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MAJOR ARTICLE

Impact of a Multidisciplinary Infection Prevention Initiative on Central Line and Urinary Catheter Utilization in a Long-term Acute Care Hospital

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Background. Prolonged central line (CL) and urinary catheter (UC) use can increase risk of central line–associated bloodstream infection (CLABSI) and catheter-associated urinary tract infection (CAUTI).

Methods. This interventional study conducted in a 76-bed long-term acute care hospital (LTACH) in Southeast Michigan was divided into 3 periods: pre-intervention (January 2015–June 2015), intervention (July–November 2015), and postintervention (December 2015–March 2017). During the intervention period, a multidisciplinary infection prevention team (MIPT) made weekly recommendations to remove unnecessary CL/UC or switch to alternate urinary/intravenous access. Device utilization ratios (DURs) and infection rates were compared between the study periods. Interrupted time series (ITS) and 0-inflated poisson (ZIP) regression were used to analyze DUR and CLABSI/CAUTI data, respectively.

Results. UC-DUR was 31% in the pre- and postintervention periods and 21% in the intervention period. CL-DUR decreased from 46% (pre-intervention) to 39% (intervention) to 37% (postintervention). The results of ITS analysis indicated nonsignificant decrease and increase in level/trend in DURs coinciding with our intervention. The CAUTI rate per catheter-days did not decrease during intervention (4.36) compared with pre- (2.49) and postintervention (1.93). The CLABSI rate per catheter-days decreased by 73% during intervention (0.39) compared with pre-intervention (1.45). Rates again quadrupled postintervention (1.58). ZIP analysis indicated a beneficial effect of intervention on infection rates without reaching statistical significance.

Conclusions. We demonstrated that a workable MIPT initiative focusing on removal of unnecessary CL and UC can be easily implemented in an LTACH requiring minimal time and resources. A rebound increase in UC-DURs to pre-intervention levels after intervention end indicates that continued vigilance is required to maintain performance.

Keywords. catheter-associated urinary tract infection; central line–associated blood stream infection; device utilization ratio; infection prevention; long-term acute care.

Long-term acute care hospitals (LTACHs) have become a novel model for continued medical care in the US health care system [1]. The national number of LTACHs has increased from 277 in 2003 to 407 in 2016, and the number of hospital discharges to these facilities also increased from 1.9% in 2004 to 4.9% in 2009 [2, 3]. The LTACH population is mainly comprised of patients recovering from critical illness who continue to require inpatient/intensive care unit (ICU) level care [1]. These facilities will continue to play an important role in health care delivery due to the aging of the US population and advances in critical care, both of which will increase the number of patients with chronic critical illness [3].

It has been reported that utilization of central lines (CLs) and urinary catheters (UCs) in LTACHs approaches that of intensive care units (ICUs) in acute care hospitals [4]. This is not surprising as the high acuity of care delivered in LTACHs necessitates the use of these devices. However, studies in acute care hospitals and ICUs note that most of these devices are left in place longer than necessary and physicians are often unaware of their presence in patients [5, 6]. Prolonged use of these devices increases the risk of infection, which in turn leads to extended hospital stays, morbidity, mortality, and excess hospital costs [7–12].

Although several studies have looked at central line–associated blood stream infection (CLABSI) and cather-associated urinary tract infection (CAUTI) reduction through reduction of unnecessary device use in acute care hospitals, there is a scarcity of similar interventions in an LTACH setting [13–16]. Interventions that incorporate the unique characteristics of this health care setting are urgently needed. Therefore, the goals of our study were 2-fold: (1) to introduce a workable infection

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prevention initiative that focused on reducing unnecessary use of central lines and urinary catheters in an LTACH and (2) to study the impact of this intervention in reducing device utilization ratio (DUR) and rates of CLABSI and CAUTI.

METHODS

Study Setting and Study Periods

This interventional study was performed at a 76-bed LTACH in the greater Detroit area. A Multidisciplinary Infection Prevention Team (MIPT) consisting of an infectious disease consultant (employed part-time to oversee infection prevention and antibiotic stewardship), pharmacist, and registered nurse (RN) trained in infection control was formed. The MIPT team was active from July 1, 2015, to November 30, 2015 (intervention period). The impact of the MIPT intervention was assessed by comparing predefined outcomes during the intervention period with those during the pre-intervention (January 1, 2015–June 30, 2015) and postintervention periods (December 1, 2015–March 31, 2017). The study was approved by the LTACH ethics committee.

Data Collection and Definitions

Patient-days, central line–days, and urinary catheter–days were obtained from the facility administrative database. LTACH-onset CAUTI and CLABSI were defined using 2015 National Healthcare Safety Network [17] criteria throughout the study period. CLABSI and CAUTI rates were calculated for 1000 central line–days and 1000 urinary catheter–days, respectively. In addition, CLABSI and CAUTI rates were calculated for 10 000 patient-days. Surveillance of CLABSI and CAUTI was conducted by the same RN trained in infection control during all 3 study periods. Other members of the MIPT team were not involved in infection surveillance. Central line and urinary catheter device utilization ratios (DUR) were calculated by dividing the number of catheter-days by number of patient-days during each study period. Infections with symptom onset within 48 hours of admission were excluded to study only LTACH-acquired infections.

Intervention Period

The MIPT was rounded weekly during the intervention period and was available for remote consultation for remainder of the week. Before the MIPT weekly rounds, the RN collected details on all patients with indwelling medical devices including patient medical history, current clinical status, available test results, device indications, device start date, and any device-related adverse events. This information was reviewed by MIPT during weekly rounds to access device appropriateness. The weekly rounds, which combined infection prevention with antibiotic stewardship, lasted about 1 to 1.5 hours (antibiotic stewardship portion of the study has been published previously [18]). Criteria for appropriateness of central line and urinary catheters were based on previously published data and are noted in Table 1 [5, 19–21]. When indication for a central line was no longer present or when alternate intravenous access (midline or peripheral venous catheter) could be used to instill medications, the recommendation was made to discontinue the central line or switch from the central line to a midline or peripheral line. When indication for a urinary catheter was no longer present or when alternative methods could be used to drain urine, the recommendation to discontinue or switch to an alternative method, such as condom catheters or intermittent catheterization, was made. The final recommendations of the MIPT were communicated to the physician in charge of the patient by phone or email. The team continued rounding from July to November 2015. The MIPT intervention was suspended in November 2015 due to completion of the infection disease consultant's contract with the facility and not related to the intervention itself.

Outcome Assessment

The primary outcomes were (1) to ascertain the impact of MIPT rounds on the total urinary catheter–days, central line–days, and DURs and (2) to analyze the effect of MIPT intervention on LTACH-onset CLABSI and CAUTI rates. The effectiveness of the program was determined by comparing these outcomes between the 3 study periods.

Statistical Analysis

The monthly rates were combined to calculate the CAUTI rate, CLABSI rate, central line utilization ratio (CL DUR), and urinary catheter utilization ratio (UC DUR) during the 3 study periods.

Segmented regression analysis of interrupted time series (ITS) was used to evaluate the changes in level and trend in DURs during the intervention and postintervention periods. As our series had 2 change points corresponding to the start and end of the intervention period, we used the following model, as suggested by Wagner et al. [22].

Table 1. Acceptable Indications for Urinary Catheter and Central Line

Urinary Catheter
Open sacral wound for incontinent patients
Urinary obstruction/neurogenic bladder
Accurate intake and outake monitoring
Urology surgery
Comfort care in patients with terminal illness
Central Venous Catheter
Total parentral nutrition administration
Dialysis
Irritant and vesicant medication including intravenous vancomycin
Use of vasopressor and inotrope
Use of any intravenous medication in patients with difficult vascular access

The table shows the checklist created by the infection prevention team based on the various consensus guidelines [5, 9, 20, 21]. These criteria were used during our weekly rounds to check for the appropriateness and necessity of both foley and central lines.

$$Y_t = \beta_0 + \beta_1 \times \text{time}_t + \beta_2 \times \text{intervention start}_t + \beta_3 \times \text{time after intervention start}_t + \beta_4 \times \text{intervention end}_t + \beta_5 \times \text{time after intervention end}_t + e_t,$$

where Y_t is the dependent variable (DUR); time is a continuous variable indicating time in months (coded as 1 when the study started and then increasing by 1 for each month thereafter); intervention start is a dummy variable coded as 0 (pre-intervention period) and 1 (intervention and postintervention periods); time after intervention start is the number of months after the start of the intervention period with a value of 0 before the start of the intervention period and then increasing by 1 for each month thereafter; intervention end is a dummy variable coded as 0 (pre-intervention and intervention period) and 1 (postintervention period); time after intervention end is the number of months after the end of the intervention period with a value of 0 for each month until November 31, 2015, and then increasing by 1 for each month thereafter; e_t is the random variability at time *t* not explained by the model.

Furthermore, the coefficient β_0 estimates the baseline level of the dependent variable (DUR); β_1 estimates the baseline trend (slope) before the intervention; β_2 estimates the level change in DURs after intervention, that is, from the end of the pre-intervention period; β_3 estimates the change in trend following the intervention; β_4 estimates the level change in DURs from the end of the intervention period to the first postintervention period; β_5 estimates the change in trend after the end of the intervention period.

We checked our time series data for nonstationarity (augmented Dickey-Fuller test) and autocorrelation (Durbin-Watson statistic and stepwise auto-regression). Autoregressive parameters were set to account for seasonality, but there was none present in either of our DUR models. UC DUR data indicated nonstationarity; therefore, first-order differencing was done to convert the data to a stationary series.

We used 0-inflated poisson (ZIP) regression to analyze our CLABSI and CAUTI rates. This model was used to account for excess 0s in our CLABSI and CAUTI data. We performed the Vuong test, which further confirmed that a ZIP model was superior compared with a plain poisson model. The ZIP model has 2 components, a logistic model that predicts the occurrence of having a 0 CLABSI/CAUTI rate (certain 0s) and a poisson model to generate count data. Catheter-days, patient-days, and intervention/no intervention were used as variables in the model to evaluate their effects on infection rates. We noticed a possible lagged effect of our intervention in the month of December 2015; therefore, this month was included as yes to intervention. In addition, our CLABSI and CAUTI rates data did not indicate first-order autocorrelation, seasonality, or nonstationarity.

A *P* value <.05 was considered statistically significant. All statistical analyses were performed using SAS software, version 9.4 (Cary, NC).

RESULTS

The total patient-days, total central line–days, and total urinary catheter–days for the entire study duration were 32 099, 12 969, and 9338, respectively.

Urinary Catheter and Central Line Utilization Ratio

The device utilization ratios for UC and CL during the 3 study periods are given in Figure 2 and Table 2.

The average UC DUR decreased from 31% (pre-intervention and postintervention period) to 21% during the intervention period. At the end of the intervention period, the UC DUR was at 15%. It decreased further to 6% in the month after stopping the intervention. The CL DUR decreased from 46% (pre-intervention period) to 39% (intervention period) to 37% (postintervention).

ITS analysis indicated no significant trend (β_1) in UC DUR during the pre-intervention period (Table 3). After beginning the intervention, we noticed nonsignificant decreases in level and trend in UC DURs. When the intervention was stopped, we noticed an increase in level (β_4) that was close to statistical significance (*P* = .06). Increased trend (β_5) in UC DURs after stopping the intervention was not significant (*P* = .99). With regards to CL DUR, there was no significant baseline trend (β_1) noted. Although we noticed decreases and increases in level and trend

Table 2. Device Utilization Ratios—Interrupted Time Series

	UC DUR		CL DUR	
	Estimate	*P* Value	Estimate	*P* Value
Baseline level (β_0)	–0.0442	.61	0.5033	<.0001
Baseline trend (β_1)	0.0101	.63	–0.007024	.7
Change in level after intervention start (β_2)	–0.0403	.65	–0.0965	.11
Change in trend after intervention start (β_3)	–0.0160	.56	–0.000288	.99
Change in level after intervention end (β_4)	0.1118	.06	0.0787	.12
Change in trend after intervention end (β_5)	0.0000300	.99	0.005098	.74

Table 2 shows interrupted time series analysis looking at changes in levels and trend in urinary catheter device utilization ratio and central line device utilization ratio before and after intervention.

Abbreviations: CL DUR, central line utilization ratio; UC DUR, urinary catheter utilization ratio.

Table 3. Results of 0-Inflated Poisson Model on Association Between Different Variables on CAUTI and CLABSI Rates

	Estimate	Wald 95% Confidence Limits		*P* Value
CAUTI, Poisson model				
Intervention	−0.1408	−0.8465	0.5649	.69
Patient-days	0.0009	−0.0003	0.0021	.14
Catheter-days	−0.0055	−0.0081	−0.0029	<.0001
CAUTI, 0 model				
Intercept	−0.2041	−1.1131	0.7048	.65
Intervention	−1.4060	−3.7387	0.9267	.23
CLABSI, Poisson model				
Intervention	−0.0803	−2.0496	1.8890	.93
Patient-days	−0.0014	−0.0043	0.0014	.31
Catheter-days	0.0010	−0.0041	0.0060	.7
CLABSI, 0 model				
Intercept	−1.2487	−2.8668	0.3694	.13
Intervention	2.5734	−0.3839	5.5308	.08

Table 3 shows the results of the 0-inflated Poisson model on the association between different variables on central line–associated blood stream infection and catheter-associated urinary tract infection rates.

Abbreviations: CAUTI, catheter-associated urinary tract infection; CLABSI, central line–associated blood stream infection.

coinciding with our intervention, statistical significance was not achieved (Table 3). We repeated the analysis after including the month of December 2015 in the intervention period to account for lagged effects from the intervention. Changes in level or trend in this analysis were not significantly different compared with our previous analysis without accounting for lagged effect (data not shown).

CLABSI and CAUTI Rates

CAUTI and CLABSI rates during the 3 study periods are given in Figure 1, Figure 3, and Table 3.

The increase in CAUTI rates differed based on the denominator used (patient-days: 19.9% increase; vs catheter-days: 75% increase). Results of ZIP analysis indicated that the intervention was not significantly associated with a decrease in CAUTI rate per catheter-days, or predicted the occurrence of 0 CAUTI. The patient-days variable was not significantly associated with decrease in CAUTI rates either. ZIP analysis also indicated that as the total urinary catheter–days per month decreased, the CAUTI rates increased significantly ($P < .0001$).

We noticed a 73% reduction in CLABSI rate per catheter-days during the intervention period. When the intervention was stopped, CLABSI rate per catheter-days quadrupled. Results of ZIP analysis indicated that our intervention was associated with a decrease in CLABSI rate per catheter-days and predicted the occurrence of 0 CLABSI; however, statistical significance was not achieved ($P = .93$ and .08, respectively). In addition, neither patient-days nor catheter-days was significantly associated with increase or decrease in CLABSI rates.

DISCUSSION

Despite the high device utilization and increased burden of CLABSI and CAUTI in LTACHs, studies that focus on device-associated infection prevention are rarely done in this setting [3, 23–25]. We came across 2 studies that focused on

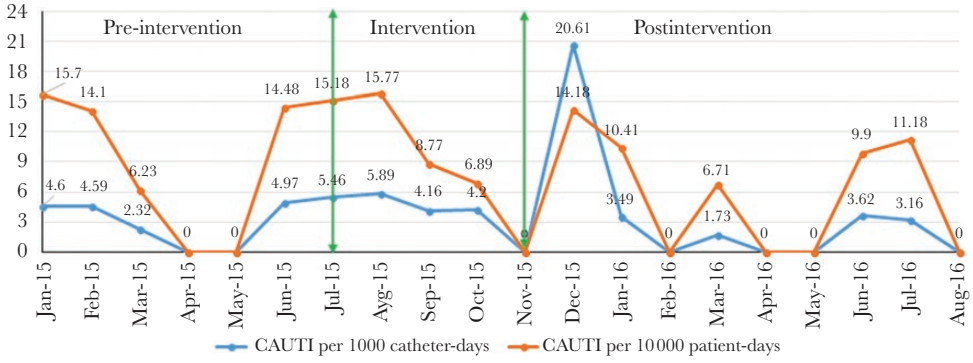

Figure 1. Catheter-associated urinary tract infection (CAUTI) rate measured as rate per catheter-days and patient-days during the 3 study periods. Only selected months of data from the postintervention phase are reported in the figure.

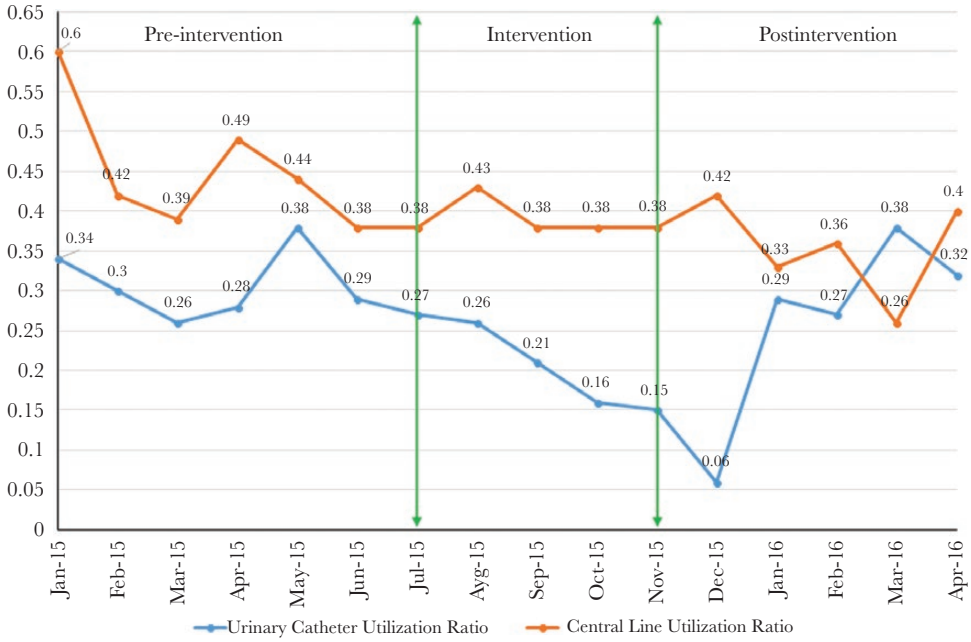

Figure 2. Urinary catheter and central line device utilization ratio during the 3 study periods.

reducing CLABSI and CAUTI rates in an LTACH setting [24, 25]. One study primarily focused on reducing CLABSI through implementation of CL maintenance bundle [24]. This study did not change catheter removal practices in the LTACHs. Another study focused on reducing CAUTI rates and DUR through a nurse-driven protocol to promote appropriate discontinuation of urinary catheters [25].

To our knowledge, ours is the only study specifically focusing on reducing unnecessary CL and UC use with the aim to reduce DURs, CLABSI, and CAUTI in an LTACH setting.

We demonstrated that a "2 in 1" CLABSI and CAUTI prevention initiative using an MIPT approach can be readily implemented in an LTACH setting. Our program requires minimal time and resources and is feasible in an LTACH setting where resources and staff availability are limited. In addition, this initiative can be combined with antibiotic stewardship to further improve patient care.

Our infection prevention initiative primarily focused on reducing unnecessary use of urinary and central lines. Current evidence-based strategies including focused education, electronic medical record alerts, computerized order entry, stop orders, nurse-driven protocols, reminders by a physician leader, and medical directives have been used to reduce unnecessary urinary catheter use [16, 19, 26–29]. With regards to central lines, interventions to reduce unnecessary catheter use have mostly been implemented as part of a bundled intervention

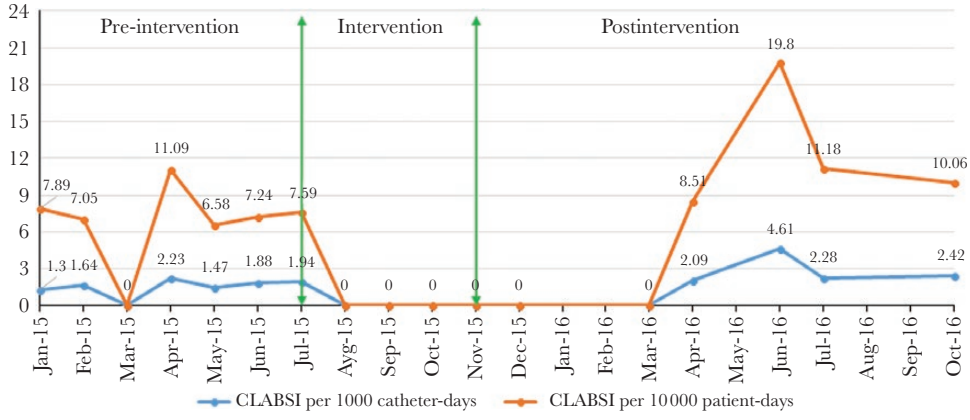

Figure 3. Central line–associated bloodstream infection (CLABSI) rate measured as rate per catheter-days and patient-days during the 3 study periods. Only selected months of data from the postintervention phase are reported in the figure.

involving proper insertion and maintenance practices [30]. Prevention strategies focusing on aseptic insertion of central line and urinary catheters are unlikely to be helpful in the LTACH setting as most patients have these devices at the time of admission. Therefore, we focused on weekly reminders to reduce unnecessary catheter use as this strategy requires limited resources and could easily be combined with antibiotic stewardship.

Our primary goal was to reduce DURs by removing unnecessary central line and urinary catheters. In the pre-intervention period, UC DUR at our LTACH was at the lower limit of previously reported rates (median, 0.55; range, 0.12–0.87) [4].

Despite the low DUR to begin with, our intervention was successful in reducing DUR by almost half at the end of the intervention period, and we achieved the lowest DUR of 6% in the month after stopping the intervention. Implementing a similar intervention in LTACHs with DURs in the higher end of spectrum could lead to much larger reductions. ITS analysis also demonstrates a fluctuating UC DUR that coincides with our intervention, with an increasing level after stopping the intervention (close to statistical significance). This is not surprising as it was a common culture in our LTACH staff to resist urinary catheter removal due to the inconvenience of managing their patients without these devices. We were able to overcome this resistance during our intervention period through repeated reminders. Other LTACHs planning to implement similar measures should be aware of these barriers, which could lead to rebound increase in DUR if constant reminders are not imparted. Our experience suggested that having a physician or nursing leader will help overcome barriers related to removal of urinary catheters. Future studies should evaluate ways to change the existing culture in LTACHs and sustain these changes over longer periods.

We were also able to achieve reduction in CL DUR with our intervention. Pre-intervention CL DUR in our LTACH was comparable to previously reported rates in LTACHs (median, 0.67; range, 0.19–1.0) [4]. CL DUR continued to decrease during the intervention and postintervention periods. However, these differences were not statistically significant on ITS analysis. A continued decrease in CL DUR during postintervention period could be credited to the RN who continued to work in the LTACH during the postintervention period. The RN continued to monitor device use and stress the importance of removing unnecessary central lines and/or switching to alternate intravenous access.

Despite the reduction in UC DUR during the intervention period, this did not lead to a decrease in CAUTI rates. It is hypothesized that interventions focusing on early removal of urinary catheters might preferentially target patients at low risk of CAUTI, leaving patients at high risk with catheters who will continue to contribute to numerator data while the low risk patients who had catheters removed cease to contribute to the denominator of catheter-days, leading to an increase in CAUTI rate per 1000 catheter-days [19]. This likely occurred in our patient population as well, as we noted less increase in CAUTI rates when patient-days was used as the denominator. Results of our regression analysis further support the theory that a decrease in catheter-days was responsible for the increase in CAUTI rate in our population. Therefore, when early catheter removal is the focus of the intervention, programs should measure CAUTI rate using patient-days as the denominator. Alternatively, the lack of reduction in CAUTI rates could be related to the short duration of our intervention period, as we achieved a 0 CAUTI rate at the end of the intervention period, when our DUR was decreased by half. Future studies in LTACHs with longer intervention periods could help provide more insight into this matter.

Our CLABSI rates per catheter-days in the pre-intervention period were comparable to previously reported rates in LTACHs (mean, 1.4) [4]. Rates decreased by 73% during the intervention period, followed by an increase in postintervention period. A decrease in CLABSI rates during the intervention period was likely related to our intervention as, to our knowledge, there was no other infection prevention intervention ongoing during our study period. Results of ZIP analysis also indicated a beneficial effect of intervention on CLABSI rate without reaching statistical significance. We continued to notice a 0 CLABSI for 4 months after stopping the intervention, which likely caused no significant effect of our intervention, even though we included the month of December as yes to intervention to account for lagged effects.

The main limitation of our study was the short intervention period, which precluded attainment of statistically significant reductions in DURs, CLABSI rate, and CAUTI rate. The study was also conducted in a single LTACH located in an underserved area, which will limit the generalizability of our findings. In addition, it is possible that changes in the patient population that we did not document might have caused changes in DURs and infection rates, although these are unlikely to have coincided with the 3 study periods.

In conclusion, tailored infection prevention initiatives targeting CLABSI and CAUTI are urgently needed in LTACHs, where device utilization and infection rates are comparable to intensive care units. We demonstrated that a workable infection prevention initiative focusing on reducing unnecessary central line and urinary catheter use can be easily implemented in an LTACH, requiring minimal time and resources. Although our study did not show a significant reduction in DURs, CLABSI rate, and CAUTI rate, evidence from studies done in ACHs clearly indicates that reducing unnecessary use will result in reduction of DUR and infection rates. Even a simple initiative could result in substantial gains in an LTACH with high device utilization. Furthermore, LTACHs implementing these interventions should be aware of potential barriers that could affect the program's effectiveness and sustainability.

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Author contributions. All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors of this manuscript have read and approved the final version submitted.

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References

1. Weinstein RA, Munoz-Price LS. Long-term acute care hospitals. Clin Infect Dis **2009**; 49:438–43.
2. Medicare Payment Advisory Commission. Long-term Care Hospital Services. Report to the Congress: Medicare Payment Policy. Washington, DC: MedPAC; **2017**.
3. Kahn JM, Le T, Angus DC, et al; ProVent Study Group Investigators. The epidemiology of chronic critical illness in the United States*. Crit Care Med **2015**; 43:282–7.
4. Chitnis AS, Edwards JR, Ricks PM, et al. Device-associated infection rates, device utilization, and antimicrobial resistance in long-term acute care hospitals reporting to the National Healthcare Safety Network, 2010. Infect Control Hosp Epidemiol **2012**; 33:993–1000.
5. Saint S, Wiese J, Amory JK, et al. Are physicians aware of which of their patients have indwelling urinary catheters? Am J Med **2000**; 109:476–80.
6. Rotz S, Sopirala MM. Assessment beyond central line bundle: audits for line necessity in infected central lines in a surgical intensive care unit. Am J Infect Control **2012**; 40:88–9.
7. Gil RT, Kruse JA, Thill-Baharozian MC, Carlson RW. Triple- vs single-lumen central venous catheters. A prospective study in a critically ill population. Arch Intern Med **1989**; 149:1139–43.
8. Maki DG, Tambyah PA. Engineering out the risk for infection with urinary catheters. Emerg Infect Dis **2001**; 7:342–7.
9. Renaud B, Brun-Buisson C; ICU-Bacteremia Study Group. Outcomes of primary and catheter-related bacteremia. A cohort and case-control study in critically ill patients. Am J Respir Crit Care Med **2001**; 163:1584–90.
10. Blot SI, Depuydt P, Annemans L, et al. Clinical and economic outcomes in critically ill patients with nosocomial catheter-related bloodstream infections. Clin Infect Dis **2005**; 41:1591–8.
11. Saint S. Clinical and economic consequences of nosocomial catheter-related bacteriuria. Am J Infect Control **2000**; 28:68–75.
12. Klevens RM, Edwards JR, Richards CL Jr, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. Public Health Rep **2007**; 122:160–6.
13. Huang WC, Wann SR, Lin SL, et al. Catheter-associated urinary tract infections in intensive care units can be reduced by prompting physicians to remove unnecessary catheters. Infect Control Hosp Epidemiol **2004**; 25:974–8.
14. Marra AR, Cal RG, Durão MS, et al. Impact of a program to prevent central line-associated bloodstream infection in the zero tolerance era. Am J Infect Control **2010**; 38:434–9.
15. Topal J, Conklin S, Camp K, et al. Prevention of nosocomial catheter-associated urinary tract infections through computerized feedback to physicians and a nurse-directed protocol. Am J Med Qual **2005**; 20:121–6.
16. Magers TL. Using evidence-based practice to reduce catheter-associated urinary tract infections. Am J Nurs **2013**; 113:34–42; quiz 44, 43.
17. Center for Disease Control and Prevention, National Healthcare Safety Network. Patient safety component manual. Updated April 2015. https://www.cdc.gov/nhsn/pdfs/validation/2015/2015-validation-manual.pdf. Accessed May 2018.
18. Mushtaq A, Awali RA, Chandramohan S, et al. Implementing an antibiotic stewardship program at a long-term acute care hospital in Detroit, Michigan. Am J Infect Control **2017**; 45:e157–60.
19. Meddings J, Rogers MA, Krein SL, et al. Reducing unnecessary urinary catheter use and other strategies to prevent catheter-associated urinary tract infection: an integrative review. BMJ Qual Saf **2014**; 23:277–89.
20. Loeb M, Hunt D, O'Halloran K, et al. Stop orders to reduce inappropriate urinary catheterization in hospitalized patients: a randomized controlled trial. J Gen Intern Med **2008**; 23:816–20.
21. Topal J, Conklin S, Camp K, et al. Prevention of nosocomial catheter-associated urinary tract infections through computerized feedback to physicians and a nurse-directed protocol. Am J Med Qual **2005**; 20:121–6.
22. Wagner AK, Soumerai SB, Zhang F, Ross-Degnan D. Segmented regression analysis of interrupted time series studies in medication use research. J Clin Pharm Ther **2002**; 27:299–309.
23. Mody L, Meddings J, Edson BS, et al. Enhancing resident safety by preventing healthcare-associated infection: a national initiative to reduce catheter-associated urinary tract infections in nursing homes. Clin Infect Dis **2015**; 61:86–94.
24. Cobb DK, High KP, Sawyer RG, et al. A controlled trial of scheduled replacement of central venous and pulmonary-artery catheters. N Engl J Med **1992**; 327:1062–8.
25. Edwards M, Purpura J, Kochvar G. Quality improvement intervention reduces episodes of long-term acute care hospital central line-associated infections. Am J Infect Control **2014**; 42:735–8.
26. Schwartz BC, Frenette C, Lee TC, et al. Novel low-resource intervention reduces urinary catheter use and associated urinary tract infections: role of outcome measure bias? Am J Infect Control **2015**; 43:348–53.
27. Cornia PB, Amory JK, Fraser S, et al. Computer-based order entry decreases duration of indwelling urinary catheterization in hospitalized patients. Am J Med **2003**; 114:404–7.
28. Cho HJ, Khalil S, Poeran J, et al. "Lose the tube": a choosing wisely initiative to reduce catheter-associated urinary tract infections in hospitalist-led inpatient units. Am J Infect Control **2017**; 45:333–5.
29. Leis JA, Corpus C, Rahmani A, et al. Medical directive for urinary catheter removal by nurses on general medical wards. JAMA Intern Med **2016**; 176:113–5.
30. Blot K, Bergs J, Vogelaers D, et al. Prevention of central line-associated bloodstream infections through quality improvement interventions: a systematic review and meta-analysis. Clin Infect Dis **2014**; 59:96–105.