Notice to CE enrollees:
This article has been designated for CE contact hour(s). The evaluation tests your knowledge of the following objectives:

1. Identify the critical methodological components required to determine whether implementation of a central catheter bundle in a hospital results in fewer infections.
2. Articulate the necessity of including statistical analysis of the infection rate trend before and after bundle implementation to accurately determine the impact of the bundle on infection reduction.
3. List the components of a catheter maintenance bundle together with the associated education and follow-up required for bundle compliance.

To complete evaluation for CE contact hour(s) for test #A1625022, visit www.ajcconline.org and click the “CE Articles” button. No CE test fee for AACN members. This test expires on January 1, 2019.

Objective Evidence-based guidelines have resulted in decreases in bloodstream infections associated with central catheters (CLABSIs) in hospital intensive care units. However, relatively little is known about CLABSI incidence and prevention in long-term acute care hospitals (LTACHs).

Methods A central catheter maintenance bundle was implemented in 30 LTACHs, and compliance with the bundle was tracked for 6 months. CLABSI rates were monitored for 14 months before and 14 months after the bundle was implemented.

Results The pooled mean CLABSI rate (No. of infections per 1000 days with a central catheter) was 1.28 before the bundle and 0.96 after the bundle (repeated measures general linear model; \( F_{1,58} = 6.973; P = .01; \) partial \( \eta^2 = .11 \)). From 14 months before to 14 months after the bundle was implemented, the mean number of CLABSIs per LTACH decreased by 4.5 (95% CI, 1.85-7.15). Time series modeling showed a significant decrease in the mean hospital CLABSI rate after the bundle was implemented (-0.511 CLABSI/1000 catheter days, SE = 0.050), indicating an immediate effect of the bundle. The mean hospital CLABSI rate was decreasing slightly before the bundle was implemented and continued to decrease at a reduced rate after the bundle was implemented.

Conclusion The bundle resulted in a significant and sustained reduction in CLABSI rates in 30 LTACHs for 14 months. These results encourage the development and implementation of similar bundles as effective strategies for infection reduction in LTACHs. (American Journal of Critical Care. 2016;25:165-172)
Many patients admitted to long-term acute care hospitals (LTACHs) are colonized or infected with multidrug-resistant bacteria that could contribute to the incidence of “central line–associated bloodstream infections” (CLABSIs). Despite the heightened risk of CLABSIs in LTACH patients, few studies have addressed the long-term incidence of CLABSIs in LTACHs. In studies on the impact of changes in central catheter procedures on CLABSIs, researchers have examined a single intervention (the effects of chlorhexidine gluconate bathing and port placement) in a single hospital. In contrast, the use of CLABSI prevention bundles and checklists in intensive care units has been extensively investigated.

Widespread efforts to prevent health care–associated infections (HAIs) through the use of evidence-based guidelines have resulted in decreases in CLABSI rates in intensive care units. The Centers for Disease Control and Prevention (CDC) estimated that approximately 200,000 CLABSIs were prevented between 1990 and 2010, presumably through the application of evidence-based CLABSI prevention programs. However, 15,000 preventable CLABSIs still occurred in intensive care units in 2010, and the number of CLABSIs reported could be tripled if settings other than intensive care units were included.

LTACHs treat patients who require long-term acute care services for chronic critical illness, which is a syndrome of multiorgan system failure resulting from continuous aberrant response of the sympathetic nervous system, adrenal-endocrine system, and immune system following survival of an acute episode of critical illness; these factors result in prolonged dependence on intensive care therapies such as mechanical ventilation. Patients with chronic critical illness typically have a history of prolonged stays in short-term acute care hospitals, including stays in the intensive care unit. By the time they have transferred to the LTACH, patients with chronic critical

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Methods

Study Setting
A total of 39 out of 110 Select Medical LTACHs (as of the date of the study) volunteered to implement process improvement initiatives aimed at infection reduction through controlled venous catheter maintenance. The results from 30 hospitals were analyzed; 3 hospitals that volunteered already had a central catheter protocol and/or team and
had a central catheter and completed a checklist to week, at random times, inspected every patient who nurse director of quality management who, once a central catheter maintenance bundle. Compliance completed an online quiz on the components of the at the beginning, middle, and end of the study and participating hospitals attended a training webinar part. The number of central catheter days was 120 137 before and 119 412 after the bundle was implemented.

Central Catheter Bundle

At the core of this study was the development and implementation of a clinically relevant, evidence-based bundle for central catheter maintenance and the systematic education of the clinical staff in the execution of the bundle through an interactive webinar. In addition to the CDC guidelines, the bundle protocol included education on the protocol, mandatory use of alcohol-based central catheter caps (which have since been added to the CDC guidelines), chlorhexidine gluconate dressings, and formation of a central catheter team of nurses who demonstrate competency in maintaining and following the protocol. Before the start of the initiative, each hospital’s chief nursing officer organized a team of registered nurses who had previously successfully demonstrated competency in the care of central catheters and verified that their hospital had alcohol-based central catheter caps and chlorhexidine gluconate dressings available. The chief nursing officer also communicated with staff that each patient who was admitted to the LTACH with a central catheter or who had a central catheter placed in the LTACH during the study period would be evaluated for central catheter maintenance in accordance with the bundle. For the purposes of this study, patients qualified if they had, as defined by the CDC, a central venous catheter whose tip terminates in a great vessel, including short- and long-term central venous catheters and peripherally inserted central catheters. All members of the central catheter teams at participating hospitals attended a training webinar at the beginning, middle, and end of the study and completed an online quiz on the components of the central catheter maintenance bundle. Compliance with the bundle was assessed at each LTACH by a nurse director of quality management who, once a week, at random times, inspected every patient who had a central catheter and completed a checklist to capture data on the degree of adherence to the bundle. A clinical trial manager also reviewed each LTACH’s checklist data weekly and conducted an on-site compliance visit to each LTACH. The bundle compliance checklist contained information on whether (1) the central catheter dressing was intact and 100% occlusive, (2) a date was present on the dressing, (3) initials were present on the dressing, (4) nongauze dressings were changed within 7 days, or if gauze, within 48 hours, (5) daily assessments of the dressing sites were made by a nurse or catheter team, (6) a sterile cap was in place on all intravenous/stopcock ports, and (7) a chlorhexidine sponge or dressing was in place at the catheter insertion site. The major components of the overall central catheter maintenance bundle are shown in Table 1. The bundle did not include changes to standard practices for central catheter removal.

The bundle also did not change the standard method used at each hospital for identifying CLABSI. The only difference between hospital staffing before and after implementation of the bundle was the creation of a central catheter maintenance team. The process of identifying CLABSI did not change. No new staff changes, beyond a normal level of attrition, were made to address CLABSI reporting. The standard protocol, which was in place both before and after bundle implementation, was for physicians at each hospital to make the final identification of a hospital-acquired CLABSI.

The quasi-experimental study was designed to compare the effects of implementation of the bundle by using a 6-month pretest baseline measurement of CLABSI rate (number of CLABSI per 1000 central catheter days). Baseline data were collected retrospectively for the period immediately preceding implementation of the bundle. The impact of the bundle on CLABSI rates was monitored during the implementation period, and overall results were reported to the individual hospitals midway through and at the conclusion of the study. Bundle compliance data were collected as part of the standard of care for central catheter maintenance, as specified in the CDC’s published guidelines. Data collection did not include any protected health information or patient identifiers and was determined to be exempt by the institutional review board.

Data Analysis

The consistency of competency of each hospital’s chief nursing officer was examined at the beginning and end of the study by using a paired-samples t test.
Adherence to the bundle over time was measured by comparing scores at the beginning of the study with scores 5 weeks into the study by using a $\chi^2$ test. Changes in CLABSI rates were operationally monitored with control chart functions throughout the study time window (Figure 1). Two analyses were conducted on CLABSI rates before and after the bundle was implemented: (1) repeated-measures general linear model and (2) autoregressive integrated moving average (ARIMA) time series analysis ($\alpha$ was set at .05 for both models). Because a separate control group was not available, the level and trend of the CLABSI rate before implementation became the control for the CLABSI rate after implementation. We standardized central catheter utilization by calculating CLABSIs as a standardized infection ratio (SIR), setting the expected value to the pooled mean for LTACH adult care areas published by the National Healthcare Safety Network in 2013.5

We hypothesized that the central catheter maintenance bundle would reduce the CLABSI SIRs at the start of the program and that the reduction would persist over time. In order to test this hypothesis, we chose to analyze the bundle’s impact on CLABSI SIRs by using an interrupted time series analysis. Time series analysis was used to examine the temporal sequence of correlations between measured events because uncorrected correlation between observations over time could result in over-estimation of the significance of the intervention.24 An interrupted time series model examines multiple

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### Table 1
Components of the central catheter maintenance bundle and strength of evidence

<table>
<thead>
<tr>
<th>Content</th>
<th>Strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>A trained central catheter team of nurses who follow the regimented bundle protocol</td>
<td>I</td>
</tr>
<tr>
<td>Competency testing before being certified for the team</td>
<td>II</td>
</tr>
<tr>
<td>Education on the bundle protocol</td>
<td>II</td>
</tr>
<tr>
<td>Knowledge assessments on the evidence-based practices of central catheter maintenance</td>
<td>II</td>
</tr>
<tr>
<td>Documented daily review of the necessity of the central catheter and checklists</td>
<td>II</td>
</tr>
<tr>
<td>Hand hygiene and aseptic technique</td>
<td>II</td>
</tr>
<tr>
<td>Gloved dressing changes</td>
<td>II</td>
</tr>
<tr>
<td>Sterile gauze or sterile, transparent, semipermeable dressing</td>
<td>II</td>
</tr>
<tr>
<td>Replacement of transparent dressing at least every 7 days</td>
<td>II</td>
</tr>
<tr>
<td>Gauze dressing if patient is diaphoretic or if site is bleeding or oozing, replaced every 48 hours</td>
<td>II</td>
</tr>
<tr>
<td>Catheter site assessed every shift for redness, tenderness, pain, or exudate</td>
<td>II</td>
</tr>
<tr>
<td>Alcohol-based central catheter caps</td>
<td>I</td>
</tr>
<tr>
<td>Change of dressing if compromised, loose, or damp</td>
<td>II</td>
</tr>
<tr>
<td>Application of a chlorhexidine-impregnated sponge dressing</td>
<td>I</td>
</tr>
</tbody>
</table>

*a Adapted from published recommendations of the Centers for Disease Control and Prevention.*

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![Figure 1](Grigonis3_16pgs.indd)
time points before and after an initiative in order to detect whether or not the initiative had a significantly greater effect than any underlying long-term trend.

The time trends before and after the bundle implementation were statistically compared in the interrupted time series data by using an ARIMA model. ARIMA models estimate the effects of the initiative while taking into account the time trend and autocorrelation among the observations (the extent to which data collected close together in time are correlated with each other). In the ARIMA (3,1,0) model, estimates for regression coefficients corresponding to 2 standardized effect sizes are obtained: a change in overall level and a change in trend before and after the initiative. A change in overall level occurs when the observed level at the first postinitiative time point differs from the level predicted by the preinitiative time trend, and a change in trend occurs when the slopes are different before and after the initiative. A negative change in level and slope would indicate a reduction in CLABSI SIRs. A total of 14 months before implementation (June 2011 through July 2012) and 14 months after implementation (August 2012 through September 2013) of the bundle were used in the model.

Results

Competency

All nurses selected for the central catheter team were required to have passed a competency assessment on central catheter maintenance. The competency assessment was available for use at the hospitals as a standard tool for evaluating nurse performance. Each hospital’s chief nursing officer attended an initial training webinar on central catheter maintenance at the beginning of the initiative, a review webinar 3 months into the initiative, and a webinar at the end of the study. At the end of the initial training webinar, the chief nursing officers completed a 4-item quiz on the frequency of central catheter maintenance and assessment, and on the materials used in a central catheter dressing change. The quiz was repeated at the beginning of each of the subsequent review webinars. The mean proportion of correct responses increased from 83% (before bundle implementation) to 86% (6 months after bundle implementation); however, the difference was not significant (paired samples test; \( t_{18} = -1.065, P = .30 \), \( d = -0.346 \)).

Compliance

Although compliance was more than 90% for each checklist measure during the first week of the bundle initiative, bundle compliance increased significantly during the first 5 weeks following implementation (Table 2). The high level of compliance continued throughout the course of the study.

Central Catheter–Associated Infections

According to the National Healthcare Safety Network’s definition, CLABSIs were defined as a primary bloodstream infection in a patient with a central catheter in place within a 48-hour period before blood cultures indicated an infection.20 All study hospitals routinely detected CLABSIs on the basis of CDC surveillance algorithms to determine the specific source of the infection, which may or may not be attributed to the central venous catheter.25 The mean LTACH central catheter utilization decreased slightly from before (67%) to after (66%) implementation of the bundle; however, use of CLABSI SIRs mitigated the difference. In the 6 months before the bundle was implemented, the CLABSI SIR was 1.28 (95% CI, 1.11-1.46).2 Six months after the bundle was implemented, the CLABSI SIR was 29% lower than the previous CLABSI SIR, at 0.96 (95% CI, 0.82-1.12); general linear model repeated-measures design for monthly CLABSI rates; \( F_{5,18} = 6.973 \), \( P = .01 \); partial \( \eta^2 = .31 \); Figure 2). From 14 months before to 14 months after bundle implementation, a mean

<table>
<thead>
<tr>
<th>Measure</th>
<th>Compliance, %</th>
<th>Test results&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central catheter dressings intact and occlusive</td>
<td>97.8</td>
<td>99.6</td>
</tr>
<tr>
<td>Date present on dressing</td>
<td>95.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Dressings initialed</td>
<td>91.0</td>
<td>98.0</td>
</tr>
<tr>
<td>Dressing changed in less than 7 days</td>
<td>98.7</td>
<td>99.5</td>
</tr>
<tr>
<td>Daily assessment of dressing site</td>
<td>98.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Chlorhexidine dressing in place</td>
<td>96.8</td>
<td>99.5</td>
</tr>
</tbody>
</table>

<sup>a</sup> Measured by related-samples Friedman 2-way analysis of variance by ranks (n = 17).
Following implementation and maintenance of the bundle in LTACHs, the CLABSI rate was reduced significantly (29%), from a SIR of 1.28 to a SIR less than 1.0 and no different from the expected CLABSI rate, because the mean 95% CI of the CLABSI SIR includes the expected value of 1.0. During the time of this study, the Centers for Medicare and Medicaid Services’ National Action Plan to Prevent HAIs set a national 5-year goal for CLABSI SIR reduction at 25%.8 Although the goal was set for short-term acute care hospitals and not LTACHs, results of the current study indicate that this goal was exceeded after the central catheter maintenance bundle was implemented in LTACHs. A mean reduction of 4.5 CLABSIs per LTACH occurred for the LTACHs studied for 14 months after the bundle was implemented. This infection reduction could translate to a savings of approximately $3.7 million annually for the 30 LTACHs studied and could have potentially saved 20 patients’ lives, assuming a 15% mortality rate from CLABSIs.30

Overall, implementation of the bundle had an immediate effect on CLABSI rates; in a within-hospital interrupted time series analysis, there was no time lag between bundle implementation and reduction in the number of infections. The bundle was developed from the CDC’s infection prevention guidelines, which include specific central catheter maintenance processes ranked according to their effectiveness as reported in prior studies. Components of the bundle were chosen on the basis of the strength of evidence for their effectiveness, implementation feasibility, and relevance to LTACH patients’ clinical requirements. Although the number of CLABSIs was significantly reduced after the bundle was implemented, because the bundled protocol contained many different processes, it cannot be determined which components of the bundle were most effective in contributing to CLABSI reduction. In addition, other processes or factors could have contributed to the observed CLABSI reduction. For example, operational change and increased focus on central catheters could have influenced the results irrespective of specific components of the bundle.30-32 Overall compliance may also have contributed to the positive results observed because compliance-reinforcement strategies can produce substantial results when implementing best-practice initiatives,33 although the high level of compliance observed prevented correlating variance in compliance to CLABSI rates. Although compliance data collection and structured bundle reinforcement processes ended 6 months after the central catheter maintenance bundle was implemented, CLABSI rates remained low 8 months after the study ended.

**Conclusions**

An estimated 20% of all hospital-associated infections (HAIs) have been attributed to the use of central venous catheters,26 and interventions to prevent CLABSIs could save as much as $32,000 per patient in adjusted variable costs attributable to CLABSIs (as estimated in 2010).25-29 More importantly, CLABSI prevention can reduce morbidity.30

**Application of similar bundles is an effective strategy for infection reduction.**

Reduction of 4.5 (95% CI, 1.85-7.15) CLABSIs per LTACH was observed for the LTACHs studied.

Time series modeling demonstrated a significant decrease in the mean hospital CLABSI rate immediately after the bundle was implemented, a statistically significant negative autoregressive parameter of -0.746 (t = -5.785, P < .001) and a significant intervention parameter of -0.390 (t = -3.610, P = .001). The mean hospital CLABSI rate was decreasing slightly before the bundle was implemented (slope = -0.047 CLABSI/1000 central catheter days, SE = 0.018). The mean CLABSI rate shifted abruptly when the bundle was implemented (-0.511 CLABSI/1000 central catheter days, SE = 0.052), which suggests that the impact of the bundle was immediate rather than gradual. After the abrupt shift that was coincident with implementation of the bundle, the slope for the CLABSI rate continued to decrease, although at a much reduced rate (slope = -0.005 CLABSI/1000 central catheter days, SE = 0.009).

The model goodness-of-fit statistic, stationary $R^2$, was 0.65, indicating the percentage variance in CLABSI rate explained by the interruption parameter (defined as the bundle) using the ARIMA (3,1,0) model.

**Figure 2 Central catheter–associated bloodstream infections presented as a standardized infection ratio.**
In the LTACHs studied, before the bundle was implemented, it is likely that nurses used many of the processes associated with the bundle when maintaining central catheters. However, no formal, comprehensive, standardized protocols for central catheter maintenance were in place, nor were there central catheter teams of nurses, alcohol-impregnated end caps in use, or compliance checklists; use of chlorhexidine-impregnated dressings also was intermittent. The results of this study are consistent with others’ experiences with bundles, where the bundle as a whole was more effective than individual components alone.34

Further study to elucidate specific components of the bundle that are effective in reducing CLABSI should include (1) identification of the primary source of CLABSI before and after the bundle was implemented35; (2) examination of the time between central catheter insertion and infection36; in the present study, most patients had their central catheters inserted before admission to the LTACH and insertion date data from the short-term acute care hospital was not available37; (3) determination of the type(s) of CLABSI pathogen(s) present before and after bundle implementation; (4) calculation of the proportion of patients with multiple central catheters; and (5) identification of the type and degree of physician involvement in the insertion, maintenance, and removal of central catheters.

Results from the present initiative indicate successful implementation of a central catheter maintenance bundle for an extended period in multiple LTACHs. Application of the bundle resulted in a significant and sustained reduction in CLABSI rates in LTACHs for 14 months. These results encourage the development and implementation of similar bundles as effective strategies for infection reduction in LTACHs.

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REFERENCES


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