 2002
Cosgrove SE, 2006	Evidence that prevention makes cents: Costs of catheter-associated bloodstream infections in the intensive care unit.	Does not pertain to calculated attributable CLABSI cost estimates
Cosgrove SE, 2005	The impact of methicillin resistance in Staphylococcus Aureusbacterimia on patient outcomes: mortality, length of stay, and hospital charges.	Compares and/or combines CLABSI cost estimates with other HAI
Crawford AG, 2004	Cost-benefit analysis of chlorhexidinegluconate dressing in the prevention of catheter-related bloodstream infections.	Does not pertain to calculated attributable CLABSI cost estimates
Curtis LT 2008	Prevention of hospital-acquired infections: review of non-pharmacological interventions.	Review, meta-analysis and systematic review articles
DiazGranados CA, 2005	Comparison of mortality associated with vancomycin-resistant and vancomycin-susceptible enterococcal bloodstream infections: a meta-analysis.	Review, meta-analysis and systematic review articles

Author, Year	Title	Reason for Exclusion
Digiovine B, 1999	The attributable mortality and costs of primary nosocomial bloodstream infections in the intensive care unit.	Published before 2002
Dimick JB, 2001	Increased resource use associated with catheter-related bloodstream infection in the surgical intensive care unit.	Published before 2002
Dimick JB, 2001	Intersive care unit physician staffing is associated with decreased length of stay, hospital cost, and complications after espothageal resection.	Published before 2002
Dixon RE, 1987	Costs of nosocomial infections and benefits of infection control programs. In: Wenzel RP, ed. Prevention and Control of Nosocomial Infections, 1st ed.	Published before 2002
Donowitz LG, 1987	Neonatal intensive care unit bacteremia: emergence of gram-positive bacteria as major pathogens.	Published before 2002
Edmond MB, 1999	Nosocomial bloodstream infections in United States hospitals: a three-year analysis.	Published before 2002
Engemann JJ, 2003	Adverse clinical and economic outcomes attributable to methicillin resistance among patients with Staphylococcusaureus surgical site infection.	Does not pertain to CLABSI specific HAI
Esatoglu AE, 2006	Additional cost of hospital-acquired infections to the patient: a case study in Turkey.	Pertains to hospital(s) not within the United States
Evans RS, 1998	A computer-assisted management program for antibiotics and other anti-infective agents.	Published before 2002
Falagas ME, 2006	Attributable mortality of candidemia: a systematic review of matched cohort and case-control studies.	Review, meta-analysis and systematic review articles
Fraher MH, 2009	Cost-effectiveness of employing a total parenteral nutrition surveillance nurse for the prevention of catheter-related bloodstream infections.	Pertains to hospital(s) not within the United States
Fukuda H, 2011	Variations in analytical methodology for estimating costs of hospital-acquired infections: a systematic review.	Review, meta-analysis and systematic review articles
Gagne JJ, 2006	Costs associated with candidemia in a hospital setting.	Does not pertain to CLABSI specific HAI
Garrouste-Orgeas M, 2000	A one-year prospective study of nosocomial bacteremia in ICU and non-ICU patients and its impact on patient outcome.	Published before 2002
GianinoMS, 1993	The impact of a nutritional support team on the cost and management of multilumen central venous catheters.	Published before 2002

Author, Year	Title	Reason for Exclusion
Goldstein M, 2000	The medical and financial costs associated with termination of a nutrition support nurse.	Published before 2002
Gonzales RD, 2001	Infections due to vancomycin-resistant Enterococcus faecium resistant to linezolid.	Published before 2002
Graves N, 2007	Effect of healthcare-acquired infection on length of hospital stay and cost.	Pertains to hospital(s) not within the United States
Graves N, 2005	Correcting for bias when estimating the cost of hospital-acquired infection: an analysis of lower respiratory tract infections in non-surgical patients.	Pertains to hospital(s) not within the United States
Graves N, 2007	Economics and preventing hospital acquired infection–broadening the perspective.	Simulated cost model
Gudlaugsson O, 2003	Attributable mortality of nosocomial candidemia, revisited.	Does not pertain to calculated attributable CLABSI cost estimates
Haley RW, 1991	Measuring the costs of nosocomial infections: methods for estimating economic burden on the hospital.	Published before 2002
Haley RW, 1985	The nationwide nosocomial infection rate: a new need for vital statistics.	Published before 2002
Haley RW, 1985	The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals.	Published before 2002
Haley RW, 1998	Cost-benefit analysis of infection control activities.	Published before 2002
Haley RW, 1987	The financial incentive for hospitals to prevent nosocomial infections under the prospective payment system: an empirical determination from a nationally representative sample.	Published before 2002
Halton K, 2007	Economic evaluation and catheter-related bloodstream infections.	Review, meta-analysis and systematic review articles
Heiselman D, 1994	Nosocomial bloodstream infections in the critically ill.	Published before 2002
Herwaldt LA, 2006	A prospective study of outcomes, healthcare resource utilization, and costs associated with postoperative nosocomial infections.	Does not pertain to calculated attributable CLABSI cost estimates
Higuera F, 2007	Attributable cost and length of stay for patients with central venous catheter-associated bloodstream infection in Mexico City intensive care units: a prospective, matched analysis.	Pertains to hospital(s) not within the United States
Hollenbeak CS 2011	The cost of catheter-related bloodstream infections: implications for the value of prevention.	Article not peer reviewed

Author, Year	Title	Reason for Exclusion
Hollenbeak CS 2002	Nonrandom selection and the attributable cost of surgical-site infections.	Does not pertain to CLABSI specific HAI
Hoste EA, 2004	Effect of nosocomial bloodstream infection on the outcome of critically ill patients with acute renal failure treated with renal replacement therapy.	Pertains to hospital(s) not within the United States
Jarvis WR, 1996	Selected aspects of the socioeconomic impact of nosocomial infections: morbidity, mortality, cost and prevention.	Published before 2002
Kim JS, 2011	Reduction of catheter-related bloodstream infections through the use of a central venous line bundle: epidemiologic and economic consequences.	Does not pertain to calculated attributable CLABSI cost estimates
Klevens RM, 2007	Estimating health care-associated infections and deaths in U.S. hospitals, 2002.	Compares and/or combines CLABSI cost estimates with other HAI
Kluger DM, 1999	The relative risk of intravascular device related bloodstream infections in adults [abstract].	Published before 2002
Landry SL, 1989	Hospital stay and mortality attributed to nosocomial enterococcal bacteremia: a controlled study.	Published before 2002
Laupland KB, 2002	Population based assessment of intensive care unit-acquired bloodstream infections in adults: incidence, risk factors, and associated mortality rate.	Does not pertain to calculated attributable CLABSI cost estimates
Laupland KB, 2006	Cost of intensive care unit-acquired bloodstream infections.	Pertains to hospital(s) not within the United States
Li J, 2001	Comparison of length of hospital stay for patients with known or suspected methicillin-resistant Staphylococcus species infections treated with linezolid or vancomycin: a randomized, multi-center trial.	Published before 2002
Lodise TP, 2005	Clinical and economic impact of methicillin resistance in patients with staphylococcus aureus bacteremia.	Does not pertain to CLABSI specific HAI
Luce B, 1996	Estimating costs in cost-effectiveness analysis.	Published before 2002
Martin MA, 1989	Coagulase-negative staphylococcal bacteremia: mortality and hospital stay.	Published before 2002
McCollum M, 2003	Cost analysis of switching from IV vancomycin to PO linezolid for the management of methicillin-resistant Staphylococcus species.	Does not pertain to calculated attributable CLABSI cost estimates
Meier PA, 1998	Impact of a dedicated intravenous therapy team on nosocomial bloodstream infection rates.	Published before 2002

Author, Year	Title	Reason for Exclusion
Mermel LA, 2000	Prevention of intravascular catheter-related infections.	Published before 2002
Mermel LA, 2000	Correction: catheter related bloodstream-infections.	Published before 2002
Misset B, 2004	A continuous quality-improvement program reduces nososcomial infection rates in the ICU.	Does not pertain to CLABSI specific HAI
Moran C, 2009	Candida albicans and non-albicans bloodstream infections in adult and pediatric patients: comparison of mortality and costs.	Does not pertain to calculated attributable CLABSI cost estimates
Morgan J, 2005	Excess mortality, hospital stay, and cost due to candidemia: A case-control study using data from population-based candidemia surveillance.	Does not pertain to CLABSI specific HAI
Mullins C, 2006	Cost-effectiveness analysis of linezolid compared with vancomycin for the treatment of nosocomial pneumonia caused by methicillin-resistant *Staphylococcus aureus*.	Does not pertain to CLABSI specific HAI
Nehme AE 1980	Nutritional support of the hosptalized patient: the team concept.	Published before 2002
Nightingale CH, 1993	Impact of nosocomial infections on hospital costs.	Published before 2002
Niven DJ, 2010	Cost and outcomes of nosocomial bloodstream infections complicating major traumatic injury.	Pertains to hospital(s) not within the United States
Nixon M, 2006	Methicillin-resistant Staphylococcus aureus on orthopaedic wards: incidence, spread, mortality, cost and control.	Cost estimates not in U.S. dollars
Nosrati M, 2010	Excess costs associated with common healthcare-associated infections in an Iranian cardiac surgical unit.	Pertains to hospital(s) not within the United States
O'Grady N, 2002	Guidelines for the prevention of intravascular catheter-related infections.	Does not pertain to calculated attributable CLABSI cost estimates
Ostrowsky B, 2001	Reality check: should we try to detect and isolate vancomycin-resistant enterococci patients?	Published before 2002
Parodi S, 2001	Early switch and early discharge opportunities in intravenous vancomycin treatment of suspected methicillin-resistant staphyloccal species infections.	Does not pertain to calculated attributable CLABSI cost estimates
Pennsylvania Health Care Cost Containment Council2005	Hospital-acquired infections in Pennsylvania. PHC4	Article not peer reviewed

Author, Year	Title	Reason for Exclusion
Pennsylvania Health Care Cost Containment Council 2005	Reducing hospital-acquired infections: the business case. PHC4	Article not peer reviewed
Pennsylvania Health Care CostContainment Council 2006	Hospital-acquired infections in Pennsylvania. PHC4	Article not peer reviewed
Pirson M, 2005	Costs associated with hospital acquired bacteraemia in a Belgian hospital.	Pertains to hospital(s) not within the United States
Pittet D, 1997	Nosocomial bloodstream infections.	Published before 2002
Plowman RP, 2001	The rate and cost of hospitalacquired infections occurring in patients admitted to selected specialties of a district general hospital in England and the national burden imposed.	Published before 2002
Pronovost P, 2006	An intervention to decrease catheter-related bloodstream infections in the ICU.	Does not pertain to calculated attributable CLABSI cost estimates
Puzniak L, 2004	Has the epidemiology of nosocomial candidemia changed?	Does not pertain to CLABSI specific HAI
Rello J, 1994	Nosocomial acteremia in a medical-surgical intensive care unit: Epidemiologic characteristics and factors influencing mortality in 111 episodes.	Published before 2002
Renaud B, 2001	Outcomes of primary and catheterrelated bacteremia. A cohort and case-control study in critically ill patients.	Published before 2002
Rentz AM, 1998	The impact of candidemia on length of hospital stay, outcome, and overall cost of illness.	Published before 2002
Rubin RJ, 1999	The economic impact of Staphylococcus aureus infection in New York City hospitals.	Published before 2002
Saint S, 2000	The clinical and economic consequences of nosocomial central venous catheter-related infection: are antimicrobial catheters useful?	Published before 2002
Salgado CD, 2003	Outcomes associated with vancomycin-resistant enterococci: a meta-analysis.	Review, meta-analysis and systematic review articles
Sanchez-Velazquez LD, 2006	The burden of nosocomial infection in the intensive care unit: effects on organ failure, mortality and costs. A nested case-control study.	Pertains to hospital(s) not within the United States

Author, Year	Title	Reason for Exclusion
Scheckler WE, 1980	Hospital costs of nosocomial infections: a prospective three month study in a community hospital.	Published before 2002
Shorr AF, 2009	Burden of early-onset candidemia: analysis of culture-positive bloodstream infections from a large U.S. database.	Does not pertain to CLABSI specific HAI
Shorr AF, 2003	New choices for central venous catheters: potential financial implications.	Does not pertain to calculated attributable CLABSI cost estimates
Shorr AF, 2006	Morbidity and cost burden of methicillin-resistant Staphylococcus aureus in early onset ventilator-associated pneumonia.	Does not pertain to CLABSI specific HAI
Slonim AD, 2001	Nosocomial bloodstream infection and cost.	Published before 2002
Smith SD, 1996	Costs of nosocomial infections.	Published before 2002
Song X, 2003	Effect of nosocomial vancomycin- resistant enterococcal bacteremia on mortality, length of stay, and costs.	Does not pertain to CLABSI specific HAI
Soufir L, 1999	Attributable morbidity and mortality of catheter-related septicemia in critically ill patients: a matched, risk adjusted, cohort study.	Published before 2002
Spengler RF, 1978	Hospital costs and mortality attributed to nosocomial bacteremias.	Published before 2002
Steiner C, 2002	The healthcare Cost and Utilization project: an overview.	Does not pertain to calculated attributable CLABSI cost estimates
Stevens DL, 2002	Linezolid versus vancomycin for the treatment of methicillin-resistant.	Does not pertain to calculated attributable CLABSI cost estimates
Stone PW, 2005	Systematic review of economic analyses of health care-associated infections.	Review, meta-analysis and systematic review articles
Stone PW, 2002	A systematic audit of economic evidence linking nosocomial infections and infection control interventions: 1990–2000.	Review, meta-analysis and systematic review articles
Stosor V, 1998	Enterococcus faecium bacteremia: does vancomycin resistance make a difference?	Published before 2002
Suljagic V, 2005	Nosocomial bloodstream infections in ICU and non-ICU patients.	Pertains to hospital(s) not within the United States
Tagalakis V, 2002	The epidemiology of peripheral vein infusion thrombophlebitis: A critical reivew.	Does not pertain to CLABSI specific HAI

Author, Year	Title	Reason for Exclusion
Tarricone R, 2010	Hospital costs of central line-associated bloodstream infections and cost-effectiveness of closed vs. open infusion containers. The case of Intensive Care Units in Italy.	Pertains to hospital(s) not within the United States
Taylor GJ, 1990	Determinants of hospital charges for coronary artery bypass surgery: the economic consequences of postoperative complications.	Published before 2002
Teres D, 2002	Effects of severity of illness on resource use by survivors and nonsurvivors of severe sepsis at intensive care unit admission.	Compares and/or combines CLABSI cost estimates with other HAI
Tomford JW, 1985	The IV therapy team: impact on patient care and costs of hospitalization.	Published before 2002
Tompkins RG, 1992	Infections of Burn Wounds. 3rd ed.	Published before 2002
Toufen C, 2003	Prevalence rates of infection in intensive care units of a tertiary teaching hospital.	Pertains to hospital(s) not within the United States
Turpin, RS 2011	Nutrition therapy cost analysis in the US pre-mixed multi-chamber bag versus compounded parenteral nutrition.	Does not pertain to calculated attributable CLABSI cost estimates
Umscheid CA, 2011	Estimating the proportion of healthcare-associated infections that are reasonably preventable and the related mortality and costs.	Does not pertain to calculated attributable CLABSI cost estimates
US Department of Health & Human Services 2008	Part II: Department of Health and Human Services: Centers for Medicare & Medicaid Services. 42 CFR.	Does not pertain to CLABSI specific HAI
Valles J, 1997	Nosocomial bacteremia in critically ill patients: A multicenter study evaluating epidemiology and prognosis.	Published before 2002
Vincent JL 2003	Nosocomial infections in adult intensive –care units.	Review, meta-analysis and systematic review articles
Vincent J-L, 1995	The prevalence of nosocomial infection in intensive care units in Europe: Results of the European Prevalence of Infection in Intensive Care (EPIC) study.	Published before 2002
Vogel TR, 2006	The open abdomen in trauma.	Does not pertain to CLABSI specific HAI
Vrijens F, 2010	Hospital-acquired, laboratory-confirmed bloodstream infections: linking national surveillance data to clinical and financial hospital data to estimate increased length of stay and healthcare costs.	Pertains to hospital(s) not within the United States
Wakefield DS, 1987	Use of the appropriateness evaluation protocol for estimating the incremental costs associated with nosocomial infections.	Published before 2002

Author, Year	Title	Reason for Exclusion
Warren DK, 2004	The effect of an education program on the incidence of central venous catheter-associated bloodstream infection in a medical ICU.	Does not pertain to calculated attributable CLABSI cost estimates
Warren DK, 2004	Occurrence of co-colonization or co-infection with vancomycin-resistant enterococci and methicillinresistant Staphylococcus aureus in a medical intensive care unit.	Does not pertain to calculated attributable CLABSI cost estimates
Waters HR, 2011	The business case for quality: economic analysis of the Michigan Keystone Patient Safety Program in ICUs.	Does not pertain to calculated attributable CLABSI cost estimates
Weinstein RA 1998	Nosocomial infection update.	Published before 2002
Weintraub WS, 1989	Determinants of prolonged length of stay after coronary bypass surgery.	Published before 2002
Wenzel RP 1995	The economics of nosocomial infections.	Published before 2002
Wenzel RP, 1991	Feasible and desirable future targets for reducing the costs of hospital infections.	Published before 2002
Wenzel RP, 2001	The impact of hospital-acquired bloodstream infections.	Published before 2002
Wey SB, 1988	Hospital acquired candidemia: the attributable mortality and excess length of stay.	Published before 2002
Wisplinghoff H, 2003	Outcomes of nosocomial bloodstream infections in adult neutropenic patients: a prospective cohort and matched case-control study.	Pertains to hospital(s) not within the United States
Wisplinghoff H, 2004	Nosocomial bloodstream infections in US hospitals: analysis of 24,179 cases from a prospective nationwide surveillance study.	Does not pertain to calculated attributable CLABSI cost estimates
Ye X, 2011	Economic impact of use of chlorhexidine-impregnated sponge dressing for prevention of central line-associated infections in the United States.	Does not pertain to calculated attributable CLABSI cost estimates
Young EM, 2006	Translating evidence into practice to prevent central venous catheter-associated bloodstream infections: a systems-based intervention.	Does not pertain to calculated attributable CLABSI cost estimates
Young LS, 2006	Preoperative use of mupirocin for the prevention of healthcare-associated Staphylococcus aureus infections: a cost-effectiveness analysis.	Does not pertain to CLABSI specific HAI
Zack JE, 2002	Effect of an education program aimed at reducing the occurrence of ventilator-associated pneumonia.	Does not pertain to calculated attributable CLABSI cost estimates
Zaoutis TE, 2005	The epidemiology and attributable outcomes of candidemia in adults and children hospitalized in the United States: a propensity analysis.	Does not pertain to CLABSI specific HAI

Appendix D

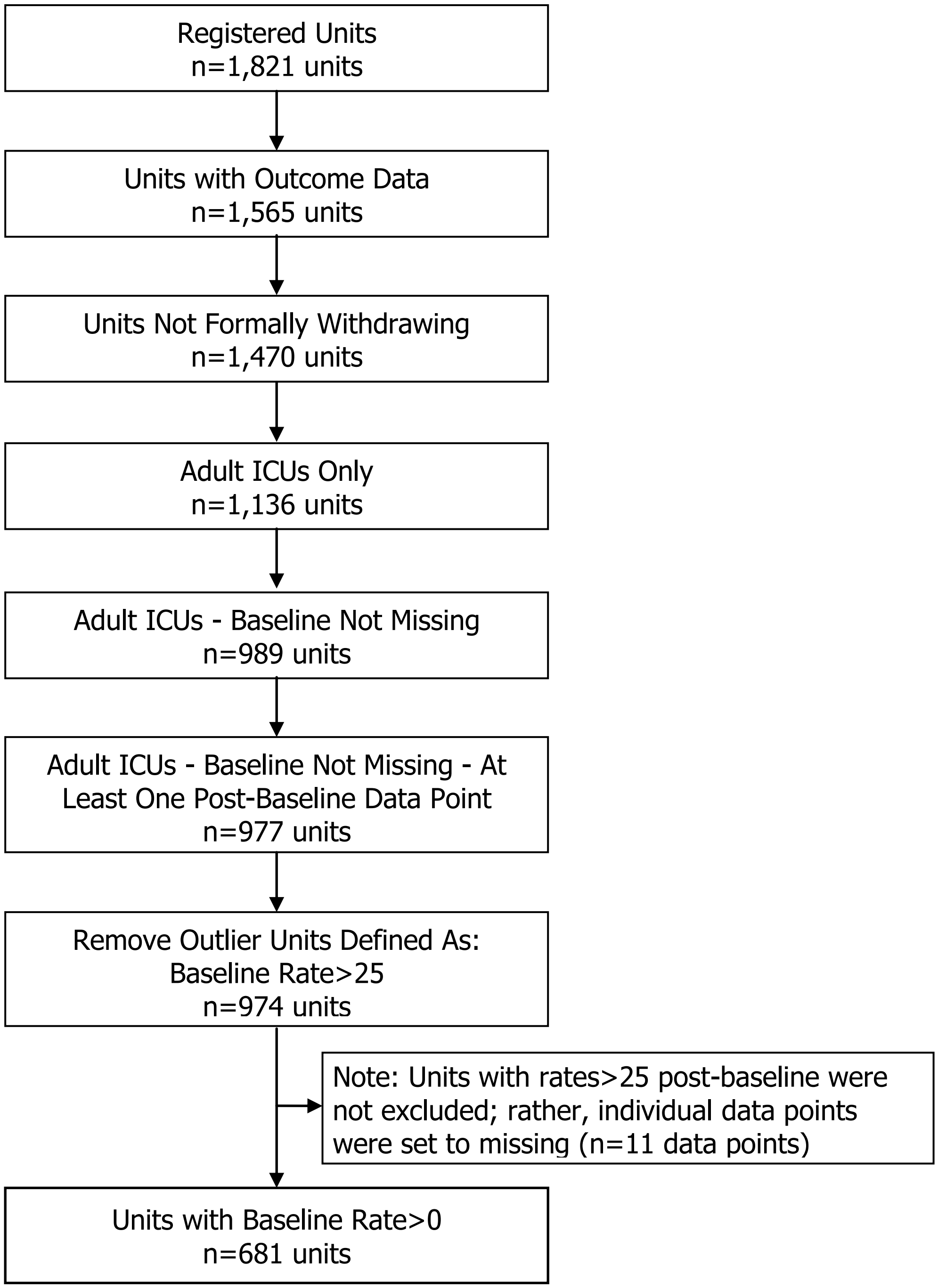
Data Interpolation Example

Table 20. Example of unit data pre and post data interpolation

Original Data								
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Unit ABC	3	2		0	1	0	0	
Unit XYZ		1	0		0	1	0	0
Data Post Interpolation								
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Unit ABC	3	2	1	0	1	0	0	0
Unit XYZ	1	1	0	0	0	1	0	0

Appendix E

Moderating Factors Flowchart



Appendix F

Team Checkup Tool Version One

TEAM CHECKUP TOOL

ICUID:

Month/year for which data provided:

Please answer the following questions with respect to the last month only:

1. Please indicate the CUSP activities in which your team participated by checking all that apply:	
a. Science of Safety video	☐ No ☐ Yes
b. AM Briefing	☐ No ☐ Yes
c. Daily Goals	☐ No ☐ Yes
d. Culture Debriefing	☐ No ☐ Yes
e. Observing Rounds	☐ No ☐ Yes
f. Staff Safety Assessment i. If yes to 1.f., were safety issues grouped and prioritized?	☐ No ☐ Yes
2. Approximately what portion of staff on the unit has viewed the Science of Safety video?	☐ Few ☐ Some ☐ Most ☐ All
a. Was the Science of Safety video included as part of orientation for new staff members?	☐ No ☐ Yes ☐ N/A, No new staff members this month
3. What portion of staff on the unit consistently uses the following?	
a. Appropriate hand hygiene	☐ Few ☐ Some ☐ Most ☐ All
b. Chlorhexidine skin preparation	☐ Few ☐ Some ☐ Most ☐ All
c. Full-barrier precautions during line insertion (maintaining a sterile field)	☐ Few ☐ Some ☐ Most ☐ All
d. Avoid femoral site for placement	☐ Few ☐ Some ☐ Most ☐ All
e. Removing unnecessary lines	☐ Few ☐ Some ☐ Most ☐ All
4. Which of the following did your team undertake to teach others on the unit how to prevent bloodstream infections (check all that apply)?	☐ Internal seminar ☐ Infection Control visit/ talk ☐ In-services/ demos ☐ New written policy ☐ Posted the steps ☐ Put the protocols on all clipboards
5. How many times did your team meet (please enter number)?	__________
6. How often did your senior executive partner meet with your team regarding the ICU project (please enter number)?	__________
7. Please indicate the type of data shared with your senior executive partner this month by checking all that apply:	☐ ICU infection rates ☐ Findings from the Staff Safety Assessment ☐ Data from the ICU culture assessment
8. Did the senior executive partner:	
a. Participate in safety rounds?	☐ No ☐ Yes
b. Participate in the prioritization of safety issues?	☐ No ☐ Yes
9. Did your team have a chance to present your unit's ICU performance data to other senior hospital/health system leaders?	☐ No ☐ Yes
10. Did your team have a chance to present your unit's ICU performance data to the hospital/health system Board?	☐ No ☐ Yes
11. How often did your team review your performance data (please enter number)?	__________
12. How often did your team share your performance results broadly with	__________

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ICU staff (please enter number)?	
13. If data were shared with ICU staff, please indicate how feedback was provided by checking all that apply:	☐ Verbal Report ☐ Poster ☐ Written Report ☐ Staff meeting ☐ ___________
14. Did the team identify a patient safety defect?	☐ No ☐ Yes
a. If yes, did the team work through a process to learn from the defect?	☐ No ☐ Yes
i. If yes, did the team share findings with others?	☐ No ☐ Yes, it was shared within the unit ☐ Yes, it was shared outside the unit
15.a. Did anyone on your quality improvement team permanently leave? b. Check here if you ADDED anyone to the team. ☐	☐ The hospital ☐ The unit ☐ The team
16. Did your team or unit attempt to/ were you asked to share information or detailed advice about this project with…?	☐ Another ICU, same hospital; ☐ Non-ICU, same hospital; ☐ Outside hospital
17. Has there been any event in your unit that has distracted staff from this work?	☐ No ☐Yes, What? _____________
18. In the past month, did any of the following slow your team's progress?	
a. Insufficient knowledge of evidence supporting interventions	☐ No ☐ To Some Extent ☐ Yes
b. Lack of team member consensus regarding goals	☐ No ☐ To Some Extent ☐ Yes
c. Not enough time	☐ No ☐ To Some Extent ☐ Yes
d. Lack of quality improvement skills	☐ No ☐ To Some Extent ☐ Yes
e. Not enough buy-in from other staff members in your area	☐ No ☐ To Some Extent ☐ Yes
f. Not enough buy-in from other physician staff in your area	☐ No ☐ To Some Extent ☐ Yes
g. Not enough buy-in from other nursing staff in your area	☐ No ☐ To Some Extent ☐ Yes
h. Staff turnover	☐ No ☐ To Some Extent ☐ Yes
i. Confusion about how to proceed with CUSP activities	☐ No ☐ To Some Extent ☐ Yes
j. Burden of data collection	☐ No ☐ To Some Extent ☐ Yes
k. Not enough leadership support from executives	☐ No ☐ To Some Extent ☐ Yes
l. Not enough leadership support from physicians	☐ No ☐ To Some Extent ☐ Yes
m. Not enough leadership support from nurses	☐ No ☐ To Some Extent ☐ Yes
n. Insufficient autonomy/authority	☐ No ☐ To Some Extent ☐ Yes
o. Inability of team members to work together	☐ No ☐ To Some Extent ☐ Yes
If response to 18o is To Some Extent or Yes, did any of the following contribute:	
o.1. Insufficient participation of one or more team members	☐ No ☐ To Some Extent ☐ Yes
o.2. Some members do not value the contributions of other team members	☐ No ☐ To Some Extent ☐ Yes
o.3. Low or no feeling of being a team	☐ No ☐ To Some Extent ☐ Yes
o.4. Personality conflicts	☐ No ☐ To Some Extent ☐ Yes
o.5. Poor conflict resolution skills	☐ No ☐ To Some Extent ☐ Yes

Team Checkup Tool Version Two

SECTION 1: Implementation of CUSP Steps

SCIENCE OF SAFETY TRAINING

1. Since you began participating in the project, what portion of your staff have viewed the science of safety video?

○ None/Few ○ Under 1/2 ○ 1/2 ○ Over 1/2 ○ Almost All/All

2. Is the Science of Safety video now part of new staff orientation for your unit?

○ Yes ○ No

STAFF SAFETY ASSESSMENT

3. Did you survey staff about how the next patient might be harmed (two-question survey)? (Please note: staff safety assessment should be administered at the start of the project and as needed thereafter)

○ Yes ○ No ○ No, but we used a different method to assess how the next patient might be harmed.

SENIOR EXECUTIVE PARTNERSHIP

4. In the past month:

	Yes	No
Did your team have a Sr. Executive partnering with you?	○	○
Were CLABSI rates shared with a Sr. Executive?	○	○
Were MTCT reports (barriers/activities) shared with a Sr. Executive?	○	○

5. In the past month:

	0	1	2 - 3	≥ 4
How many times has your team or team lead met with a Sr. Executive regarding the CUSP project?	○	○	○	○
How many times has a Sr. Executive participated in unit safety rounds?	○	○	○	○

SECTION 1: Implementation of CUSP Steps

STAFF IDENTIFIED AND LEARNED FROM DEFECTS

1. In the past month, has your team:

	Yes	No
Selected a safety defect to work on?	◯	◯
Worked through a process to learn from a defect?	◯	◯
Shared information learnings from the process with others?	◯	◯

TOOLS IMPLEMENTED TO IMPROVE SAFETY

2. In the past month for what proportion of:

	None/Few	Under 1/2	1/2	Over 1/2	Almost All/All
Days were morning briefings used?	◯	◯	◯	◯	◯
Patients were Daily Goals Checklists used?	◯	◯	◯	◯	◯

SECTION 2: Implementation of CLABSI Reduction Steps

UNIT STAFF EDUCATION ABOUT CLABSI

1. What portion of your staff have been educated on CLABSI prevention?

◯ None/Few ◯ Under 1/2 ◯ 1/2 ◯ Over 1/2 ◯ Almost All/All

CENTRAL LINE INSERTIONS

2. In the past month, for what portion of line insertions did the following occur?

	Never/Rarely	Under 1/2 the time	1/2 the time	Over 1/2 the time	Almost Always/Always	N/A
Central line cart or kit was used?	◯	◯	◯	◯	◯	◯
Central line checklist was used?	◯	◯	◯	◯	◯	◯
Appropriate hand hygiene?	◯	◯	◯	◯	◯	◯
Appropriate staff gloves, mask, gown or hat?	◯	◯	◯	◯	◯	◯
Chlorhexidine skin prep of patient?	◯	◯	◯	◯	◯	◯
Full Drape of patient?	◯	◯	◯	◯	◯	◯
Femoral site avoided in adults?	◯	◯	◯	◯	◯	◯

3. If you answered N/A to any of the central line insertion questions, please indicate why this does not apply to your unit.

EMPOWERMENT OF STAFF TO STOP PROCEDURE IF GUIDELINES ARE NOT FOLLOWED

4. Guidelines:

	Yes	No
Were the line insertion guidelines (referenced in the previous section) always followed?	◯	◯

5. Guidelines

	Never/Rarely	Under 1/2 the time	1/2 the time	Over 1/2 the time	Almost Always/Always
How often in the last month did a staff member speak up?	◯	◯	◯	◯	◯
When staff spoke up, how often did a central line insertion proceed WITHOUT correction?	◯	◯	◯	◯	◯

REMOVAL OF CENTRAL LINES

6. In the past month, for what portion of days was there daily review of line necessity?

◯ None/Few ◯ Under 1/2 ◯ 1/2 ◯ Over 1/2 ◯ Almost All/All

SECTION 3: Barriers To Your Unit Team's Progress with CLABSI & CUSP Activit...

TIME

1. In the past month, how often did these barriers affect your progress?

	Never/Rarely	Under 1/2 the time	1/2 the time	Over 1/2 the time	Almost Always/Always
Not enough time	◯	◯	◯	◯	◯
Burden of data collection	◯	◯	◯	◯	◯

KNOWLEDGE

2. In the past month, how often did these barriers affect your progress?

	Never/Rarely	Under 1/2 the time	1/2 the time	Over 1/2 the time	Almost Always/Always
Insufficient knowledge of evidence supporting the interventions	◯	◯	◯	◯	◯
Lack of quality improvement skills	◯	◯	◯	◯	◯
Confusion about how to proceed with CUSP activities	◯	◯	◯	◯	◯

LEADERSHIP

3. In the past month, to what extent did these barriers affect your progress?

	Never/Rarely	Under 1/2 the time	1/2 the time	Over 1/2 the time	Almost Always/Always
Not enough leadership support from executives	◯	◯	◯	◯	◯
Not enough leadership support from nurses	◯	◯	◯	◯	◯
Not enough leadership support from physicians	◯	◯	◯	◯	◯

SECTION 3: Barriers to your Unit Team's Progress

SAFETY ENGAGEMENT ("BUY-IN")

1. In the past month, to what extent did these barriers affect your progress?

	Never/Rarely	Under 1/2 the time	1/2 the time	Over 1/2 the time	Almost Always/Always
Not enough buy-in from unit staff	○	○	○	○	○
Not enough buy-in from unit nurses	○	○	○	○	○
Not enough buy-in from unit physicians	○	○	○	○	○

TEAM FACTORS

2. In the past month, to what extent did these barriers affect your progress?

	Never/Rarely	Under 1/2 the time	1/2 the time	Over 1/2 the time	Almost Always/Always
Lack of team consensus regarding goals	○	○	○	○	○
Inability of team members to work together	○	○	○	○	○
Insufficient participation of one or more team members	○	○	○	○	○
Some members don't value contributions of other team members	○	○	○	○	○
Low or no feeling of being a team	○	○	○	○	○
Personality conflicts	○	○	○	○	○
Poor conflict resolution skills	○	○	○	○	○
Insufficient autonomy/authority	○	○	○	○	○
Staff turnover on the unit	○	○	○	○	○
Staff turnover on your CUSP team	○	○	○	○	○
Staff distraction due to other events in your unit or hospital	○	○	○	○	○
Staff distraction due to competing priorities for time/resources	○	○	○	○	○

SECTION 4: Team and Unit Functioning

COMPOSITION & MEETINGS

1. In the past month how often did your team meet as a group?

○ 0 times ○ 1 time ○ 2 - 3 times ○ ≥ 4 times

DATA REVIEW & SHARING

2. On your UNIT in the past month:

	Yes	No
Did your team review your performance data?	◯	◯
Did your team share your data broadly with unit staff?	◯	◯

Appendix G

Readiness Assessment

Survey of Team Exposure to Elements of the Intervention &

1. Hospital/Respondent Information

Please complete each item for YOUR ICU or clinical area. We will only contact you if we have questions about your responses. Shared data WILL NOT include identifiers. Hospital and individual data are confidential. Thank you for taking the time to complete the survey.

* **1. Hospital name**

* **2. City and State**

City/Town:

State:

* **3. Who may we contact with follow-up questions on the content of these responses (primary respondent)?**

4. Contact Title:

* **5. Contact Phone number:**

2. Description of Clinical Area

*** 6. Are you reporting data for an ICU or another clinical area?**

- ◯ ICU
- ◯ Other clinical area

FOR NON-ICU: Please specify clinical area

7. For ICU's ONLY: How many ICUs are there in this hospital?

8. For ICUs ONLY: Type/ designation of the ICU for which you are reporting.

- ◯ Burn ICU
- ◯ Coronary ICU
- ◯ Surgical cardiothoracic ICU
- ◯ Medical ICU
- ◯ Medical/surgical ICU – major teaching
- ◯ Medical/surgical ICU – all others
- ◯ Pediatric medical/surgical ICU
- ◯ Neurosurgical ICU
- ◯ Surgical ICU
- ◯ Trauma ICU
- ◯ Other (please specify)

Survey of Team Exposure to Elements of the Intervention &

3. Safety Activities

For each of the following questions, please indicate the degree to which each of the following has taken place in your ICU/clinical area by selecting the item that reflects the experience in your ICU/clinical area.

*** 9. Participation in any organized multi-site effort to reduce bloodstream infections**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project
- ◯ Fully implemented outside of STOP BSI project.

*** 10. Having all staff view the Josie King video**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project
- ◯ Fully implemented outside of STOP BSI project.

*** 11. "Partnership" with a Senior Executive for patient safety**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project
- ◯ Fully implemented outside of STOP BSI project.

*** 12. Systematic analysis and proactive learning from harmful events or events with potential for harm as raised by front-line staff (other than M&Ms and official RCA)**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project
- ◯ Fully implemented outside of STOP BSI project

*** 13. Setting daily goals for each patient based on a standard tool**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

Survey of Team Exposure to Elements of the Intervention &

*** 14. Viewing the "Science of Safety" video by Dr. Peter Pronovost**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

*** 15. Use of an independent line cart or kit, stocked with essentials for placing a central-line catheter**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

*** 16. Inclusion of chlorhexidine in central line kit**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

*** 17. Routine use of chlorhexidine for dressing changes**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

*** 18. Use of a standard protocol for dressing changes**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

*** 19. Use of a line-insertion checklist to ensure compliance with evidence-based practices**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

Survey of Team Exposure to Elements of the Intervention &

4. Assessment of Safety Culture

The following questions request information on whether your hospital/unit have completed an assessment of safety culture.

20. Any unit-wide assessment of teamwork and safety culture (e.g, Safety Attitudes Questionnaire (SAQ), Hospital Survey on Patient Safety (HSOPS))?

- ◯ Not implemented and no plans to do so outside of the STOP BSI project.
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

21. If the answer to Question 20 is CURRENTLY PLANNING IMPLEMENTATION OR FULLY IMPLEMENTED, what instrument will be/was used to measure safety culture?

- ◯ Hospital Survey on Patient Safety (HSOPS/AHRQ)
- ◯ Safety Attitudes Questionaire (SAQ)
- ◯ Other

Please specify the survey instrument used

22. If the answer to Question 20 is CURRENTLY PLANNING IMPLEMENTATION OR FULLY IMPLEMENTED, what method will be/was used for survey administration?

- ◯ Paper Forms
- ◯ Web-based Data Entry

Other (please specify)

23. If the answer to Question 20 is CURRENTLY PLANNING IMPLEMENTATION OR FULLY IMPLEMENTED, please indicate those areas of the hospital that did or will participate in the survey

- ☐ Hospital-wide with sample of ICU staff
- ☐ Hospital-wide with entire ICU staff
- ☐ ICU only

Survey of Team Exposure to Elements of the Intervention &

5. Central Venous Catheters

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 (CDC, NHSN).

*** 24. Does your hospital use CDC national healthcare safety network (NHSN) definitions for central line-associated blood stream infection?**

- ◯ Yes
- ◯ No

*** 25. Does your hospital participate in reporting to the Centers for Disease Control's (CDC) National Healthcare Safety Network (NHSN)**

- ◯ Not implemented and no plans to do so outside of the STOP BSI project
- ◯ Currently planning for implementation outside of STOP BSI project.
- ◯ Fully implemented outside of STOP BSI project.

*** 26. Please indicate how frequently your hospital reports catheter-associated blood stream infections (monthly or quarterly) and whether reporting is internal and/or external by checking all that apply.**

	Internal	External
Monthly	◯	◯
Quarterly	◯	◯
Does not report	◯	◯

Other (please specify)

*** 27. Does your hospital include arterial catheters in calculating central line-associated blood stream infections?**

- ◯ Yes
- ◯ No
- ◯ Don't Know

*** 28. Does your hospital include PICC lines in calculating central line-associated blood stream infections?**

- ◯ Yes
- ◯ No
- ◯ Don't Know

Survey of Team Exposure to Elements of the Intervention &

*** 29. Does your hospital have a PICC team for PICC line placement?**

- ◯ Yes
- ◯ No
- ◯ Outside contractual services

*** 30. Are PICC line dressings routinely changed by a PICC team member?**

- ◯ Yes
- ◯ No
- ◯ N/A

*** 31. Does your hospital have a policy or procedure for central line placement?**

- ◯ Yes
- ◯ No

*** 32. Does your hospital have a policy or procedure for central line removal?**

- ◯ Yes
- ◯ No

*** 33. Does your hospital have a policy or procedure for central line dressing changes?**

- ◯ Yes
- ◯ No

Survey of Team Exposure to Elements of the Intervention &

6. Intensive Care Unit/ Clinical Area

Please use the following key when answering the questions that follow:

Routinely--90% of the time or greater;
Frequently—-more than 50% of the time;
Half the time--50% of the time;
Infrequently--less than 50% of the time;
Rarely/Never--10% of the time or less.

*** 34. Does your ICU/Clinical Care Area currently use heparinized solution as a routine flush, a scheduled flush or in flush bags for central venous catheters?**

- ◯ Routinely
- ◯ Frequently
- ◯ Half the time
- ◯ Infrequently
- ◯ Rarely/Never

*** 35. Does your ICU/Clinical Care Area currently use a chlorhexidine impregnated patch for central venous line care?**

- ◯ Routinely
- ◯ Frequently
- ◯ Half the time
- ◯ Infrequently
- ◯ Rarely/Never

36. If any use of a patch, which patch is used?

- ◯ BioPatch
- ◯ Generic
- ◯ Other

Other (Name of chlorhexidine patch)

Survey of Team Exposure to Elements of the Intervention &

*** 37. Does your ICU/Clinical Care Area currently use antiseptic or antibiotic impregnated or coated central catheters?**

- [ ] Routinely
- [ ] Frequently
- [ ] Half the time
- [ ] Infrequently
- [ ] Rarely/Never

*** 38. Does your ICU/Clinical Care Area currently use a positive displacement needle-less connector valve for central venous catheters?**

- ○ Routinely
- ○ Frequently
- ○ Half the time
- ○ Infrequently
- ○ Rarely/Never

39. If yes, (for use of displacement needle-less connector)which one?

- ○ CLC2000
- ○ InVision-Plus
- ○ SmartSite Plus
- ○ MaxPlus
- ○ Ultrasite
- ○ Other

Other (Name of positive displacement valve)

*** 40. Do you routinely use ultrasound to place central venous catheters (Check all that apply)?**

- [ ] For subclavian lines
- [ ] For internal jugular lines
- [ ] Don't routinely use

Survey of Team Exposure to Elements of the Intervention &

*** 41. Do you bathe patients in this clinical care area with chlorhexidine?**

- ◯ Routinely
- ◯ Frequently
- ◯ Half the time
- ◯ Infrequently
- ◯ Rerely/Never

42. For central venous catheters, what dressing method have you found to be the best and why?