Journal of Microbiology, Immunology and Infection (2018) 51, 666–671

Available online at www.sciencedirect.com

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Original Article

Implementation of a national bundle care program to reduce central line-associated bloodstream infections in intensive care units in Taiwan

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Received 9 October 2017; received in revised form 10 October 2017; accepted 10 October 2017
Available online 25 October 2017

KEYWORDS
Central line-associated

Abstract *Background/purpose:* This study assessed the effect of the central line bundle on the rate of central line-associated bloodstream infections (CLABSI) in intensive care units (ICUs) in Taiwan.

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https://doi.org/10.1016/j.jmii.2017.10.001

bloodstream infections;
Bundle care;
Intensive care units;
Taiwan

Methods: This national study was conducted in 27 ICUs with 404 beds total, including 15 medical ICUs, 11 surgical ICUs, and one mixed ICU. The study period was divided into two phases: a pre-intervention (between June 1, 2011 and October 31, 2011) and intervention phase (between December 1, 2011 and October 31, 2012). Outcome variables, including CLABSI rates (per 1000 catheter-days) and catheter utilization rates, were measured.
Results: The overall rate of CLABSI significantly decreased by 12.2% ($p < 0.001$) from 5.74 per 1000 catheter-days in the pre-intervention phase to 5.04 per 1000 catheter-days in the intervention phase. The catheter utilization rate decreased by 1.1% from 55.3% in the pre-intervention phase to 54.2% in the intervention phase. The decline in CLABSI varied significantly among hospital and ICU levels, except surgical ICUs ($p = 0.59$).
Conclusions: Implementing a multidimensional central-line bundle significantly reduced the rates of CLABSI by 12.2% in nearly all participating ICUs, except surgical ICUs.

Introduction

Central venous catheters (CVC) are indicated to monitor hemodynamic status and administer drugs with a low risk of phlebitis, as well as for hemodialysis and intravenous access; thus, it is a common device in hospitals. However, CVC insertion can cause complications including pneumothorax, bleeding problems, air embolism, arrhythmias and even death. Additionally, the delayed complication, known as central line-associated bloodstream infection (CLABSI), can occur and have negative impacts such as increasing mortality, morbidity, hospital stay, and overall medical costs.[1–4] In Taiwan, a previous study evaluating the comparative impact of hospital-acquired infections on medical costs, length of hospital stay, and outcomes clearly demonstrated that patients with hospital-acquired BSI were associated with prolonged hospital stay (mean, 15.5 days in one medical center and 16.6 days in two regional hospitals) and extra hospital costs (mean, US$4872 and US$4643 in the medical center and regional hospitals, respectively).[5] CLABSI is a major life-threatening disease in intensive care units (ICUs) worldwide,[6] with Taiwan being no exception.[7–10]

Fortunately, CLABSI is preventable with appropriate care.[11] Several evidence-based interventions, such as chlorhexidine gluconate (CHG) use to prepare the insertion site, maximal sterile barriers when inserting the CVC, use of the subclavian or internal jugular vein as the insertion site, hand hygiene, and early removal of the CVC if not needed, were developed to prevent CLABSI.[12–15] The Institute for Healthcare Improvement (IHI) incorporated these interventions into a care bundle known as the central line bundle. A recent meta-analysis including 79 studies reported after implementation of insertion or maintenance or both central-line bundles CLABSI in ICUs can decrease by 60%, from 6.4 per 1000 catheter-days to 2.5 per 1000 catheter-days.[11] Moreover, in a meta-analysis of nine studies, the estimated cost savings for every prevented episode of CLABSI can be as high as US$42,609.[11]

In Taiwan, the CLABSI rates among ICUs in medical centers and regional hospitals were 5.5 and 3.5 per 1000 catheter-days, respectively, in 2012.[10] Thus, a government-led force combined with a professional organization to promote vascular and urinary catheter care quality is imperative, and the Centers for Disease Control in Taiwan (Taiwan CDC) implemented a national action plan to reduce CLABSI in Taiwan in 2013. In this project, the CLABSI bundle care was implemented and the effect of the bundle care was assessed in 27 ICUs in medical centers and regional and district hospitals.

Methods

Setting and participating hospitals

This study was conducted in nine medical centers, three regional hospitals, and one district hospital. After obtaining the approval of the Institutional Review Board at each investigation site, this national study was conducted in 27 ICUs, with a total of 404 beds, including 15 medical ICUs, 11 surgical ICUs, and 1 mixed ICU (Table 1). Among the 27 ICUs, 21 were located in 20 medical centers, five in five regional hospitals and one in a district hospital. The number of participating ICUs (number of beds) was eight (107) in northern Taiwan, four (76) in middle Taiwan, 13 (186) in southern Taiwan, and two (35) in eastern Taiwan. This study period was divided into the pre-intervention (between June 1, 2011 and October 31, 2011) and intervention phase (between December 1, 2011 and October 31, 2012).

Study interventions

After expert meetings, a national evidence-based guideline of the CLABSI bundle was developed. The CVC bundle in this project included the insertion and maintenance bundles. The insertion bundle included hand hygiene, maximal sterile barriers upon insertion, use of CHG for preparing skin, and avoidance of femoral veins as the access site. The maintenance bundle included hand hygiene, proper dressing changes, aseptic technique for accessing and changing needleless connectors, and a daily review of catheter necessity.[16,17]

Table 1 Baseline characteristics of 27 intensive care units (ICUs) with a total of 404 beds participating in this study.

Region of Taiwan (no. of ICUs, beds)	Type of hospitals	Type of ICUs	No. of beds
Northern	Medical center	MICU	9
(n = 8, 107)	Medical center	MICU	16
	Medical center	SICU	13
	Medical center	SICU	16
	Medical center	MICU	10
	Medical center	MICU	13
	Medical center	MICU	10
	Medical center	SICU	20
Middle	Medical center	MICU	22
(n = 4, 76)	Medical center	SICU	15
	Medical center	MICU	17
	Medical center	SICU	22
South	Medical center	MICU	12
(n = 13, 186)	Medical center	SICU	12
	Medical center	MICU	6
	Medical center	SICU	9
	Medical center	MICU	14
	Medical center	SICU	13
	Medical center	SICU	14
	Medical center	MICU	13
	Medical center	MICU	13
	Regional hospital	MICU	22
	Regional hospital	MICU	21
	Regional hospital	SICU	17
	District hospital	Mix ICU	20
East (n = 2, 35)	Regional hospital	MICU	14
	Regional hospital	SICU	21

MIC = medical ICU; SICU = surgical ICU.

Definitions

CLABSI was defined per the CDC guidelines.[18] All participating units provided the total number of CLABSI, catheter-days, and other healthcare-associated infections. Outcome data, including rates of CLABSI (per 1000 catheter-days), and catheter utilization rates (days of catheter use divided by total inpatient-days) were collected. Process surveillance by the checklist was developed to assess bundle practice compliance, which was defined as the frequency of adherence to the five bundle elements, including hand hygiene, maximal barrier precautions upon insertion, optimal catheter site selection, chlorhexidine skin disinfection, and daily review of line necessity, to the number of CVC insertions.

Statistical analysis

We compared the CLABSI rate during the pre-intervention and intervention phases and calculated the percent change in the CLABSI rate between the two phases. Analyses were performed using Microsoft Excel 2013 (Microsoft Corporation, Redmond, WA, USA), and a p value of <0.05 was considered statistically significant.

Results

CLABSI rates during the pre- and intervention phases

The CLABSI rate decreased by 12.2%, from 5.74 per 1000 catheter-days in the pre-intervention phase to 5.04 per 1000 catheter-days in the intervention phase ($p < 0.001$) (Table 2). The catheter utilization rate decreased by 1.1%

Table 2 Rate changes for central line-associated bloodstream infections (CLABSIs) between the pre-intervention phase (June 1, 2011 to October 31, 2011) and the intervention phase (December 1, 2011 to October 31, 2012) in different intensive care units (ICUs) and hospital categories in Taiwan.

Study units (no.)	No. of CLABSI episodes		Catheter-days		CLABSI rate (cases per 1000 catheter-days)			p value[a]
	Pre-intervention phase	Intervention phase	Pre-intervention phase	Intervention phase	Pre-intervention phase	Intervention phase	Change (%)	
Hospital type								
Medical center (20)	376	272	58,119	47,460	6.47	5.73	−11.41	**<0.0001**[a]
Regional hospital (5)	38	25	13,336	10,648	2.85	2.35	−17.60	**0.02**
District hospital (1)	3	0	1138	808	2.64	0.00	−100.00	**<0.0001**
ICU type								
MICU (15)	260	175	39,379	32,160	6.60	5.44	−17.58	**<0.0001**
SICU (11)	154	122	32,076	25,948	4.80	4.70	−2.07	0.59
Mixed ICU (1)	3	0	1138	808	2.64	0.00	−100.00	**<0.0001**
Overall	417	297	72,593	58,916	5.74	5.04	−12.20	**<0.0001**

[a] p values in boldface indicate significant differences in CLABSI rate (cases per 1000 catheter-days) between pre-intervention and intervention phases.
MICU = medical ICU; SICU = surgical ICU.

from 55.3% in the pre-intervention phase to 54.2% in the intervention phase. The change varied among hospital settings. In the medical centers, CLABSI rate decreased from 6.47 (pre-intervention phase) to 5.73 per 1000 catheter-days (intervention phase) ($p < 0.001$). In the regional hospitals, CLABSI rate decreased from 2.85 (pre-intervention phase) to 2.35 per 1000 catheter-days (intervention phase) ($p = 0.02$). In the only district hospital, CLABSI rate decreased from 2.63 (pre-intervention phase) to zero per 1000 catheter-days (intervention phase) ($p < 0.001$). Such a decline in CLABSI rate occurred among different ICU types, including medical and mixed ICUs. In contrast, the difference in surgical ICUs was not statistically significant ($p = 0.59$).

Rates of other infections in the pre- and intervention phases

Overall, the rates of bloodstream infection (BSI) and ventilator-associated pneumonia (VAP) were 4.2 per 1000 inpatient-days and 1.8 per 1000 ventilator-days in the pre-intervention phase, and 3.8 per 1000 inpatients-days and 1.3 per 1000 ventilator-days in the intervention phase, respectively. In contrast, the rate of catheter-associated urinary tract infection (CAUTI) was 4.0 per 1000 catheter-days in the pre-intervention phase and increased to 4.2 per 1000 catheter-days in the intervention phase (Table 3).

In the medical centers, the rates of BSI and VAP were 4.7 per 1000 inpatient-days and 1.9 per 1000 ventilator-days in the pre-intervention phase, decreasing to 4.5 per 1000 inpatient-days and 1.7 per 1000 ventilator-days in the intervention phase, respectively. In contrast, the rate of CAUTI was 4.2 per 1000 catheter-days in the pre-intervention phase, and increased to 4.5 per 1000 catheter-days in the intervention phase. These changes were not statistically significant.

In the regional hospitals, the rates of BSI, CAUTI, and VAP were 2.8 per 1000 inpatient-days, 3.9 per 1000 catheter-days, and 1.2 per 1000 ventilator-days in the pre-intervention phase, and decreased to 1.6 per 1000 inpatient-days, 3.2 per 1000 catheter-days, and 0.9 per 1000 ventilator-days in the intervention phase, respectively. These changes were not statistically significant.

In the district hospital, the rates of BSI, CAUTI, and VAP were 1.5 per 1000 inpatient-days, 1.8 per 1000 catheter-days, and 2.5 per 1000 ventilator-days in the pre-intervention phase, and increased to 2.9 per 1000 inpatient-days, 3.6 per 1000 catheter-days, and 6.8 per 1000 ventilator-days in the intervention phase, respectively. However, these increases were not statistically significant.

CVC bundle care compliance

Of the five CVC bundle elements, compliance was the lowest for the optimal insertion site. In this study, 42.4% (n = 2062) of CVCs were inserted via femoral veins. We further reviewed the causes of femoral vein insertion, which included double lumen catheter insertion for emergent hemodialysis (28.7%), neck veins occupied by a CVC catheter (10.7%), high risk of pneumothorax (6.8%), and short neck (6.1%).

Discussion

This study found several significant results regarding the effects of implementing a national CVC bundle care program. Most importantly, the CLABSI rate declined significantly after introducing this intervention, and this reduction was noted among all hospital levels, including medical centers, regional hospitals, and district hospital. This finding is consistent with that of implementing CAUTI bundle in 13 high-risk units in Taiwan in which the CAUTI rate decreased by 22.7%, from 3.86 to 2.98 per 1000 catheter-days (95% confidence interval [CI], 0.65–0.82; $p < 0.0001$) before and after introducing CAUTI bundle.[19] Several national studies in other countries[20–23] have shown that a central-line bundle can prevent CLABSIs in ICUs. In Colombia, implementing the multidimensional

Table 3 Rates of bloodstream infections (BSIs), ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infections (CAUTIs) between pre-intervention and intervention phases in intensive care units (ICUs) of different hospitals in Taiwan.

Infection rate	Hospital category (no. of ICUs)			
	Medical center (n = 21)	Regional hospital (n = 5)	District hospital (n = 1)	Overall (n = 27)
BSI (cases per 1000 inpatient-days)				
Pre-intervention phase	4.7	2.8	1.5	4.2
Intervention phase	4.5	1.6	2.9	3.8
vvChange in rate (%)	−4.3	−42.9	+93.3	−9.5
VAP (cases per 1000 ventilator-days)				
Pre-intervention phase	1.9	3.9	2.5	1.8
Intervention phase	1.7	3.2	6.8	1.3
Change in rate (%)	−10.5	−17.9	+172.0	−27.8
CAUTI (cases per 1000 catheter-days)				
Pre-intervention phase	4.2	1.2	1.8	4.0
Intervention phase	4.5	0.9	3.6	4.2
Change in rate (%)	+7.1	−25.0	+100.0	+5.0

infection control approach to prevent CLABSI was associated with a significantly reduced CLABSI rate of 73% (relative risk, 0.27; 95% CI, 0.14–0.52; $p = 0.002$).[20] In New Zealand, the CLABSI rate decreased from 3.32 per 1000 catheter-days at baseline to 0.28 per 1000 catheter-days after implementing IHI care bundles for catheter insertion and maintenance.[21] In Kuwait, the CLABSI rate decreased from 14.9 per 1000 catheter-days at baseline to 11.08 per 1000 catheter-days after introducing the central-line insertion bundle.[22] In India, the CLABSI rate declined from 6.4 per 1000 catheter-days at baseline to 3.9 per 1000 catheter-days, for a 53% reduction after implementing bundle care.[23] These examples indicate the positive impact of the central-line bundle on preventing CLABSI in ICUs.

In this study, the CLABSI rate was reduced to zero in one ICU in a district hospital after introducing bundle care. This finding should inspire the entire team involved, as zero CLABSI is approachable and has been demonstrated in several studies.[24–26] Moreover, long-term sustainability of zero CLABSI is possible, if the compliance to all care bundle elements can be maintained.[24,25] Zero CLABSI has been maintained for >600 days in a neonatal ICUs and for 38 months in a mixed adult ICU.[24,25] Although CLABSI was reduced after implementing bundle care in most ICUs in this study, more effort is needed to reach the target of zero CLABSI.

Although the CLABSI rate significantly decreased after implementing a central line bundle in the hospitals, we found this trend in medical and mixed ICUs. In surgical ICUs, the CLABSI rate did not change after introducing bundle care (4.80 per 1000 catheter-days *vs*. 4.70 per 1000 catheter-days, $p = 0.59$). Despite the causes may be multifactorial, this indicates that the bundle care's effect differs among units. Further study is needed to determine specific causes of bundle care ineffectiveness for each unit. After repeated "Plan-Do-Check-Act" cycles, the quality of on-site care may improve with appropriate bundle care.

Because implementing central-line bundle care in ICUs would increase the ICU team's workload, especially for critical care nurses, we had concerns that this increased workload would reduce the care for ventilators or indwelling urinary catheters, thus leading to an increase of other healthcare-associated infections (HCAIs) such as VAP and CAUTI. However, we found no significant changes the rates of BSIs, VAP, and CAUTIs after implementing the central-line bundle in this study, as noted previously.[27] In a neurosurgery ICU, after implementing the CAUTI bundle, the CAUTI rate, as well as the rates of CLABSI, VAP, and HCAIs declined simultaneously. It is likely that the team members better understood the importance of infection control practices HCAIs after introducing the bundle care and continuing education. Thus, despite the increased workload, the HCAI rates were not affected.

To assess the process quality, we measured the compliance of several major components of bundle care. Compliance rates for the optimal catheter insertion site were the lowest, only 57.6%. This was consistent with one previous study,[17] in which compliance with the central-line insertion bundle was lowest for optimal site selection (62.2%). Moreover, we evaluated the reasons for femoral vein insertions, and most were rational. Followed by optimal site selection, hand hygiene had the compliance rate of 86.2%. Hand hygiene is an essential component of all infection control measures; therefore, low compliance is inexcusable during the multidimensional infection control process. Based on this surveillance, more effort is needed to improve hand hygiene compliance in Taiwan.

In this study, like other studies in Taiwan,[7,17] medical costs saved after the implementation of CLABSI bundle care was not assessed, but the favorable economic outcomes related to CLABSI bundle care have been well demonstrated by previous studies.[2–4] In this national project, we implemented similar components of CLABSI bundle care as most studies and can effectively reduce CLABSI rates. Therefore, bundle care in this study could be presumed to be cost-effective. Further investigations are warranted to analyze the cost-effectiveness of this bundle care in Taiwan.

In conclusion, the national pilot project involving 27 ICUs at 14 hospitals of various levels found that the CLABSI rate declined by 12.2% after implementing multidimensional bundle care.

Acknowledgement

This study was supported by a grant provided by the Centers for Diseases Control of Taiwan (MOHW104-CDC-C-114-112402).

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