



ORIGINAL ARTICLE

## Decreasing catheter-related bloodstream infections in the intensive care unit: Interventions in a medical center in central Taiwan

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### KEYWORDS

Catheter-related bloodstream infection;  
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Maximal sterile barrier precautions

**Background:** A high catheter-related bloodstream infection (CRBSI) rate, in comparison with that in the National Healthcare Safety Network report, is an important concern in our hospital. Therefore, evidence-based interventions have been introduced to reduce the rate of CRBSI. **Methods:** A surveillance study conducted from March 2008 to May 2010 to observe the reduction of infection rate after interventions in two intensive care units (ICUs). The major intervention, introduced in November 2009, was the standardization of the process of central venous catheter (CVC) implantation, including hand hygiene and maximal sterile barrier precautions. **Results:** The utilization ratios of CVC changed little during the study. The median CRBSI infection rates decreased from 1.95 (mean 1.58) infections per 1000 catheter-days at baseline to 0 (mean 1.06) after interventions ( $p = 0.310$  by the Wilcoxon signed ranks test). The rate of CRBSI in one ICU showed 0 infections per 1000 catheter-days, which was sustained for 6 months after interventions.

**Conclusion:** The reduction of infection rates could be possible by standardizing the CVC implantation procedure. However, more interventions, such as cleaning the skin with chlorhexidine, avoiding the femoral site when possible, and removing unnecessary catheters, should also be considered to reduce the rate of CRBSI.

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## Introduction

Catheter-related bloodstream infections (CRBSIs) are prevalent and often fatal, and incur extra hospital cost.<sup>1</sup> According to the National Nosocomial Infections Surveillance (NNIS) system and Centers for Disease Control and Prevention (CDC) report, the median rate of CRBSI in intensive care units (ICUs) ranges from 1.8 to 5.2 per 1000 catheter-days.<sup>1–3</sup> The National Healthcare Safety Network (NHSN) report showed that the 50<sup>th</sup> and 90<sup>th</sup> percentiles of mean CRBSI rate in medical ICUs are 1.0 and 4.3 per 1000 catheter-days, respectively.<sup>4</sup> The Taiwan Nosocomial Infections Surveillance System (TNIS) report in 2009 showed that the 50<sup>th</sup> and 90<sup>th</sup> percentiles of mean CRBSI rate in medical ICUs were 5.8 and 11.2 per 1000 catheter-days in medical centers, and 3.7 and 8.9 per 1000 catheter-days in regional hospitals.<sup>5</sup> In the Changhua Christian Hospital, we have monitored the rates of CRBSI since March 2008. Our surveillance data from March 2008 to October 2009 showed that the infection rate was high (mean 1.8 per 1000 catheter-days). This is therefore an important issue in our hospital.

A prospective study supported the use of maximal sterile barrier precautions and antimicrobial-coated catheters in reducing the risk of CRBSI, and these two interventions had an independent and significant association with a decrease in the risk of catheter infections.<sup>6</sup> In addition, several large-scale studies support the observation that evidence-based interventions can reduce the rate of CRBSI.<sup>1,7,8</sup> The strategies for prevention of CRBSI include hand washing, using full-barrier precautions, cleaning the skin with chlorhexidine, catheter site selection (avoiding the femoral site), and removing unnecessary catheters.<sup>1,4,7–9</sup> We introduced evidence-based interventions to develop a modified standard procedure of central venous catheter (CVC) implantation in our hospital to reduce the rate of CRBSI.

## Materials and methods

### Hospital setting

Changhua Christian Hospital is a medical center in central Taiwan with a total of 1700 beds, including 2 medical ICUs. In total there are 55 ICU beds: 29 in ICU1 and 26 in ICU2 (including 8 coronary care unit beds in ICU2).

### Definitions

Infections were categorized using the CDC/NHSN standard definitions that include laboratory and clinical criteria.<sup>10</sup> The blood and tip cultures were collected according to clinical criteria, such as sudden onset fever and insertion site wound infection. The definition of definite CRBSI is the same microorganism in both blood and tip cultures. The CVC utilization ratio is calculated as (number of device-days/number of patient-days) × 100%, and the rate of CRBSI as (number of CRBSIs/number of device-days) × 1000‰.

## Surveillance

Since March 2008 the numbers of patient-days, device-days, and CRBSIs have been collected monthly from the infection-control practitioner. A surveillance study was conducted from March 2008 to May 2010 to observe the reduction of infection rate after interventions in ICU1 and ICU2. Interventions were introduced in November 2009.

## Interventions

The strategies for prevention of catheter-related infections have been reviewed.<sup>1,2,7–9</sup> Four of the five recommendations for prevention of CRBSI are associated with catheter insertion. Because use of skin antiseptic agent with chlorhexidine was not yet approved in Taiwan when the study began, and the catheter site selection (avoiding the femoral site) should be determined by clinical physicians, a modified standard procedure of CVC implantation was developed in the hospital. This includes hand hygiene with chlorhexidine gluconate agent and maximal sterile barrier precautions (e.g., cap, surgical mask, sterile gown, sterile gloves, and full body sterile drape, similar to the drapes used in the operating room).<sup>11</sup> When the study began, 10% povidone-iodine alcoholic solution and 70% alcohol were used for skin preparation. In addition, the same antiseptic agents were used for skin disinfection after catheter insertion and transparent medical dressing was used to cover catheter insertion sites. Educational programs were arranged in November 2009 for the staff in medical ICUs, including attending physicians, chief residents, and nurse practitioners.

Other interventions were introduced gradually into the hospital after this study period, such as education of insertion site selection, skin antiseptic agent with chlorhexidine, catheter site dressing regimens with chlorhexidine, and bedside ultrasound for the placement of CVCs.

## Statistical analysis

A paired difference test was used to compare the difference after intervention, which derived data from December 2008 to May 2009 and December 2009 to May 2010. Because the CRBSI data followed a nonnormal distribution, the *p*-values were based on Wilcoxon signed ranks test. In addition, Poisson regression model was used to analyze the relative risk (RR) of the rate of catheter related bloodstream infection after interventions.

## Results

The surveillance data from March 2008 to May 2010 are summarized in Table 1. The trends of the utilization ratios of CVC and the rate of CRBSI are shown in Figs. 1 and 2.

The overall median utilization ratios of CVC before (March 2008 to October 2009) and after (December 2009 to May 2010) interventions were 56.3% (mean 57.6%) and 57.1%

**Table 1** The surveillance data from March 2008 to May 2010

Year	Month	ICU1		ICU2		Overall		
		Utilization ratios(%)	Infection rates(‰)	Utilization ratios(%)	Infection rates(‰)	Utilization ratios(%)	Infection rates(‰)	
2008	03	81.8	0.0	66.1	0.0	74.3	0.0	
	04	75.9	6.5	48.3	0.0	62.6	4.1	
	05	76.7	7.8	52.2	2.5	65.0	5.7	
	06	63.2	2.0	45.0	3.1	54.6	2.4	
	07	62.2	1.9	49.7	0.0	56.3	1.1	
	08	61.9	3.8	47.7	0.0	55.2	2.2	
	09	61.6	2.0	48.4	0.0	55.2	1.2	
	10	55.2	2.2	47.5	0.0	51.5	1.2	
	11	59.7	0.0	51.0	0.0	55.0	0.0	
	12	63.2	3.7	53.3	2.5	58.5	3.2	
	2009	01	54.4	2.1	56.4	0.0	55.4	1.1
		02	56.8	2.2	63.0	0.0	59.7	1.1
03		56.9	4.2	52.5	0.0	54.9	2.3	
04		51.8	0.0	54.4	2.5	52.9	1.1	
05		65.4	1.8	58.0	0.0	61.9	1.0	
06		55.3	0.0	40.9	0.0	48.6	0.0	
07		57.4	4.3	57.2	2.4	57.3	3.4	
08		61.0	4.1	54.8	0.0	58.1	2.3	
09		64.2	0.0	53.6	2.6	59.2	1.1	
10		67.7	1.9	43.7	0.0	56.2	1.2	
11 <sup>a</sup>		55.2	0.0	52.3	2.8	53.8	1.3	
12		57.8	4.0	56.7	0.0	57.3	2.1	
2010	01	64.7	0.0	59.6	0.0	62.3	0.0	
	02	60.2	4.4	59.4	0.0	59.9	2.3	
	03	55.0	0.0	58.6	0.0	56.8	0.0	
	04	53.5	0.0	56.7	0.0	55.0	0.0	
	05	55.5	4.3	53.0	0.0	54.3	2.3	
Before <sup>b</sup>	Mean	62.6	2.5	52.2	0.8	57.6	1.8	
	Median	61.8	2.1	52.4	0.0	56.3	1.2	
After <sup>c</sup>	Mean	57.8	2.1	57.3	0.0	57.6	1.1	
	Median	56.7	2.0	57.7	0.0	57.1	1.1	

<sup>a</sup> Educational programs arranged in November 2009.

<sup>b</sup> Before intervention: December 2008 to October 2009.

<sup>c</sup> After intervention: December 2009 to May 2010.

(mean 57.6%). The Wilcoxon signed ranks test showed no significant change in the utilization ratios (Table 2).

The overall median rates of CRBSI before and after interventions were 1.2 (mean 1.8) and 1.1 (mean 1.1) infections per 1000 catheter-days (Table 1). The median infection rate decreased from 1.95 (mean 1.58) infections per 1000 catheter-days at baseline to 0 (mean 1.06) after interventions ( $p = 0.310$ ,  $n = 12$ ). Individually, the median rates of CRBSI in ICU1 and ICU2 showed no significant change (ICU1: 2.14 [mean 2.34] infections per 1000 catheter-days at baseline and 2.02 [mean 2.11] after interventions [ $p = 0.893$ ,  $n = 6$ ]; ICU2: 0 [mean 0.82] infections per 1000 catheter-days at baseline and 0 [mean 0] after interventions [ $p = 0.180$ ,  $n = 6$ ] (Table 3). The rate of CRBSI in ICU2 was 0 infections per 1000 catheter-days, which was sustained for 6 months after interventions (Table 1, Fig. 2). The Poisson regression analysis shows the relative risk of CRBSI in ICU2 is 0 (relative risk = 0.000, 95% confidence interval = 0.000–0.000,  $p = 0.000$ ) after interventions (Table 4).

## Discussion

The CRBSI rate in this hospital before intervention (mean 1.8 per 1000 catheter-days) was higher than the 50th percentile (1.0 per 1000 catheter-days) reported by the NHSN.<sup>4</sup> After interventions, the overall mean infection rates was still higher at 1.1 per 1000 catheter-days and than the NHSN report 50th percentile. However, the Poisson regression analysis showed that the relative risk of CRBSI in ICU2 was 0 after interventions. In addition, the infection rate remained at 0 per 1000 catheter-days for 6 months in ICU2. We believe that these simple interventions can reduce the risk for serious catheter-related infection<sup>9</sup>; our modified standard process of CVC implantation could reduce the rates of CRBSI.

The TNIS report in 2009 distinguished between medical center and regional hospital, and showed that the 50th percentiles were 5.8 per 1000 catheter-days in medical centers, and 3.7 in regional hospitals.<sup>5</sup> The report showed

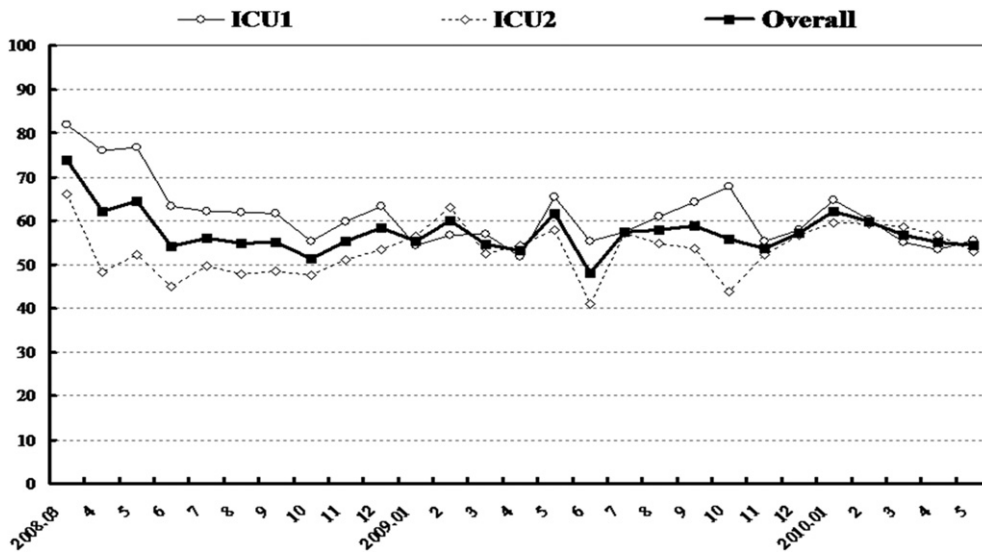


Figure 1. The utilization ratios of central venous catheter in ICU1, ICU2, and overall.

a relatively higher infection rate than the NHSN report, whether in a medical center or regional hospital. Our CRBSI rate is higher than the NHSN report but lower than the TNIS report. However, as CRBSIs are associated with high morbidity and mortality, zero tolerance may be the nonnegotiable objective.<sup>12</sup>

The five evidence-based recommendations to reduce CRBSI are hand washing, using full barrier precautions, cleaning the skin with chlorhexidine, avoiding the femoral site when possible, and removing unnecessary catheters.<sup>9</sup> A collaborative cohort study in Michigan, USA, which used these recommendations, reported that the CRBSI rates decreased from a mean of 7.7 and median of 2.7 per 1000 catheter days at baseline to 1.3 and 0, respectively, at 16 to 18 months after implementation. They remained at 1.1 and 0 at Months 34 to 36 (−1% vs. 18 months, 95% CI −9% to +7%).<sup>8</sup>

In our hospital, two of the five recommendations, hand washing using a chlorhexidine-based product and using full barrier precautions, were easy to accomplish as they had been generally promoted in our operating theater. Our surgeons assisted the educational programs in November 2009 to the staff in medical ICUs, including attending physicians, chief residents, and nurse practitioners. In addition, the chief residents in ICU educated new staff before they started ICU training.

However, the next two recommendations, cleaning the skin with chlorhexidine and avoiding the femoral site when possible, could not be introduced when the study began. The skin antiseptic agent with chlorhexidine was not approved in Taiwan at that time, and the catheter site selection (avoiding the femoral site) should be determined by clinical physicians. The evidence for avoiding femoral catheters is based on the higher risk for deep venous

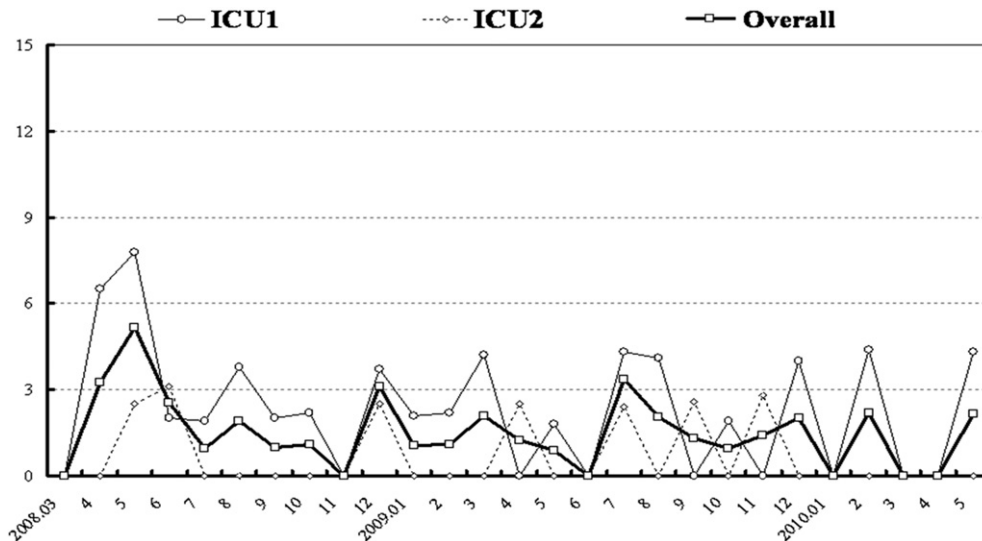


Figure 2. The rates of catheter-related blood stream infection in ICU1, ICU2, and overall.

**Table 2** The utilization ratios of central venous catheter from baseline to 6 months of follow-up

	Ward												Overall (n = 12)					
	ICU1 (n = 6)						ICU2 (n = 6)											
	Mean	SD	Median	Min	Max	p-value	Mean	SD	Median	Min	Max	p-value	Mean	SD	Median	Min	Max	p-value <sup>a</sup>
Before intervention <sup>b</sup>	58.09	5.22	56.89	51.77	65.42	0.917	56.26	3.86	55.42	52.51	62.97	0.753	57.18	4.48	56.64	51.77	65.42	0.875
After intervention <sup>c</sup>	57.78	4.13	56.63	53.48	64.71		57.33	2.49	57.69	52.96	59.57		57.56	3.26	57.26	52.96	64.71	

<sup>a</sup> p-value by Wilcoxon Signed Ranks Test.

<sup>b</sup> Before intervention: December 2008 to May 2009.

<sup>c</sup> After intervention: December 2009 to May 2010.

**Table 3** Rates of catheter-related bloodstream infection from baseline to 6 months of follow-up

	Ward												Overall (n = 12)					
	ICU1 (n = 6)						ICU2 (n = 6)											
	Mean	SD	Median	Min	Max	p-value	Mean	SD	Median	Min	Max	p-value	Mean	SD	Median	Min	Max	p-value <sup>a</sup>
Before intervention <sup>b</sup>	2.34	1.49	2.14	0.00	4.20	0.893	0.82	1.27	0.00	0.00	2.48	0.180	1.58	1.54	1.95	0.00	4.20	0.310
After intervention <sup>c</sup>	2.11	2.31	2.02	0.00	4.36		0.00	0.00	0.00	0.00	0.00		1.06	1.91	0.00	0.00	4.36	

<sup>a</sup> p-value by Wilcoxon signed ranks test.

<sup>b</sup> Before intervention: December 2008 to May 2009.

<sup>c</sup> After intervention: December 2009 to May 2010.



**Table 4** Poisson regression analysis of catheter-related bloodstream infection rates

Parameter	RR	95% CI	p-value
Intercept	0.001	0.001-0.002	0.000
After interventions	0.878	0.384-2.008	0.758
Before interventions	1.000		
ICU2	0.324	0.095-1.108	0.072
ICU1	1.000		
After interventions × ICU2	0.000	0.000-0.000	0.000
After interventions × ICU1	1.000		
Before interventions × ICU2	1.000		
Before interventions × ICU1	1.000		

RR = relative risk; CI = confidence interval.

thrombosis and higher colonization rates, which suggests that such catheters are more likely to get infection.<sup>13,14</sup> No randomized trials have compared the risk for infection associated with catheter insertion into jugular, subclavian, or femoral sites, but an epidemiologic, prospective, observational study revealed that the incidence of CVC infection in an intensive care unit population is not different at all three sites.<sup>15</sup> It is difficult to convince clinical physicians to comply with this recommendation.

Another important issue is the utilization ratios of CVCs. The NHSN report showed that the 50<sup>th</sup> and 90<sup>th</sup> percentiles of mean CVC utilization ratio in medical ICUs were 44% and 69%.<sup>4</sup> Our study showed the mean overall median utilization ratio of CVC was 57.6% before interventions were introduced, and remained at this level after (Table 2). Higher utilization ratios may be due to poor adherence to the recommendation to remove unnecessary catheters.

It is difficult to interpret the better outcome in ICU2 after intervention. The patient source was different between ICU1 and ICU2 (8 coronary care unit beds of the 26 in ICU2), which may explain the relative lower utilization ratios and CRBSI rate in ICU2 before intervention, and lower CRBSI rate after intervention. However, the utilization ratios were not different between ICU1 and ICU2 after intervention because the utilization ratio in ICU1 had a downward trend. The Hawthorne effect may be the other reason for the CRBSI rate and utilization ratio tending to decrease in ICU1 (Fig. 1), although the change was not significant.

Our study has several limitations. First, all data are from a single-center and may be not extrapolate to other centers. However, several large scale studies have supported the finding that evidence-based interventions can reduce the rate of CRBSI.<sup>1,4,7,9</sup> Second, we lacked the assessments for staff adherence. The Greater Cincinnati Health Council successfully reduced CRBSI by using a checklist and standardizing insertion of central lines.<sup>16</sup> The checklist is necessary to confirm the accuracy of CVC implantation. Third, the duration of follow-up is short. A relatively short period of the surveillance was analyzed to determine the outcomes of our interventions. Other interventions were introduced gradually into our hospital after this study period. The short follow-up duration may be the reason for change after interventions being nonsignificant. However, Poisson regression analysis showed that the relative risk of CRBSI in ICU2 reduced.

The use of maximal sterile barrier precautions in reducing the risk of CRBSI has been documented.<sup>6</sup> In addition, the relative risk of CRBSI in ICU2 was 0 after interventions, and the infection rates sustained 0 per 1000 catheter-days for 6 months in ICU2. We believe our modified standard procedure of CVC implantation could reduce the rates of CRBSI. We conclude the reduction of infection rates could be possible by our modified standard process of CVC implantation, which included the first two recommendations to reduce CRBSI. However, more interventions, such as cleaning the skin with chlorhexidine, avoiding the femoral site when possible, and removing unnecessary catheters, should be considered to reduce the incidence of CRBSI further. In addition, quality assurance by checklist and continuing education are also necessary.

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