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Major Article

A hospital-wide reduction in central line–associated bloodstream infections through systematic quality improvement initiative and multidisciplinary teamwork

Jingjing Han MM [a], Jun Wan MD [b], Yujia Cheng MB [a], Dan Li MD [c], Min Deng MD [d], Xuefen Wang MM [e], Jiarui Feng MM [f], Yuhong He MM [a], Qing Ye MD [a], Li Wang MM [a], Yourong Lei MB [a], Jianmiao Wang MD [g,*]

[a] Department of Infection Control, Renmin Hospital of Wuhan University, Wuhan, China
[b] Department of Cardiology Medicine, Renmin Hospital of Wuhan University, Wuhan, China
[c] Department of Pharmacy, Renmin Hospital of Wuhan University, Wuhan, China
[d] Department of Infection Control, Xiehe Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China
[e] Department of Nursing, Renmin Hospital of Wuhan University, Wuhan, China
[f] Department of Medicine, Renmin Hospital of Wuhan University, Wuhan, China
[g] Department of Infection Control, Department of Respiratory Medicine, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

Key Words:
Central venous catheter
Infection control program
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Background: Few data are available on hospital-wide incidence of central line–associated bloodstream infection (CLABSI) rates in patients with central venous catheter (CVC) in China, where many systemic obstacles holding back evidence-based guidelines implementation exist.

Methods: This study was conducted prospectively in 2 phases. The baseline and intervention phases were performed in a teaching hospital in China, between January 2017 and October 2018. A systematic quality improvement (SQI) and multidisciplinary teamwork (MDT) CLABSI infection control program was introduced in the intervention phase. In the intensive care units (ICUs) and non-ICUs, CLABSIs were continuously monitored, data collected, then analyzed.

Results: After intervention, the CLABSI rate decreased from 2.84-0.56 per 1,000 CVC days in ICUs ($P < .001$), and from 0.82-0.47 per 1,000 CVC days in non-ICUs ($P = .003$). The length of time until CLABSI occurrence increased from 8.72-13.60 days in ICUs ($P = .046$), and from 10.00-12.00 days in non-ICUs ($P = .048$). The number of multidrug-resistant bacteria isolated from CLABSI episodes decreased both in ICUs and in non-ICUs.

Conclusions: The SQI and MDT CLABSI infection control program is effective in reducing hospital-wide CLABSI in patients with CVC, both in ICUs and in non-ICUs.

The Centers for Disease Control and Prevention (CDC) definition of a central venous catheter (CVC) is an intravenous catheter in which the tip terminates in 1 of the great vessels at or close to the heart.[1] With the development of advancing health care, the use of a CVC has become a fundamental part of the management of patients, including hemodynamic monitoring and the delivery of lifesaving treatments such as intravenous fluids, blood products, antibiotics, chemotherapy, hemodialysis, and total parenteral nutrition. However, a central line–associated bloodstream infection (CLABSI) can occur when a CVC is inserted or maintained improperly, and result in significant costs to health systems and society because such infections increase the risk of morbidity and mortality, as well as prolonged hospitalizations.[2] In developing countries, the accurate rate of CLABSI is often underestimated,[3] and only limited data on CLABSI have been reported to date in China.[4] Nearly 90% of catheter-related bloodstream infections are caused by CVCs;[5] however, according to the unpublished data, in our hospital four-fifths of CLABSI events have occurred in CVC patients. Therefore, the prevention of CLABSI related to CVCs is very important.

The CDC and the Society for Healthcare Epidemiology of America have published evidence-based guidelines and procedures about CVC.[6] Previous data from intensive care units (ICUs) have concluded that CLABSIs are preventable with adherence to evidence-based practices and infection prevention bundles.[7,8] Between 2008 and

* Address correspondence to Jianmiao Wang, MD, Department of Infection Control, Department of Respiratory Medicine, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, 430030, China.
E-mail address: 894069719@qq.com (J. Wang).
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2013, CLABSI rates have decreased by 46% across the United States, the dramatic decrease of which was attributed to large-scale projects that focused on implementing best practices to reduce CLABSI in ICUs.[9] However, a recent study in China showed that the CLABSI rate was 7.66 per 1,000 CVC days in 7 ICUs in 4 hospitals,[10] which is similar to the pooled rate of 6.8 per 1,000 CVC days in ICUs from developing countries, described in the last International Nosocomial Infection Control Consortium report,[11] but more than 3-fold higher than the 1.65 per 1,000 CVC days in ICUs, which is comparable to the US ICUs described in the National Health Safety Network (NHSN) report.[12] Therefore, the CLABSI rates in China and other developing countries are still a prominent issue. In addition, many of these studies focused on CVC-related infections only in ICUs. Although a large number of non-ICU patients are known to have CLABSI,[12] adequate research has not yet been conducted on non-ICU patients.

The evidence-based practices for preventing CLABSI are often not optimistic in China. The high rate of CLABSI reported in these Chinese ICUs, as in other middle income countries, might be related to low compliance of use of sterile drape to cover patients from head-to-toe and the use of >0.5% chlorhexidine for skin preparation at CVC insertion, although dressings are changed more often than recommended and assessment on the need of the CVC is not always conducted on a daily basis during maintenance.[13] The clinical, infection control, medical, nursing, and equipment departments are involved in CVC management. Multidisciplinary teamwork (MDT) and CVC management hospital policies are necessary to promote different departments in their various roles in preventing CLABSI. In the present study, we focused on the systemic barriers of implementing CLABSI prevention efforts, established a systematic quality improvement (SQI) and MDT infection control program, and evaluated its effect on the incidence of CLABSI in patients with CVC, both in ICUs and in non-ICUs in our hospital.

METHODS

Study setting and subjects

This study was conducted prospectively between January 2017 and October 2018 at Renmin Hospital of Wuhan University, which is a general teaching hospital with a capacity of 3,500 beds located in Wuhan, China. Annually, the total number of inpatients exceeds 160,000, and more than 80,000 surgeries are performed in this hospital. The patients in this study were new admissions to the hospital who had undergone CVC insertion between January 1, 2017, and October 31, 2018, including general ward, emergency room, operating room, and ICUs. The ICUs contain 97 beds in total, including cardiothoracic ICU (12 beds), medical ICU (45 beds), and surgical ICU (40 beds). No newborns in our hospital had undergone CVC insertion. The participating ICUs admit patients according to the type of care needed, regardless of age. The patients were recruited consecutively and followed up until death or discharged.

Study design and intervention

This 22-month study was conducted in 2 phases: the baseline phase (January 1, 2017, to October 31, 2017) and the intervention phase (November 1, 2017, to October 31, 2018). Continuous prospective surveillance of CLABSI was performed throughout the entire period. The ethics committee of our hospital approved the study protocol. Because the intervention and data collection were performed as a quality improvement study, informed consent was waived by the ethics committee of our hospital.

During the baseline phase, the infection control practitioners (ICPs) did not mandate that medical staff adhere to the CVC evidence-based guidelines. Compliance with CVC insertion and maintenance bundles by various practitioners was variable and seldom completed. Formal and activated CVC monitoring and education were not performed to prevent CLABSI.

In late 2017, with engagement of senior executive leadership, a CLABSI multidisciplinary team chaired by the vice president was established, including ICPs, anesthesia department and ICU physicians, infectious disease specialists, epidemiology staff, heads of the departments of medicine, nursing, equipment, central sterile supply, information technology, and microbiology. This SQI and MDT infection control program involved implementing evidence-based interventions or best practices designed to reduce CLABSI. As stipulated, team members participated in monthly meetings to evaluate progress with compliance, difficulties and successes, and to reinforce the interventions.[14]

The following 6 guidelines were addressed:

(1) Develop written hospital policies regarding CVC management and standard operating procedure of CVC insertion, maintenance, and care by MDT, including the responsibilities of different involved management departments; the standardized room for insertion, indications, and contraindications for CVC placement; proper procedures for insertion and maintenance; effective hand hygiene; and aseptic technique during catheter insertion and care.

(2) Establish a dedicated CVC team for our hospital. The CVC team was responsible for early identification of candidates in need of CVC insertion and maintenance, promoting best practice and minimizing variability in technique. Only credentialed medical staff were allowed to operate and assessed periodically. Clinical departments that had no credentialed member of CVC insertion could have insertion performed through consultation. Departments that frequently used CVC should have >1 nurse credentialed to maintain CVC through training.

(3) Use carts with all supplies for CVC insertions and an all-inclusive maintenance package. All of the items of maximal sterile barrier precautions, including full-body drape and sterile gown should be included in the carts for CVC insertions. The CVC MDT entered a contract with the CVC insertion packs providers in our hospital to change the small sterile drapes to the full-size sterile drapes (120 × 200 cm). The central sterile supply department was required to provide all-inclusive CVC maintenance package for the whole hospital. The CVC brands and access ports and connectors were the same during the study phases.

(4) Enhance hand hygiene practices. Hand hygiene before CVC insertion and manipulation were emphasized, particularly for the dedicated CVC team. We provided antiseptic foam (water not required) near the entrance of every room door in each clinical department and beside each bed in the ICUs to enable staff, patients, and visitors to disinfect their hands easily. We provided antiseptic foam on each cart used for CVC insertion, maintenance, or treatment. Hand rub on the cart was available at the point of care outside of the ICU. Hand hygiene monitoring had been performed according to the World Health Organization (WHO) "Five Moments for Hand Hygiene."[15]

(5) Educate. We developed a formal and active education program involved in insertion, care, and maintenance of CVC to prevent CLABSI. All CVC team members should receive quarterly reeducation organized by MDT, and attendance at these sessions was mandatory. The teaching strategy was in the form of a

combination of instructor-led courses and discussions through photo slides showing proper procedures and mistakes.

(6) Surveillance, evaluate, and feedback. Surveillance for CLABSI conducted by trained ICPs was implemented in ICUs and non-ICUs. The standard surveillance methods of the NHSN were used.[16] Key process measure audits were performed weekly through paper-based standard checklist by ICPs, the director, head nurse, and ICPs. Recent outcomes and quality improvement efforts were reviewed and reassessed monthly by the MDT, and feedback to all health care staff.

CLABSI definitions and microbial identification

The CDC/NHSN definitions are used to define CLABSI, excluding infections already present on admission and secondary bloodstream infection.[17] CLABSI is defined as a bloodstream infection (ie, a pathogen identified in a blood culture) in a patient who has a CVC at the time of or within 48 hours prior to the positive blood culture, in the absence of infection at another site. Mucosal barrier injury laboratory-confirmed bloodstream infections were excluded from the analyses, because the mechanisms responsible for them, such as translocation of gastrointestinal organisms, are different. Bacteria were cultured using standard microbiological methods. They were identified by conventional methods according to the Kirby-Bauer disk diffusion technique and the VITEK 2 system (bioMérieux, Marcy, l'Etoile, France). The results of antibiotic susceptibility testing for the isolated microbes causing CLABSI were interpreted according to the recommendations of the Clinical Laboratory Standard Institute.[18] A primary laboratory-confirmed bloodstream infection was defined as (1) a patient with a recognized pathogen (*Staphylococcus aureus*, *Enterococcus* spp, *Escherichia coli*, *Pseudomonas* spp, *Klebsiella* spp, *Candida* spp, and others) cultured from ≥1 blood culture, in which the organism cultured was not related to an infection at another site; or (2) a patient found to have at least 1 of the following signs or symptoms: fever (>38°C), chills, or hypotension and signs and symptoms and positive laboratory results were not related to an infection at another site and the same common commensal was cultured from ≥2 blood cultures drawn on separate occasions. Criterion elements must occur within a time frame that does not exceed a gap of 1 calendar day between 2 adjacent elements. Given that a patient could develop >1 CLABSI episode, a new episode was defined by the isolation of a different microorganism from subsequent blood cultures. Multidrug resistance was defined as no susceptibility to at least 1 antimicrobial agent in ≥3 drug classes.[19]

Data collection

We introduced a real-time nosocomial infection monitoring system that captured laboratory data, CLABSI events, and CVC characteristics, including: the number of times a patient received a CVC during a hospital stay, the location of the insertion, type of organism and antimicrobial susceptibility, and the duration of CVC retention. In ICUs, disease severity was measured according to the acute physiology and chronic health evaluation II score. In the CDC methodology, CVC days were calculated for each day that a patient had ≥1 CVCs in place. During both phases, the surveillance was conducted by the same ICPs adhering to CDC/NHSN. Collection methods for all data elements were the same for all periods of study and analysis. To reduce subjective bias, all of the attending ICPs had >2 years IPC experience and received standardized training about CLABSI and this program before our study started. Monthly CLABSI rates were reported as number of CLABSI events per 1,000 CVC days. The CVC utilization ratio was calculated by dividing CVC days by total patient days.[13] In addition, at least 2 ICPs and 2 physicians together checked every CLABSI case submitted to ensure data quality. All data collection sheets were reviewed by a trained research physician for potential errors. The staff responsible for data collection and analysis were blinded to the infection control program.

Data analysis

All of the experimental data were analyzed using the SPSS program (version 18.0; SPSS, Inc, Chicago, IL). Continuous variables were described as mean ± SD or median (interquartile range) as appropriate. Categorical data are presented as counts and percentage. Univariate tests of significance used an independent Student t test for normally distributed continuous data, the Mann-Whitney U test for non-normally distributed continuous data, and the X^2 test or the Fisher exact test for categorical data, in which analysis assumptions were met. The CLABSI rates were calculated by dividing the number of CLABSI pooled over the study period by 1,000 CVC days. Comparisons in incidence were drawn between before and after intervention using the unadjusted incidence relative risk (RR) ratios, which is defined as the ratio of events per defined period of time. All tests were 2-sided, and *P* values <.05 were considered significant.

Results

General characteristics of subjects and CVC insertion

The general characteristics of the subjects during the baseline and intervention phases are shown in Table 1. In ICUs, there were 661 and 945 patients in the baseline and intervention phases, respectively. In non-ICUs, there were 6,827 and 9,409 patients in the baseline and intervention phases, respectively. There were no significant differences in sex, age, the number of times a patient received a CVC, and insertion place of a CVC between the baseline and intervention phases, either in ICUs or in non-ICUs. In ICUs, there was no significant difference in the acute physiology and chronic health evaluation II score between the baseline and intervention phases. There was no significant change in the proportion of retention days of CVC >7 days in ICUs between the baseline and intervention phases, whereas the proportion of retention days of CVC >7 days was decreased in non-ICUs after intervention (*P* = .04).

CLABSI

CLABSI incidence. The incidence of CLABSI during the baseline and intervention phases is shown in Table 2 and Figure 1. During the baseline phase, a total of 86 CLABSI events occurred, of which 68 (79.07%) were in non-ICUs. In ICUs, the CLABSI rate decreased from 2.84-0.56 per 1,000 CVC days after intervention (RR, 0.20; 95% confidence interval [CI], 0.07-0.53; *P* < .001), and sustained a rate of 0 infections for 6 months. In non-ICUs, the CLABSI rate decreased from 0.82-0.47 per 1,000 CVC days after intervention (RR, 0.57; 95% CI, 0.39-0.83; *P* = .003).

CVC utilization ratio. In ICUs, the CVC utilization ratio was similar before and after intervention (*P* = .191). In non-ICUs, the CVC utilization ratio decreased from 0.092-0.083 after intervention (*P* < .001). There was no significant decrease in the CVC retention days in ICUs (*P* = .920), whereas the CVC retention days in non-ICUs decreased from 12.01-10.22 days (*P* < .001) after intervention.

Length of time until CLABSI occurrence. After intervention, the length of time until CLABSI occurrence increased from 8.72-13.60 days in ICUs (*P* = .046), and increased from 10.00-12.00 days in non-ICUs (*P* = .048).

Table 1
General characteristic of study subjects during the baseline and intervention phases

Characteristics	Patients in ICUs			Patients in non-ICUs		
	Baseline (n = 661)	Intervention (n = 945)	*P* value	Baseline (n = 6,827)	Intervention (n = 9,409)	*P* value
Male, %	393 (59.46)	601 (63.60)	.09	3,579 (52.42)	4,978 (52.91)	.54
Age (y)	62.61 ± 17.57	62.46 ± 16.54	.85	57.14 ± 17.57	57.09 ± 16.42	.98
No. of times a patient received a CVC						
1	507 (76.70)	705 (74.60)	.57	5,157 (75.54)	7,081 (75.26)	.91
2	89 (13.46)	144 (15.24)	—	1,235 (18.09)	1,716 (18.24)	—
≥3	65 (9.83)	96 (10.16)	—	435 (6.37)	612 (6.50)	—
Insertion place of CVC						
OR	162 (17.84)	221 (17.13)	.81	4,944 (55.10)	6,836 (54.38)	.54
ICU	706 (77.75)	1,006 (77.98)	—	614 (6.84)	890 (7.08)	—
Others	40 (4.40)	63 (4.88)	—	3,415 (38.06)	4,845 (38.54)	—
Retention of CVC (d)						
≤7	569 (62.66)	824 (63.88)	.56	3,596 (40.08)	5,213 (41.47)	.04
>7	339 (37.33)	466 (36.12)	—	5,377 (59.92)	7,358 (58.53)	—
APACHE II at insertion	14.90 ± 5.58	15.14 ± 6.42	.82			—

APACHE II, acute physiology and chronic health evaluation II score; *CVC*, central venous catheter; *ICUs*, intensive care units; *OR*, operating room.

Pathogens that cause CLABSI. Table 3 shows the pathogens responsible for the CLABSI events in this study. Almost all of the infection episodes involved only 1 pathogen, and only 1 episode with 2 pathogens in ICUs was identified. In ICUs, 19 pathogens were identified during the baseline phase; 47.37% of the identified microorganisms were gram-negative bacteria (mainly *Acinetobacter* spp), whereas 26.32% were gram-positive bacteria (mainly *Staphylococcus* spp) and 26.32% were fungi (mainly *Candida* spp). After intervention, only 5 pathogens were identified in ICUs, including 1 *S aureus*, 1 *Acinetobacter baumannii*, 1 *Candida parapsilosis,* and 2 *Candida albicans*. In non-ICUs, 68 pathogens were identified during the baseline phase; 52.94% of the identified microorganisms were gram-positive bacteria (mainly *Staphylococcus* spp), and whereas 35.29% were gram-negative bacteria (mainly *Acinetobacter* spp and *Klebsiella* spp) and 11.76% were fungi (mainly *Candida* spp). After intervention, only 45 pathogens were identified in non-ICUs; 44.44% of the identified microorganisms were gram-negative bacteria (mainly *Klebsiella* spp), whereas 33.33% were gram-positive bacteria (mainly *Staphylococcus* spp), and 22.22% were fungi (mainly *Candida* spp). In ICUs, a total of 12 and 2 multidrug-resistant bacteria were identified in the baseline and intervention phases, respectively, and carbapenem-resistant *Acinetobacter baumannii* (CRAB) were identified as the dominant multidrug-resistant bacteria. In non-ICUs, a total of 28 and 16 multidrug-resistant bacteria were identified in the baseline and intervention phases, respectively, and methicillin-resistant *staphylococcus aureus* (MRSA) and meticillin-resistant coagulase-negative *Staphylococcus* spp were identified as the dominant multidrug-resistant bacteria. After intervention, there was a significant decrease in the occurrence of CLABSI caused by multidrug-resistant bacteria, both in ICUs (RR, 0.118; 95% CI, 0.027-0.529; *P* =.001) and in non-ICUs (RR, 0.494; 95% CI, 0.267-0.912; *P* =.021).

DISCUSSION

In China, CLABSI still poses a huge and largely under-recognized threat to patient safety.[10] In the previous studies, most surveillance and intervention have focused on CLABSI in ICUs.[9] Recent data suggest non-ICUs have CVC utilization rates that are considerably lower than those of ICUs, but CLABSI rates are similar to those in ICUs.[20] In our study, we found that about four-fifths of CLABSI events occurred in non-ICUs, although the incidence of CLABSI in ICUs was higher than that found in non-ICUs. To reduce the occurrence of CLABSI in our hospital, we need to pay attention to that in both ICUs and non-ICUs.

A study suggested that strategies for reducing CLABSI in non-ICUs should be different from ICUs because of less-frequent insertion of CVC in non-ICUs.[9] With the development of advancing health care and the aging of the population, dialysis and the elderly, and critically ill patients, CVC insertion is very common in non-ICUs. We believe that CVC insertion in non-ICUs should not be ignored when

Table 2
CLABSI during the baseline and intervention phases

Characteristics	In ICUs				In non-ICUs			
	Baseline	Intervention	RR (95% CI)	*P* value	Baseline	Intervention	RR (95% CI)	*P* value
No. of patients	1,953	2,410	—	—	92,332	118,744	—	—
No. of CVC patients	661	945	—	—	6,827	9,409	—	—
No. of CVC insertions	908	1,290	—	—	8,973	12,571	—	—
No. of patients d	16,870	23,196	—	—	906,146	114,9812	—	—
No. of CVC d	6,326	8,901	—	—	82,924	95,980	—	—
No. of CLABSI	18	5	—	—	68	45	—	—
CLABSI rate (per 1,000 CVC d)	2.84	0.56	0.20 (0.07 - 0.53)	<.001	0.82	0.47	0.57 (0.39 - 0.83)	.003
CVC utilization ratio (CVC d / patient d)	0.37 ± 0.01	0.37 ± 0.02		.191	0.092 (0.090 - 0.092)	0.083 (0.082 - 0.084)		<.001
Retention of CVC (d)	9.41 ± 8.12	9.32 ± 7.24		.920	12.01 ± 10.32	10.22 ± 9.32		<.001
Length of time until CLABSI occurrence	8.72± 4.20	13.60± 5.86		.046	10.00 (6.00 - 12.00)	12.00 (8.00 - 15.00)		.048

CI, confidence interval; *CLABSI*, central line–associated bloodstream infection; *CVC*, central venous catheter; *ICUs*, intensive care units; *RR*, relative risk.

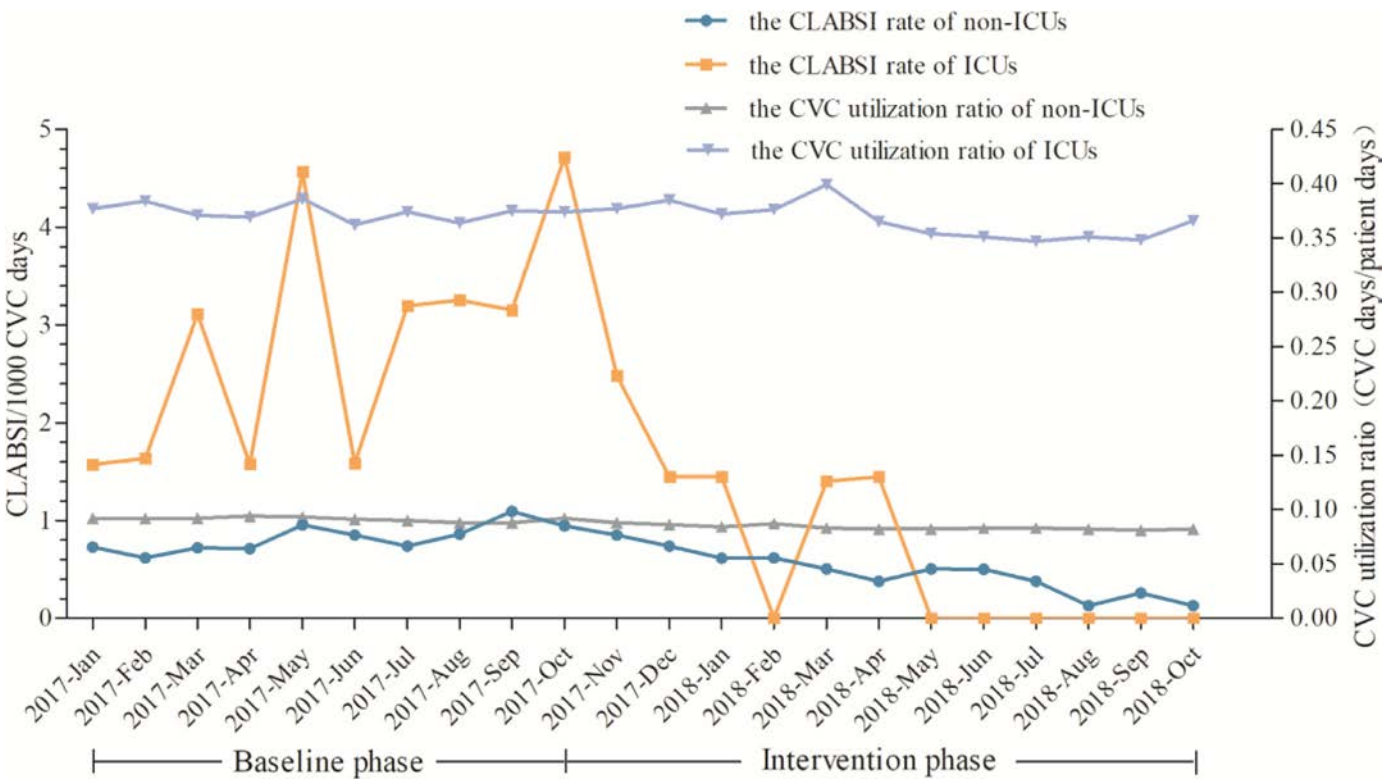

Fig 1. The CLABSI rate and the CVC utilization ratio in ICUs and non-ICUs during the baseline and intervention phases. *CLABSI*, central line–associated bloodstream infection; *CVC*, central venous catheter; *ICUs*, intensive care units.

implementing infection control and broader quality improvement initiatives. A previous study suggested that a reduction of hospital-wide CLABSI was reached with a comprehensive, multidisciplinary, and multimodal quality improvement program, including aspects of behavioral change and key principles of good implementation practice in a developed country.[21]

During the baseline phase, the CLABSI rate was 2.84 per 1,000 CVC days in ICUs, which was higher than that reported by the NHSN;[22] however, it was lower than that reported in the investigation from China.[10] In non-ICUs, the CLABSI rate was 0.82 per 1,000 CVC days, which was similar to the rate reported by the NHSN.[22] It should be considered that the bacterial examination rate of blood

Table 3
Microorganisms isolated from CVC patients with a CLABSI, before and after intervention

	In ICUs		In non-ICUs	
Classification	Baseline (n,%)	Intervention (n,%)	Baseline (n,%)	Intervention (n,%)
Pathogenic microorganisms	19	5	68	45
Gram-positive bacteria	5 (26.32)	1 (20.00)	36 (52.94)	15 (33.33)
Staphylococcus spp	4	1	27	12
Enterococcus spp	1	0	8	2
Streptococcus spp	0	0	1	1
Gram-negative bacteria	9 (47.37)	1 (20.00)	24 (35.29)	20 (44.44)
Acinetobacter spp	5	1	7	4
Enterobacter spp	1	0	3	4
Escherichia spp	0	0	5	3
Pseudomonas spp	1	0	2	1
Klebsiella spp	2	0	6	7
Serratia spp	0	0	1	1
Fungi	5 (26.32)	3 (60.00)	8 (11.76)	10 (22.22)
Candida spp	5	3	8	10
Multidrug-resistant bacteria	12	2	28	16
CRAB	5	1	5	2
MRSA	1	0	10	4
CRPA	1	0	0	1
CRE	1	0	3	4
Others	4	1	10	5

CRAB, carbapenem-resistant *Acinetobacter baumannii*; *CRE*, carbapenem-resistant *Enterobacteriaceae*; *CRPA*, carbapenem-resistant *Pseudomonas aeruginosa*; *ICUs*, intensive care units; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *Others*, ESBL-producing organisms, meticillin-resistant coagulase-negative *Staphylococcus* spp, and so on.

and catheter tips specimens may be relatively low, resulting in under registration of CLABSI. Although physicians during the CVC insertion and nurses during the CVC care and maintenance play important roles in implementing evidence-based measures for the prevention of CLABSI, there were some systemic obstacles holding back the implementation in our hospital before this program. The sterile drapes were too small during CVC insertion, and the maintenance package was not standardized. The coordination and communication between relevant departments were not good, and the knowledge and appropriate training were inadequate. Here, we show that the SQI and MDT infection control program dedicated to improving the quality and safety of CVC insertion and maintenance resulted in a significant hospital-wide CLABSI reduction. Considering that the NHSN's CLABSI and site-specific infections surveillance definition changes resulted in a relatively fluctuate in CLABSI rates,[23] we used consistent definitions during the whole research process in this study. After intervention, the incidences of CLABSI in ICUs and non-ICUs were decreased to 0.56 per 1,000 CVC days and 0.47 per 1,000 CVC days, respectively, which were lower than the CLABSI rates reported by the NHSN.[22] Additionally, no CLABSI event was reported in ICUs, from May 2018 to October 2018. The length of time until CLABSI occurrence in ICUs increased from 8.7-13.6 days, which was longer than the 7.5 days reported by Klintworth.[24] The length of time until CLABSI occurrence in non-ICUs increased from 10.0-12.0 days, which was similar to the 13 days reported by Klintworth.[24] The increased length of time until CLABSI occurrence indicated improvement in CLABSI prevention both in ICUs and in non-ICUs. After intervention, CVC retention days in non-ICUs decreased and CVC utilization ratio further decreased, but the retention days and the CVC utilization ratio in ICUs did not change. The reduction of the CVC utilization ratio in non-ICUs may be related to the decrease of CVC retention days. In addition, our study provided evidence that evidence-based guidelines and bundles about CVC are effective for the prevention of CLABSI, and the implementation of evidence-based practices for CVC operation is critical. In the process of moving evidence to practice, including the development of CVC management policy, the management of operational qualification, the establishment of dedicated CVC teams, and the standardization of insertion and maintenance packages, multiple departments are involved. We believe that the SQI and MDT infection control program of CLABSI is a strong guarantee for the success of preventive measures.

It is important to monitor local pathogens and drug sensitivities to better guide antibiotic therapy. In our study, we found that the main pathogens causing CLABSI in our hospital were *Staphylococcus* spp, *Candida* spp, and *Acinetobacter* spp. During the baseline phase, *Acinetobacter* spp was the main pathogen of CLABSI in ICUs, and *Staphylococcus* spp was the main pathogen of CLABSI in non-ICUs. After intervention, the number of pathogenic bacteria isolated from CLABSI episodes, both in ICUs and in non-ICUs, was decreased. In recent years, the proportion of coagulase-negative *Staphylococcus* causing CLABSI has decreased, with a slight increase of *Candida* species,[25] which is consistent with the results in our study. Before intervention, CRAB was the predominant multidrug-resistant bacteria in CLABSI in ICUs, and MRSA was the predominant multidrug-resistant bacteria in non-ICUs. In the present study, the number of multidrug-resistant bacteria isolated from CLABSI episodes was decreased both in ICUs and in non-ICUs after intervention.

There are some limitations in this study. As a quality improvement study, we cannot make a definitive conclusion concerning the effectiveness of a specific intervention, and we believe that several unique interventions in our CLABSI prevention program directly contributed to the success. Because this is a single-center study, the results should be interpreted with caution. In addition, the results may be biased by the relative large proportion of patients with severe illness, since the study was performed in a tertiary care hospital.

To our knowledge, this is the first study to report the intervention of CLABSI, both in ICUs and in non-ICUs in China, with detailed microbiology data, which provides important information for future comparative studies. By carrying out hospital-wide surveillance, we found that substantial numbers of CLABSI events occurred in non-ICUs, showing that surveillance for CLABSIs is necessary in non-ICUs as well as in ICUs.

CONCLUSIONS

The results of our findings highlight the importance of hospital-wide surveillance for CLABSIs. The SQI and MDT infection control program is effective in reducing hospital-wide CLABSI in patients with CVC, both in ICUs and in non-ICUs.

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References

1. Centers for Disease Control and Prevention (CDC). Device-associated module CLABSI. Available from: http://www.cdc.gov/nhsn/pdfs/pscmanual/4psc_clabscurrent.pdf. Accessed April 20, 2015.
2. Calfee DP. Crisis in hospital-acquired, healthcare-associated infections. Annu Rev Med 2012;63:359-71.
3. Rosenthal VD. Healthcare-associated infections in developing countries. Lancet 2011;377:186-8.
4. Ding JG, Sun QF, Li KC, Zheng MH, Miao XH, Ni W, et al. Retrospective analysis of nosocomial infections in the intensive care unit of a tertiary hospital in China during 2003 and 2007. BMC Infect Dis 2009;25:115.
5. Maki DD, Kluger HM, Crnich CJ. The risk of bloodstream infection in adults with different intravascular devices: a systematic review of 200 published prospective studies. Mayo Clin Proc 2006;81:1159-71.
6. Marschall J, Mermel LA, Fakih M, Hadaway L, Kallen A, O'Grady NP, et al. Strategies to prevent central line–associated bloodstream infections in acute care hospitals: 2014 update. Infect Control Hosp 2014;35:753-71.
7. Guerin K, Wagner J, Rains K, Bessesen M. Reduction in central line-associated bloodstream infections by implementation of a post insertion care bundle. Am J Infect Control 2010;38:430-3.
8. Apisarnthanarak A, Thongphubeth K, Yuekyen C, Warren DK, Fraser VJ. Effectiveness of a catheter-associated bloodstream infection bundle in a Thai tertiary care center: a 3-year study. Am J Infect Control 2010;38:449-55.
9. Centers for Disease Control and Prevention. National and state healthcare associated infections progress report. Available from: http://www.cdc.gov/HAI/pdfs/progressreport/hai-progress-report.pdf. Accessed November 10, 2015.
10. Bijie H, Lili T, Rosenthal VD, Liu K, Yun Y, Yao S, et al. Device-associated infection rates, device use, length of stay, and mortality in intensive care units of 4 Chinese hospitals: International Nosocomial Control Consortium findings. American J Infect Control 2013;41:301-6.
11. Rosenthal VD, Bijie H, Maki DG, Mehta Y, Apisarnthanarak A, Medeiros EA, et al. International Nosocomial Infection Control Consortium report, data summary of 36 countries, for 2004-2009. Am J Infect Control 2011;40:396-407.
12. Centers for Disease Control and Prevention. Vital signs: central line–associated blood stream infections—United States, 2001, 2008, and 2009. Ann Emerg Med 2011;58:447-50.
13. Valencia C, Hammami N, Agodi A, Lepape A, Herrejon EP, Blot S, et al. Poor adherence to guidelines for preventing central line-associated bloodstream infections (CLABSI): results of a worldwide survey. Antimicrob Resist Infect Control 2016;5:49.
14. Yokoe DS, Anderson DJ, Berenholtz SM, Calfee DP, Dubberke ER, Ellingson KD, et al. A compendium of strategies to prevent healthcare-associated infections in acute care hospitals: 2014 updates. Am J Infect Control 2014;42:820-8.
15. Sax H, Allegranzi B, Chraiti MN, Boyce J, Larson E, Pittet D. The World Health Organization hand hygiene observation method. Am J Infect Control 2009;37:827-34.
16. Centers for Disease Control and Prevention. CDC/NHSN surveillance definitions for specific types of infections. Available from: http://www.cdc.gov/nhsn/pdfs/pscmanual/17pscnosinfdef_current.pdf. Accessed February 5, 2014.
17. Centers for Disease Control and Prevention (CDC). CDC/NHSN surveillance definitions for specific types of infections. Available from: http://www.cdc.gov/nhsn/PDFs/pscManual/17pscNosInfDef_current.pdf. Accessed May 25, 2016.
18. Clinical and Laboratory Standards Institute (CLSI). Performance standards for antimicrobial susceptibility testing. Wayne (PA): CLSI; 2015, M100-S25.

19. Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, et al. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. Clin Microbiol Infect 2012;18:268-81.
20. Marschall J, Leone C, Jones M, Nihill D, Fraser VJ, Warren DK. Catheter-associated bloodstream infections in general medical patients outside the intensive care unit: a surveillance study. Infect Control Hosp Epidemiol 2007;28:905-9.
21. Marra AR, Cal RG, Durao MS, Correa L, Guastelli LR, MouraJr DF, 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.
22. Dudeck MA, Edwards JR, Allen-Bridson K, Gross C, Malpiedi PJ, Peterson KD, et al. National Healthcare Safety Network Report, data summary for 2013, device-associated module. Am J Infect Control 2015;43:206-21.
23. Corley A, Cantara M, Gardner J, Trexler P, Rock C, Maragakis LL. Central line–associated bloodstream infection rate elevation: attributable to National Healthcare Safety Network surveillance definition changes, ongoing opportunities for infection prevention, or both? Am J Infect Control 2017;45:1030-2.
24. Klintworth G, Stafford J, O'Connor M, Leong T, Hamley L, Watson K, et al. Beyond the intensive care unit bundle: implementation of a successful hospital-wide initiative to reduce central line-associated bloodstream infections. Am J Infect Control 2014;42:685-7.
25. Sievert DM, Ricks P, Edwards JR, Schneider A, Patel J, Srinivasan A, et al. Antimicrobial-resistant pathogens associated with healthcare-associated infections: summary of data reported to the national healthcare safety network at the centers for disease control and prevention, 2009-2010. Infect Control Hosp Epidemiol 2013;34:1-14.