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Major Article

Using the agile implementation model to reduce central line–associated bloodstream infections

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Background: Central line–associated bloodstream infections (CLABSIs) are among the most common hospital-acquired infections and can lead to increased patient morbidity and mortality rates. Implementation of practice guidelines and recommended prevention bundles has historically been suboptimal, suggesting that improvements in implementation methods could further reductions in CLABSI rates. In this article, we describe the agile implementation methodology and present details of how it was successfully used to reduce CLABSI.

Methods: We conducted an observational study of patients with central line catheters at 2 adult tertiary care hospitals in Indianapolis from January 2015 to June 2017.

Results: The intervention successfully reduced the CLABSI rate from 1.76 infections per 1,000 central line days to 1.24 (rate ratio = 0.70; $P = .011$). We also observed reductions in the rates of *Clostridium difficile* and surgical site infections, whereas catheter-associated urinary tract infections remained stable.

Conclusions: Using the AI model, we were able to successfully implement evidence-based practices to reduce the rate of CLABSIs at our facility.

BACKGROUND

Central line–associated bloodstream infections (CLABSIs) are among the most common health care–associated infections (HAIs) and can lead to increased patient morbidity and mortality rates and longer hospital stays.[1] Estimated costs associated with CLABSIs range from $400 million to $2 billion per year,[2] in addition to the potential reimbursement penalties that hospitals face from poor performance on CLABSI measures as part of federal quality monitoring programs.[3] Despite major advances in infection prevention strategies, the incidence of CLABSIs remains high among hospitalized patients; the Centers for Disease Control and Prevention (CDC) estimates that there are approximately 80,000 new CLABSIs each year.[2,4] Effective and sustainable implementation of practice guidelines and prevention bundles in the United States has been suboptimal,[5] suggesting that further reductions in CLABSI rates are possible.

In 2015, the leadership at Indiana University Health Adult Academic Health Centers (IUH AAHC) identified CLABSI reduction as the highest safety priority for their facility and sought to identify and implement an evidence-based solution that was effective and sustainable. To accomplish this goal, the IUH AAHC team used the agile implementation (AI) model[6] to identify, implement, and sustain the appropriate intervention. This article describes the process undertaken by the IUH AAHC team and the results observed.

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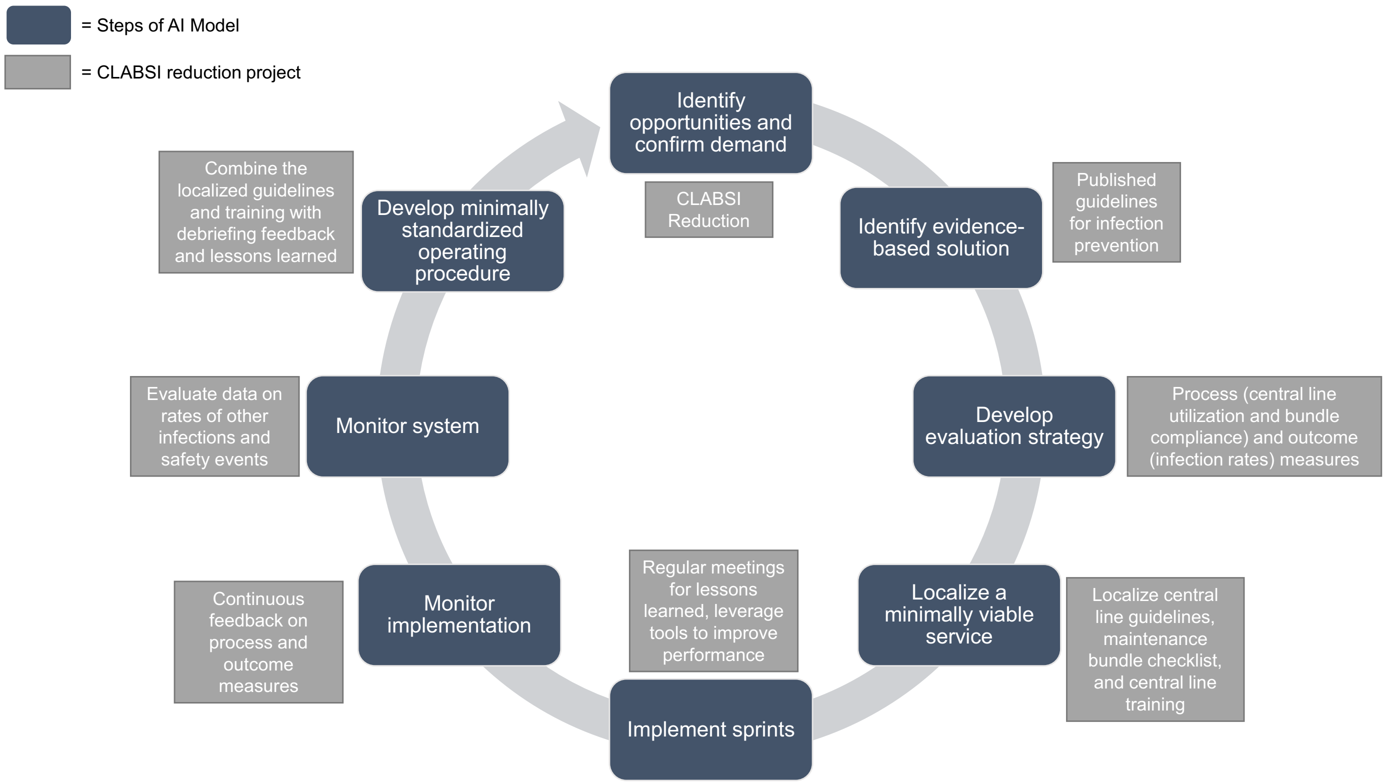

Fig 1. The Agile Implementation Model

METHODS

Setting

IUH AAHC consists of 2 adult tertiary care hospitals in Indianapolis with 1,100 licensed beds and 36,000 annual admissions. The patient population is 15% Medicaid, 43% Medicare, 40% private insurance, and 2% self-pay, and racial minorities comprise 27% of the patient population. The study includes both adult hospitals and spans the time period from January 2015 to October 2017. This study was a quality improvement project using aggregate data that did not require institutional review board approval because it was considered non−human subject data.

AI model

The AI model was developed and refined at the Indiana University Center for Health Innovation and Implementation Science[7]; an extensive description of the AI model and its underlying theories was published previously.[6] The AI model treats health care systems as complex adaptive systems (CAS), which are open and dynamic networks of interconnected individuals where the network as a whole can change in response to changes in its internal or external environment.[8-11] Within the CAS framework, the unique makeup of a health system's environment, its individual members, and their interactions govern the ability of the organization to adapt to changes. Social cognitive theories of behavioral economics add to the robustness of the AI model by informing how individuals respond to environmental stimuli, and these theories provide templates for creating choice architectures based on human tendencies designed to encourage sustainable implementation.

The AI model involves several steps (Fig 1). First, it is necessary to identify potential opportunities and confirm that there is demand at the facility by verifying that leadership is willing to allocate time and resources to address the opportunity and that the stakeholders are engaged in solving the problem. Second, one needs to identify the best available evidence-based health care solutions using published studies and topic guidelines or recommendations. The third step involves developing the evaluation strategy including appropriate measures and milestones; this strategy also includes criteria for terminating the intervention if unsuccessful and details how that is done and by whom. Next, an interdisciplinary team is assembled to convert the evidence-based solution into a "minimally viable service." This entails identifying the minimum specifications that must be included to effectively apply the evidence-based solution that also acknowledges the unique characteristics of the setting where it will be applied. These specifications will be iteratively revised and built on during ensuing steps of the process. At this point, implementation begins by performing repeated cycles or "sprints," which are short, focused efforts to implement the specifications described in the minimally viable service that result in lessons learned and applied to the process. To monitor progress, performance feedback loops of the predetermined measures provide the team with information regarding any changes that can be observed. At the same time, the team monitors the impact of the implemented service on the entire organization to see if there are either unintended consequences or emergent opportunities that need to be addressed. If the implemented solution is determined to meet goals and produce the desired change, the team then develops a minimally standardized operating procedure. This serves to instruct those attempting to implement the solution in other departments within the same organization and is updated on a regular basis as needed. Together, these steps encompass the AI model, which provided the blueprint for identifying, localizing, implementing, and sustaining an evidence-based solution to reduce CLABSI.

The implementation process

In fall 2015, the senior executive team and board of trustees at IUH AAHC established CLABSI reduction as the highest safety priority for the hospital for fiscal year 2016, demonstrating the necessary demand described in the first step of the AI model. The next step required the identification of an evidence-based solution; existing practice guidelines for preventing catheter-related infections from the CDC[1] and evidence-based recommendations for reducing CLABSI presented potential solutions[12] and provided a clear strategy for how to evaluate the success of the evidence-based solution. However, in congruence with the AI model, these recommendations needed to be tailored or "localized" to the unique environment within IUH AAHC.

An interdisciplinary team of IUH AAHC providers met several times in early 2016 to develop a course of action and a minimally viable service. During these sessions, this diverse team of physicians, nurses, pharmacists, and infection preventionists established a set of localized practice guidelines and created a maintenance bundle checklist and training curriculum for the providers and staff at IUH AAHC. The guidelines specified the indications for central line placement, removal, duration, and the type of line to be used. The maintenance bundle checklist included specifications for changing tubing (regular intravenous tubing: every 96 hours; total parenteral nutrition: every 24 hours; propofol: every 12 hours); changing dressing (transparent dressing with or without chlorhexidine gluconate: every 7 days; transparent dressing with gauze: every 48 hours); and ensuring that the dressing is clean, dry, and occlusive. The training curriculum aimed to improve multiple aspects of care, including bundle adherence as stipulated by the guidelines, sterile technique with line placement, hand hygiene, and central line maintenance. The training was designed as an interprofessional collaborative focused on improving interactions among semiautonomous agents from different professions and disciplines. Between February and September 2016, this curriculum was presented to more than 300 physicians and 1,000 nurses. New staff also received this training, including first-year residents and fellows who were expected to insert central lines. The number of staff trained reflects the significant time and effort spent to engage leadership and frontline providers in this process and to raise awareness of the problem and secure demand for the training. Key stakeholders and providers with expertise in line insertion and care participated in the development and design of the training.

In June 2016, the medical directors and nursing managers of all units with high rates of CLABSI convened to begin implementation sprints of the localized solution. Along with the IUH AAHC Quality/Safety and Infection Prevention teams, these parties met every 2 weeks to review CLABSI events in their units and discuss the top 3 implementation challenges they faced (to provide learnings for subsequent sprints). At each meeting, representatives from each unit addressed the following:

1. What did you do that worked well?
2. What did not work well?
3. What do you plan to do differently based on what you learned?

This process facilitated communication between units and fostered a sense of shared accountability across IUH AAHC. Between meetings to monitor the success of implementation, units used visual tools such as scoreboards and charts to engage frontline staff and track their progress. When an individual unit struggled with performance, staff leveraged quality resources to observe the environment and understand factors influencing performance. Specifically, staff used the skills of the infection prevention specialists and clinical nurse specialists assigned to each unit and reviewed data from clinical dashboards to identify areas for improvement. These findings were discussed at the meetings, and the best practice units supported plans for improvement. To evaluate success and sustainability of the solution used and monitor the impact on the system as a whole, several process and outcome measures were examined.

Study measurement and statistical analysis

The measures for evaluation were collected during 3 distinct time periods between January 2015 and October 2017. The period from January 2015 to February 2016 represents the baseline period, during which time the facility collected surveillance data on infection rates and central line use before the initiation of implementation sprints. Implementation occurred during March 2016 through June 2016, at which time the implementation sprints occurred. The following 14 months (July 2016 to October 2017) were used to assess the sustainability of the intervention.

The primary outcome measure was the CLABSI rate, as defined by the National Healthcare Safety Network definition[13] and presented as infections per 1,000 central line days. A standardized incidence ratio (SIR) was calculated by dividing the number of observed infections by the number of expected infections based on the patient populations defined by the CDC.[14]

Other outcomes included central line use (the number of central line days divided by number of patient days), a standardized utilization ratio (observed central line days divided by predicted central line days), and compliance with the central line bundle (daily chlorhexidine gluconate bathing, appropriate dressing, tubing changes, skin care, and hub disinfection). In addition to tracking the rate of CLABSI, the team also tracked rates of other HAIs, including catheter-associated urinary tract infections (CAUTIs), surgical site infections after abdominal hysterectomy and colon surgery, and *Clostridium difficile* (c-diff) infections. Additionally, overall harm events, comprised of the events listed previously plus falls resulting in injury, hospital-acquired pressure ulcers, medication errors, serious medical errors, and mortality, were also measured. During the sustainment period (December 2016), a debrief and feedback session was held to gain insight into the main drivers of success and to inform the development of a minimally standardized operating procedure for future implementation efforts.

The analysis used Poisson regression to test whether outcomes differed across time periods. Each model included time period as a fixed effect and an offset to account for the different exposures for each outcome variable. Logistic regression was used to determine whether procedure compliance differed across the 3 time periods. If the test for the overall effect was significant, all pairwise comparisons between time periods were examined using the Holm step-down Bonferroni method to adjust for multiple comparisons.

RESULTS

Overall, 320 CLABSIs were observed over the entire length of the study; the CLABSI rate at baseline was 1.76 infections per 1,000 central line days compared with rates of 1.39 and 1.24 during the implementation and sustainment periods, respectively (Table 1). Results from Poisson regression indicated a significant difference in the CLABSI incidence rate by time period ($P = .012$; Table 2). When compared directly, the CLASBI rate during the sustainment period (1.24) was significantly less than during the baseline period (1.76), with an estimated rate ratio (RR) of 0.70 ($P = .011$; 95% confidence interval [CI] = 0.55-0.89). The SIR for CLABSIs was also significantly lower for the sustainment period (1.22) than for the baseline period (1.61; RR = 0.72; 95% CI = 0.54-0.96; $P = .020$; Table 2).

Table 1
Calculated rates (95% confidence intervals) of hospital-acquired harms

	Baseline 1/1/15-2/28/16 (14 mo)	Implementation 3/1/16-6/30/16 (4 mo)	Sustainment 7/1/16-8/31/17 (14 mo)
CLABSI			
Total number	165	40	115
Incidence rate*	1.761 (1.512, 2.051)	1.390 (1.020, 1.895)	1.237 (1.031, 1.485)
SIR	1.614 (1.386, 1.880)	1.295 (0.950, 1.765)	1.160 (0.967, 1.393)
SUR	1.264 (1.256, 1.273)	1.344 (1.328, 1.360)	1.230 (1.221, 1.239)
CAUTI			
Incidence rate†	1.906 (1.581, 2.297)	2.139 (1.549, 2.952)	1.737 (1.434, 2.105)
SIR	1.176 (0.976, 1.418)	1.321 (0.957, 1.824)	1.085 (0.895, 1.314)
SUR	0.854 (0.847, 0.861)	0.892 (0.879, 0.905)	0.882 (0.874, 0.890)
C-diff			
Incidence rate‡	13.274 (11.995, 14.690)	9.962 (8.012, 12.385)	8.825 (7.884, 9.879)
SIR	1.045 (0.944, 1.156)	0.849 (0.683, 1.056)	0.748 (0.668, 0.837)
Overall harms			
Total number	716	171	506
Harms per month	51.1 (47.5, 55.0)	42.8 (36.8, 49.7)	36.1 (33.1, 39.4)

CAUTI, catheter-associated urinary tract infection; *C-diff*, *Clostridium difficile*; *CLABSI*, central line−associated bloodstream infection; *SIR*, standardized incidence ratio; *SUR*, standardized utilization ratio.
*Per 1,000 central line days.
†Per 1,000 Foley catheter days.
‡Per 10,000 patient days.

Analysis of the central line standardized utilization ratio revealed that the sustainment period had a significantly lower rate (1.23) than those for both the baseline period (rate = 1.25; RR = 0.97; 95% CI = 0.96-0.98; $P < .001$) and implementation period (rate = 1.34; RR = 0.92; 95% CI = 0.90-0.93; $P < .001$; Table 2). In addition, the central line bundle compliance improved from 67% at baseline to 84% during the sustainment period ($P < .001$, data not shown).

Although there were no significant differences across time periods for CAUTI rates or SIRs, improvements were seen in other HAIs and overall measured harm events. Analyses of c-diff infections revealed that the incidence rate was significantly lower for the sustainment period vs baseline (8.8 vs 13.3 per 10,000 patient days; RR = 0.67; 95% CI = 0.55-0.80; $P < .001$), as was the c-diff SIR (0.75 vs 1.05; RR = 0.72; 95% CI = 0.60-0.86; $P < .001$; Table 2). The monthly average number of harm events for the sustainment period (36 events per month) was significantly lower than for the baseline period (51 events per month; $P < .001$; Table 2).

From the debriefing session, the following themes consistently emerged as drivers of success of this project: physician and nursing engagement, focus on learning and improvement, unit-level analysis and problem solving (localization), leadership support and direction, and data transparency. CLABSI team members shared that they

Table 2
Poisson regression results

		Sustainment vs baseline		Implementation vs baseline		Sustainment vs implementation	
	Overall *P*	RR (95% CI)	*P*	RR (95% CI)	*P*	RR (95% CI)	*P*
CLABSI							
Incidence rate*	.012	0.703 (0.554, 0.892)	.011	0.789 (0.518, 1.204)	.359	0.890 (0.621, 1.276)	.527
SIR	.022	0.719 (0.537, 0.962)	.020	0.802 (0.526, 1.233)	.421	0.896 (0.578, 1.391)	.552
SUR	<.001	0.973 (0.963, 0.982)	<.001	1.063 (1.048, 1.077)	<.001	0.915 (0.903, 0.928)	<.001
CAUTI							
Incidence rate†	.536	0.912 (0.697, 1.192)	.977	1.122 (0.773, 1.629)	.997	0.812 (0.558, 1.182)	.833
SIR	.577	0.922 (0.664, 1.279)	1.000	1.123 (0.713, 1.770)	1.000	0.821 (0.519, 1.298)	.906
SUR	<.001	1.033 (1.021, 1.045)	<.001	1.044 (1.027, 1.062)	<.001	0.989 (0.972, 1.006)	.201
C-diff							
Incidence rate‡	<.001	0.665 (0.552, 0.800)	<.001	0.750 (0.560, 1.006)	.038	0.886 (0.657, 1.195)	.333
SIR	<.001	0.716 (0.595, 0.862)	<.001	0.813 (0.606, 1.089)	.090	0.881 (0.653, 1.189)	.312
Total harms							
Harms per month	<.001	0.707 (0.615, 0.812)	<.001	0.836 (0682, 1.025)	.070	0.845 (0.711, 1.006)	.070

NOTE. Estimated RRs and *P* values are from Poisson regression models.
CAUTI, catheter-associated urinary tract infection; *C-diff*, *Clostridium difficile*; *CI*, confidence interval; *CLABSI*, central line−associated bloodstream infection; *RR*, relative risk; *SIR*, standardized incidence ratio; *SUR*, standardized utilization ratio.
*Per 1,000 central line days.
†Per 1,000 Foley catheter days.
‡Per 10,000 patient days.

experienced a change in the culture from a punitive culture to one of a collaborative problem-solving approach to harm events focused on shared learning and continuous improvement.

DISCUSSION

Using the AI model, the team at IUH AAHC successfully identified and implemented evidence-based solutions for reducing CLABSIs; rates decreased by 30% from before to after the intervention. We believe that a key factor in the success and sustainability of the solution was the increase in the engagement of physicians, nurses, and other clinical staff in the process of safety improvement and infection prevention. Additionally, the organization experienced a shift in the culture regarding patient-safety events (including HAIs). The punitive attitude toward these types of events that existed before the implementation evolved into an environment focused on shared learnings and collaboratively improving care quality, as reflected in the feedback elicited during the debriefing in December 2016. These changes in the interpersonal interactions between the individuals within the health system allowed and encouraged the improvement in care. This is in step with the theoretical frameworks on which the AI model is built, such as the theory of CAS, which acknowledges the uniqueness of the individuals,[11,15] and behavioral economics, which suggests that decisions and behaviors are affected by multiple factors, including social dynamics.[16]

In addition to reductions in CLABSIs, IUH AAHC observed improvements in overall harm events and c-diff infections, whereas CAUTIs remained stable. These results also reflect the theories of CAS, where improvement is not linear and interventions are interconnected. It is likely that even though the specific intervention was focused on CLABSIs, the increase in communication and change in culture had a positive spillover effect into other areas of patient safety. However, there are no data available to assess this hypothesis. Additionally, there were other simultaneous evidence-based interventions implemented to improve overall harm and c-diff infections. Nevertheless, the degree of improvement observed in these areas is unprecedented at our institution.

The literature provides ample evidence regarding the indications for central lines, the type of central line, the appropriate duration, insertion practice, maintenance, and care bundles for central lines.[1,17] Multiple examples of strategies to reduce CLABSI rates exist involving infection prevention interventions such as skin decontamination,[18-20] and quality improvement strategies regarding change management, auditing, data feedback, standardization and training, accountability, and continuous process improvement are also abundant.[21-23] Considering that these data on how to reduce CLABSI are plentiful and yet adherence to best practices is less than optimal,[5] it is reasonable to assume that translating the science to real-world practice through effective implementation is a main barrier to achieving reduced CLABSI in the inpatient setting. The AI model provides a blueprint for how to implement evidence-based guidelines for CLABSI prevention in a successful and sustainable way.

The results of our study should be considered in light of several limitations. This study is an observational study; it was not designed to study the effectiveness of these strategies compared with conventional approaches to quality improvement. The study was conducted at a single academic institution, limiting our ability to generalize the findings to other health care settings, to multiple institutions, or to large-scale implementation. Finally, this study focused on reducing CLABSI, which has the benefit of having a large body of evidence describing optimal care and the reduction of central line infections. Therefore, it is unknown whether the approach described here would be as effective for other harm events where there may be a paucity of evidence-based practices from which to draw.

CONCLUSIONS

We successfully implemented evidence-based practices to reduce the rate of CLABSIs at our facility by using the steps described by the AI model. Increased communication and interprofessional collaboration were integral to improving care and sustaining improvement over time.

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