The effect of the automatic notification of catheter days on reducing central line-related bloodstream infection

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Abstract

Background

A central venous catheter (CVC) is an important medical device, but it could be preceding infection and the risk of central line-associated bloodstream infection (CLABSI). CLABSI is a common healthcare-associated infection but results in high cost and mortality; therefore, various efforts to reduce CLABSI have been attempted.

Methods

We reviewed and analysed the data of CLABSI rates and days from the insertion to the removal of the temporary central venous catheter between January 2018 and June 2021 in the intensive care unit (ICU) of a single tertiary care hospital. Sequentially, all patients with the CVC in the ICU underwent the following interventions: maximal barrier precaution, automatic notification of catheter days and 2% chlorhexidine gluconate bathing. An independent sample t-test was used to compare the CLABSI rates, which were shown using time-series design. In the pre-intervention period, the risk factors for CLABSI in patients with short-term CVC were evaluated using multivariate logistic regression analyses.

Results

A total of 101342 patient-days, 6378 catheter days and 86 CLABSI cases were reviewed in ICU-hospitalised patients. As additional interventions, the CLABSI rate declined from 3.1 per 1000 CVC days to 1.2 per 1000 CVC days in post-interventions. Of 5275 ICU-hospitalised patients, 2229 in the pre-intervention period had one more short-term CVC. Medical ICU, the number of indwelling CVCs and the indwelling time of the central catheter beyond 10 days were the risk factors for CLABSI in short-term CVC (odds ratio (OR), 2.56 [95% confidence interval {CI}, 1.32–4.88]; OR, 1.32 [95% CI, 1.07–1.59]; and OR, 8.21 [95% CI, 3.90–18.88], respectively). Of the three interventions, the automatic notification of catheter days was associated with decreased median monthly total central catheter days and duration of CVC days per patient.

Conclusions

Our study suggests that multidisciplinary and evidence-based interventions rather than one effort are associated with a prominent reduction in the CLABSI rates. Moreover, the automatic notification of catheter days of the electronic medical healthcare system has shortened the time of indwelling central catheter.

Background

Central line-associated bloodstream infection (CLABSI) is a leading serious hospital-acquired infection (HAI) with increasing numbers of immunocompromised patients and invasive procedures and broad antibiotic usage. CLABSI was associated with the increased medical cost, prolonged hospital stay and high mortality of up to 25% [1]. Compared with inpatients without CLABSI, inpatients with CLABSI paid an extra average of 32000 dollars, and they had a 2.27-fold higher mortality rate [2]. According to the Centers for Disease Control and Prevention (CDC), 25000 reductions of CLABSIs contributed to saving 414 million excess healthcare costs and 60000 lives [1]. Fortunately, CLABSIs were preventable HAI with proper aseptic techniques and active surveillance.

Several studies achieved to have zero preventable CLABSI rate after introducing from CLABSI bundle to multifaceted implementations, such as education, surveillance and feedback on results [3–6]. In the meta-analysis involving 2216 adult intensive care units (ICUs), the CLABSI incidence decreased from 5.7 per 1000 catheter days to 2.0 per 1000 catheter days after the implementation of the bundle [6]. The CLABSI bundles were evidence-based and concise interventions to prevent and reduce the CLABSI rates in the ICU [7–9]. Guidelines from the CDC for the prevention of CLABSI emphasised the following five strategies of the CLABSI bundle: hand hygiene; maximal barrier precautions (MBPs) during central venous catheter (CVC) insertion; chlorhexidine antisepsis, excluding the femoral insertion site as possible; and prompt and timely removal of unnecessary CVC [7, 10].

Because the duration of catheterisation is a major extrinsic risk factor associated with the development of CLABSI, efforts to immediately remove a catheter could result in the reduction in the CLABSI rates. Although the prevalence of unnecessary CVC insertion widely ranges from 18–39% in a diverse study setting [11], in a hospital-wide survey with 575 admitted patients with one more vascular catheter in a single centre, 21.9% of those had an inappropriate one more vascular catheter [12]. In a multicentre observational study, clinicians described that the unawareness of the presence of a CVC was a major barrier to timely remove it [13]. Therefore, noticing the presence of a CVC to clinicians was likely to be significant to prevent catheter-related infection.

In response, we introduced an automatic notification of catheter days to notify the presence of the CVC and re-evaluate the maintenance of the CVC. This retrospective study aimed to assess the effect of stepwise interventions to the CLABSI rates and analyse the effect of the automatic notification of catheter days. During the study periods, the MBP and 2% chlorhexidine gluconate (CHG) bathing were introduced, and the effect of the stepwise intervention on the CLABSI rates was assessed.

Methods

Data collection and study setting

We reviewed and analysed the retrospective data of ICU-hospitalised patients with CVC between January 2018 and June 2021 in the ICUs of a single tertiary care hospital. There were a total of 7 adult ICUs with 111, including the medical ICUs, surgical ICUs, stroke units, neurosurgical ICUs, coronary/cardiac care unit, cardiac ICUs and emergency ICUs. We obtained the performance compliance of the CVC checklist, monthly CLABSI cases and monthly CVC days. If a patient had two or more central catheters, each CVC was calculated in the CVC days separately. For analysing the risk factors for CLABSI, we selected the patients with short-term CVC and obtained data that included the age, sex, comorbidities, ICU type, CVC type, time from admission to insertion of CVC and indwelling time of CVC.

Intervention

The study was performed in four periods: pre-intervention period, from January 2018 to May 2019; period 1, from June 2019 to September 2019; period 2, from October 2019 to March 2020; and period 3, from April 2020 to June 2021. During whole periods, the principal management for reducing CLABSI followed the guidelines for the prevention of intravascular catheter-related infections [7]. The nurse-to-patient ratio was 1:2 to 1:4 in each ICU. Nursing staff and doctors were trained regarding the proper insertion and maintenance of central intravascular catheters. Before CVC insertion or access, healthcare staff washed their hands with soap and rubbed them with alcohol, and then, they performed the procedures aseptically. All patients excluding infants aged <2 months had their skin cleaned with 0.5% chlorhexidine with alcohol. Two nursing staff belonging to the infection control office monitored the performance compliance of the CVC checklist every 3 months. The CVC checklists consisted of hand hygiene, maximal precaution barrier, antisepsis with disinfectant and CVC catheter site. Doctors inserted a blind CVC without ultrasound guidance.

During period 1, doctors performed the procedures with the MBPs, including the use of sterile full body drape, mask, cap, sterile gloves and sterile gown. During period 2, we introduced the automatic notification of catheter days, which showed the CVC indwelling days in the prescription section of the electronic healthcare system. Medical staff evaluated the need for a CVC every day. Until the assessment of CVC maintenance, the automatic notification of catheter days continued. During period 3, all body surfaces were bathed with nonwoven fabric soaked in 2% CHG once daily.

Definition

Central catheters involved the short- and long-term central catheters. The short-term central catheters were the non-cuffed short-term CVCs, dual-lumen haemodialysis catheters and Swan sheath catheters. The long-term central catheters were the balloon-tipped pulmonary artery central catheters (Swan–Ganz), cuffed and tunnelled catheters (Hickman), implanted central catheters and peripherally inserted central catheters (PICCs).

Laboratory-confirmed bloodstream infection (LCBI) was the condition in which patients had a recognised pathogen culture from one or more blood cultures or patients had common skin contaminants from two or more blood cultures on separate sites with clinical symptoms, including fever, chills or hypotension. For these situations, there should not be apparent other sources for bacteraemia [14]. CLABSI is a primary LCBI without another infection in a patient who had central line within 48 h before infection [14]. The CLABSI incidence rate was the number of BSI in patients with an indwelling central catheter per 1000 CVC days.

Statistical analysis

Categorical variables are expressed as numbers and percentages. Comparisons of each period were performed for categorical variables using the chi-square test or Fisher's exact test. Continuous variables are expressed as mean ± standard deviations or median with interquartile ranges (IQRs) and were compared using Student's t-test or the Mann–Whitney U test. Poisson regression analysis was used to confirm the incidence rate ratio (IRR) and compare the post-intervention CLABSI rate with the pre-intervention CLABSI rate. The Kaplan–Meier analysis for CVC early removal was performed using the log-rank test, coding CVC removal within 10 days as a censored event. After excluding patients with the Hickman catheter, implanted port and PICC that typically have long-term indications, we employed multivariate logistic regression analyses to evaluate the risk factor associated with CLABSI in patients with short-term CVCs. A P value of <0.05 was considered statistically significant. All statistical analyses were performed using R statistics ver. 3.1.

Ethics Statement

The institutional review board of Kyungpook National University Hospital reviewed and approved our study protocol (approval numbers: KNUH-202202038). Considering the retrospective nature of the study and the use of anonymous clinical data for the analysis, the requirement for informed consent was waived.

Results

Trend of the CLABSI rates according to each intervention

Between January 2018 and June 2021, there were 101,342 total patient-days in ICU and 6,378 catheter days in ICU-hospitalised patients. The overall demographic data and CLABSI rates are presented in Table 1. A total of 86 CLABSI cases occurred during the entire study periods (46 in the pre-intervention period, 7 in period 1, 13 in period 2 and 20 in period 3). The CLABSI rate declined from 3.1 (IQR, 2.3–3.9) in the pre-intervention period to 0.7 (IQR, 0.0–4.0) in period 1 and 1.8 (IQR, 0.0–4.5) in period 2, but this did not show the significant reduction in the CLABSI rate. Compared with the CLABSI rate in the pre-intervention period, the CLABSI rate in period 3 was 1.2 (IQR, 1.1–2.5) per 1000 CVC days with an IRR of 0.597 (95% confidence interval [CI], 0.359–0.993; P=0.047) (Table 1). Figure 1 demonstrated the decreasing trends in the CLABSI rates by step-wide interventions.

Study population with indwelling short-term CVCs in the pre-intervention period

Table 2 shows the demographic and clinical data in 2229 ICU-hospitalised patients with short-term CVCs in the pre-intervention period. Among a total of 86 CLABSI cases, 46 occurred during pre-intervention. ICU-hospitalised patients with short-term CVCs were grouped according to CLABSI occurrence. A total of 845 patients (37.9%) were women, and the median age was 64.0 (52.0–75.0) years. Among 2229 enrolled patients, surgical ICU (70.5%) was the most common ICU, followed by medical ICU and emergency ICU. The jugular vein (44.7%) was the most common insertion site, followed by the subclavian vein (39.9%) and femoral vein (15.4%). In enrolled patients, the median indwelling time of the central catheter was 5.0 (3.0–9.0) days.

Risk factors for CLABSI in an short-term CVC

In Table 2, there were no significant differences in age, sex, duration from admission to insertion of CVC, diabetes, malignancy and steroid use between the no CLABSI group and CLABSI group. Medical ICU admission was associated with a higher risk of CLABSI, especially in comparison with surgical intensive unit admission. The numbers of indwelling CVC and indwelling time of central catheter were also associated with a higher risk of CLABSI.

The multivariate logistic analysis showed that three factors increased CLABSI occurrence, including the medical ICU (odds ratio [OR], 2.56; 95% CI, 1.32–4.88; P=0.004), number of indwelling central catheter (OR, 1.32; 95% CI, 1.07–1.59; P=0.006) and indwelling time of central catheter beyond 10 days (OR, 8.21; 95% CI, 3.90–18.88; $P < 0.001$) (Table 3).

Effect of the automatic notification of catheter days on CVC days

The median monthly total central catheter days were significantly different between the before and after automatic notification of catheter days (median, 956.0 [IQR, 856.0–1024.0] vs. 819.0 [IQR, 782.0–896.0]; $P < 0.001$) (Figure 2). The duration of short-term central venous catheterisation per patient was significantly different between the before (n = 2680) and after (n = 2595) automatic notification of catheter days (7.53 ± 7.14 vs. 6.74 ± 6.00 days, $P < 0.001$). Time to short-term CVC removal per patient was also decreased after automatic notification of catheter days (Figure 3) (P= 0.035).

Discussion

This study showed that the total patient-days in ICU (n = 101342) and catheter days (n = 6378) and CLABSI rates declined with multifaceted interventions, including MBP, automatic notification of catheter days and 2% CHG bathing. Compared with 3.9 cases per 1000 catheter days in the pre-intervention period, the CLABSI rates decreased by 1.2 cases per 1000 catheter days after the introduction of three interventions, which were lower than 1.83 cases per 1000 catheter days, the fifth percentile of the CLABSI rates through the Korean National Healthcare-associated Infections Surveillance System program in 2015 [15].

To determine how additional interventions directly affected the CLABSI occurrence would be challenging. As such, we introduced the evidence-based tools on the CDC guidelines, which were known to prevent CVC-related infection [7, 16]. In a meta-analysis study, daily 2% CHG bathing was identified to be associated with the reduction in CLABSI by eradication of especially Gram-positive skin coloniser (OR, 0.50; 95% CI, 0.35–0.71; $P < 0.001$) [17].

In this study, the number of indwelling central catheter and indwelling time of short-term CVC beyond 10 days were identified to be risk factors for CLABSI, which is consistent with the findings of the previous study [18–20]. A previous study with 5.6 cases per 1000 catheter days in 896 patients at a single hospital demonstrated that the indwelling time beyond 10 days significantly increased CLABSI cases (OR, 2.867; 95% CI, 1.823–4.507) [18]. Wu et al. showed that the central catheter maintenance duration of more than 14 days significantly increased catheter-related bloodstream infection compared with the duration of lower than 14 days (OR, 1.08; 95% CI, 1.04–1.13) [20]. Although Fong et al. suggested that disease severity was related to increased catheter line and loss of opportunity for catheter removal [21], 50% of 340 patients had at least 1 idle CVC day on discharge from ICUs to general wards [22]. In a previous study in non-ICU cases, 89 patients with temporary and non-implanted CVC had idle CVC for a mean of 4.1 days [23]. We continued efforts to reduce the duration of unnecessary central line use with the automatic notification of catheter days and focused on the relationship between the automatic notification of catheter days and duration of indwelling CVC use. This study demonstrated that the introduction of the automatic notification of catheter days in the electronic healthcare system was associated with a reduction in the indwelling time of short-term CVC per patient and reduction in total central line days. This automatic notification of catheter days contributed to decreased short-term CVC indwelling time per patient.

To date, there is no clear and standardised system for unnecessary catheter removal, and the most recommended practices are responsible for combining a CLABSI bundle with multifaceted interventions, including education and feedback [24–26]. Ilan et al. suggested that the removal of non-essential CVCs could be achieved by multidisciplinary team rounding with a checklist including reminders of central catheter removal [25]. However, each institution may have different capabilities to team up with committed multidisciplinary experts, including clinicians, infection surveillance nurses and educating clinicians. A multicentre survey-based study in Michigan described that 16.3–31.1% of 1,881 clinicians were unaware of the presence of a CVC, including the medical residents and hospitalists (13.8% vs. 27.3%, respectively) [13]. Because catheter removal is usually at the discretion of the clinicians, the awareness of the presence of a catheter and attending doctor’s decision to remove a catheter may be key point. A previous study in two 26-bed internal medicine clinical teaching units reviewed that the online tool for physician audits of CVC was associated with a significant reduction in catheter days by checking the number of central venous access and reasons for access [27]. Grady found that online tools for CVC management could be an attractive method requiring minimal effort but showing maximal effect [27]. Similarly, the automatic notification of catheter days in our electronic healthcare system simply reminded about the catheter necessity and the catheter indwelling time until the physicians decided on catheter removal. Given that the catheters’ indwelling times were longer in patients outside the ICU than inside the ICU, the daily notification of the presence of a CVC may also elicit the zero CLABSI cases in medical wards [28].

Our study has several limitations. First, we did not consider patient severity and comorbidity, which could be risk factors for CLABSI. Nevertheless, given that PICC would be placed in patients who required venous access for long days, severity and disease could not affect the indwelling time of short-term CVC. Thus, after adjustment for patient's characteristics, simple sensitisation to clinicians could decrease the duration of catheterisation and CVC infection. Second, we did not collect the prior antibiotic use and number of indwelling central catheter for each patient. Moreover, we did not discriminate which catheters caused CLABSI when there were more than two central catheters during CLABSI. However, we counted each central catheter for the same patient within the catheter days, and our CLABSI rates would be unlikely to be underestimated. Third, because this was a single-centre retrospective study, our results were difficult to generalise, and each intervention period had different observation times. Nevertheless, these interventions including the automatic notification of catheter days were principal methods and were easily carried out.

Conclusion

In summary, the proportion of CLABSI in patients inside an ICU decreased substantially after efforts to reduce contamination, skin coloniser and unnecessary CVCs. Especially, the duration of short-term CVC used decreased after the introduction of the automatic notification of catheter days. To reach the zero CLABSI cases, this study provides the evidence that simple sensitisation of the presence of CVC to physician is attractive for the removal of unnecessary CVCs.

Abbreviations

CLABSI: central line-associated bloodstream infection; HAI: hospital-acquired infection; CDC: Centers for Disease Control and Prevention; MBP: maximal barrier precautions; CHG: chlorhexidine gluconate; ICU: intensive care unit; CVC: central venous catheter; PICC: peripherally inserted central catheter; LCBI: laboratory-confirmed bloodstream infection; IQR: interquartile range; IRR: incidence rate ratio; OR: odds ratio; CI: confidence interval

Declarations

Ethics approval and consent to participate

This study was carried out in accordance with the guidelines of the Declaration of Helsinki. The study was approved by the Institutional Review Board of Kyungpook National University Hospital (approval numbers: KNUH-202202038), and a written informed consent was waived due to the retrospective chart review. The data in this study were anonymised before use.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

Competing interests

No competing interests to declare.

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Author contributions

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Tables

Table 1. Overall demographic data and CLABSI rates for each period

Period	CLABSI cases (N)	Total central line days, median (IQR)	Total patient days, median (IQR)	CLABSI rate[a], median (IQR)	IRR[b] mean, (95% CI)	*P* value[c]
Pre-intervention period	46	956.0 (856.0–1024.0)	2,526.0 (2,342.0–2,686.0)	3.1 (2.3-3.9)		
Period 1	7	792.5 (715.5–882.5)	2,475.5 (2,420.0–2,571.0)	0.7 (0.0-4.0)	0.749 (0.338-1.658)	0.475
Period 2	13	814.0 (782.0–849.0)	2,539.0 (2,224.0–2,606.0)	1.8 (0.0-4.5)	0.772 (0.400-1.490)	0.441
Period 3	20	819.0 (802.5–898.5)	2,247.0 (2,186.0–2,375.5)	1.2 (1.1-2.5)	0.597 (0.359-0.993)	0.047

[a] CLABSI cases per 1000 catheter days.

[b] Incidence rate ratio for CLABSI cases per 1000 catheter days.

[c] Compared with the pre-intervention period.

Abbreviations: CLABSI, central line-associated bloodstream infection; IQR, interquartile range; CI, confidence interval; IRR, incidence rate ratio

Table 2. Demographic and clinical features of enrolled patients in the pre-intervention period

	Total (n = 2229)	No CLABSI (n = 2188)	CLABSI (n = 46)	P value
Age, median [IQR], y	64.0 [52.0–75.0]	64.0 [52.0–75.0]	64.0 [53.0–70.0]	0.441
Female, n (%)	845 (37.9%)	831 (38.0%)	14 (34.1%)	0.735
Time from admission to insertion of central catheter, median [IQR], d	1.0 [0.0–4.0]	1.0 [0.0–4.0]	0.0 [0.0–3.0]	0.079
Intensive care unit type, n (%)				
Medical	387 (17.4 %)	369 (16.9%)	18 (43.9%)	<0.001
Surgical	1542 (70.5 %)	1542 (70.5%)	22 (53.7%)	0.031
Emergency	277 (12.7 %)	277 (12.7%)	1 (2.4%)	0.085
Diabetes mellitus, n (%)	577 (25.9%)	564 (25.8%)	13 (31.7%)	0.684
Malignancy, n (%)	357 (16.0%)	349 (16.0%)	8 (19.5%)	0.688
Steroid use during the indwelling time, n (%)	937 (42.0%)	916 (41.9%)	21 (51.2%)	0.297
Insertion site				
Subclavian	889 (39.9%)	867 (39.6%)	22 (53.7%)	0.097
Jugular	996 (44.7%)	991 (45.3%)	5 (12.2%)	<0.001
Femoral	344 (15.4%)	330 (15.1%)	14 (34.1%)	0.002
Number of indwelling central catheter, n (%)	1.0 [1.0–2.0]	1.0 [1.0–2.0]	2.0 [2.0–3.0]	<0.001
Total indwelling time of central catheter, median [IQR], d	5.0 [3.0–9.0]	5.0 [3.0–9.0]	14.0 [10.0–22.0]	<0.001
Indwelling time of central catheter beyond 10 days, n (%)	541 (24.3%)	509 (23.3%)	32 (78.0%)	<0.001

Abbreviations: CLABSI, central line-associated bloodstream infection; IQR, interquartile range.

Table 3. Risk factors for central line-associated bloodstream infection in the intensive care unit

Variable	Univariate logistic regression analysis		Multivariate logistic regression analysis	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Duration of hospitalisation	1.00 (0.99–1.01)	0.007	-	-
Medical intensive care unit	6.87 (1.36–125.25)	<0.001	2.56 (1.32–4.88)	0.004
Surgical intensive care unit	3.59 (0.70–66.09)	0.022	-	-
Femoral catheter	1.56 (0.69–3.45)	0.001	-	-
Number of indwelling central catheter	1.30 (1.05–1.58)	< 0.001	1.32 (1.07–1.59)	0.006
Indwelling time of central catheter beyond 10 days	8.24 (3.84–19.32)	< 0.001	8.21 (3.90–18.88)	< 0.001

Abbreviations: OR, odds ratio; CI, confidence interval.

Figures

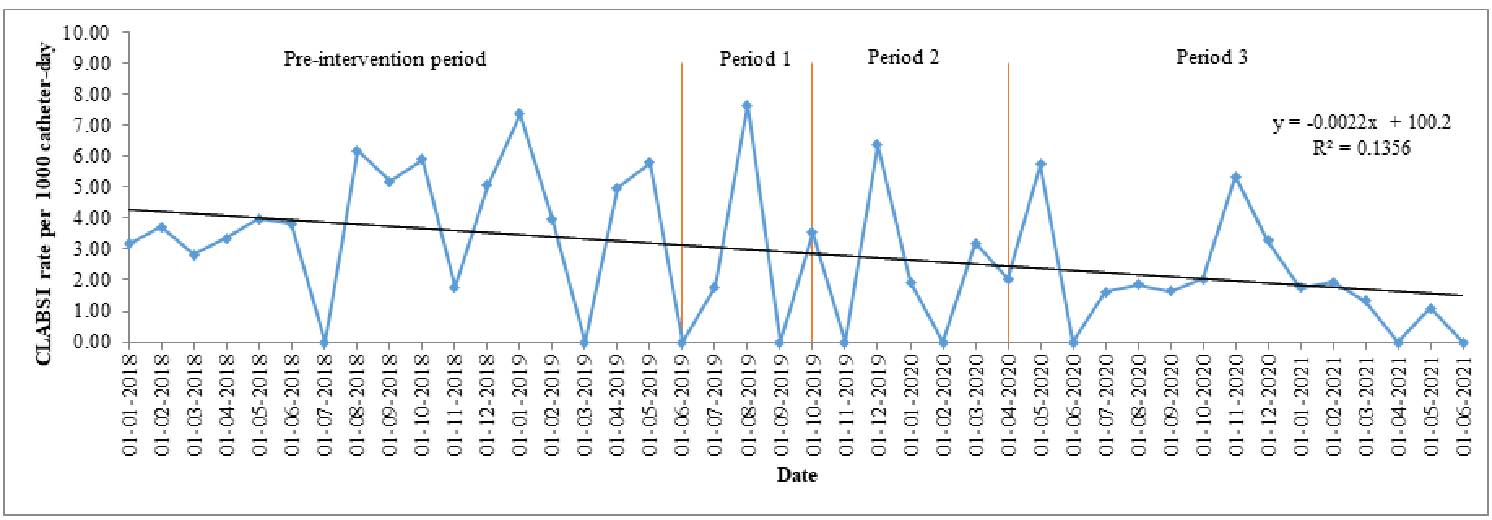

Figure 1

Trend of central line-associated bloodstream infection according to the interventions.

Closed diamonds indicate monthly CLABSI rates during each period. The three interventions were performed during the study. The pre-intervention period began in January 2018 and ended in May 2019. During period 1, from June 2019 to September 2019, infection control with MBP was performed. During period 2, from October 2019 to March 2020, procedures with MBP and automated notification of central catheter days were performed. During period 3, from April 2020 to June 2021, three interventions with MBP, automated notification of central catheter days and 2% chlorhexidine bathing were performed

Abbreviations: CLABSI, central line-associated bloodstream infection; MBP, maximal barrier precaution.

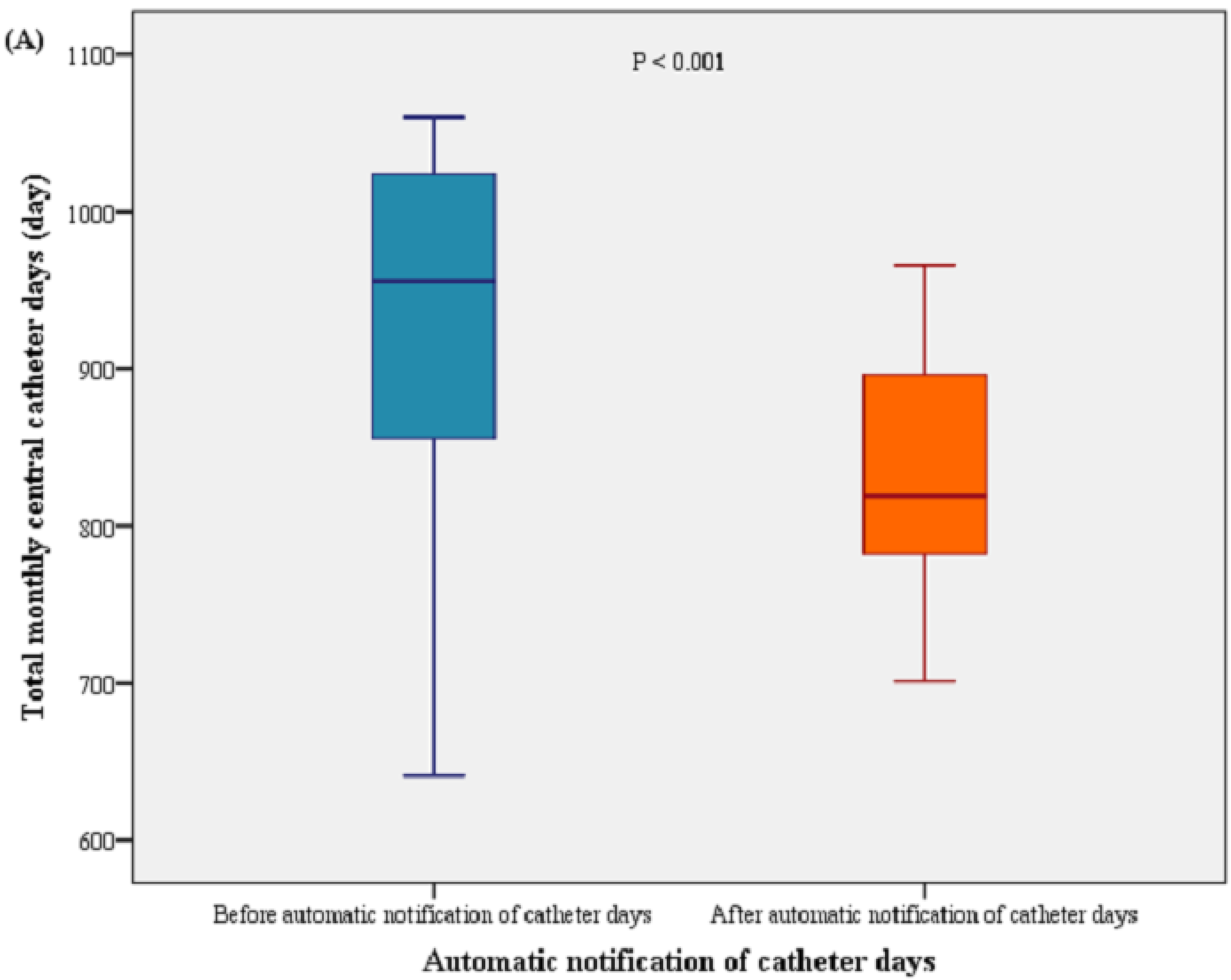

Figure 2

The effect of the automatic notification of catheter days on CVC days

Abbreviation: CVC, central venous catheter.

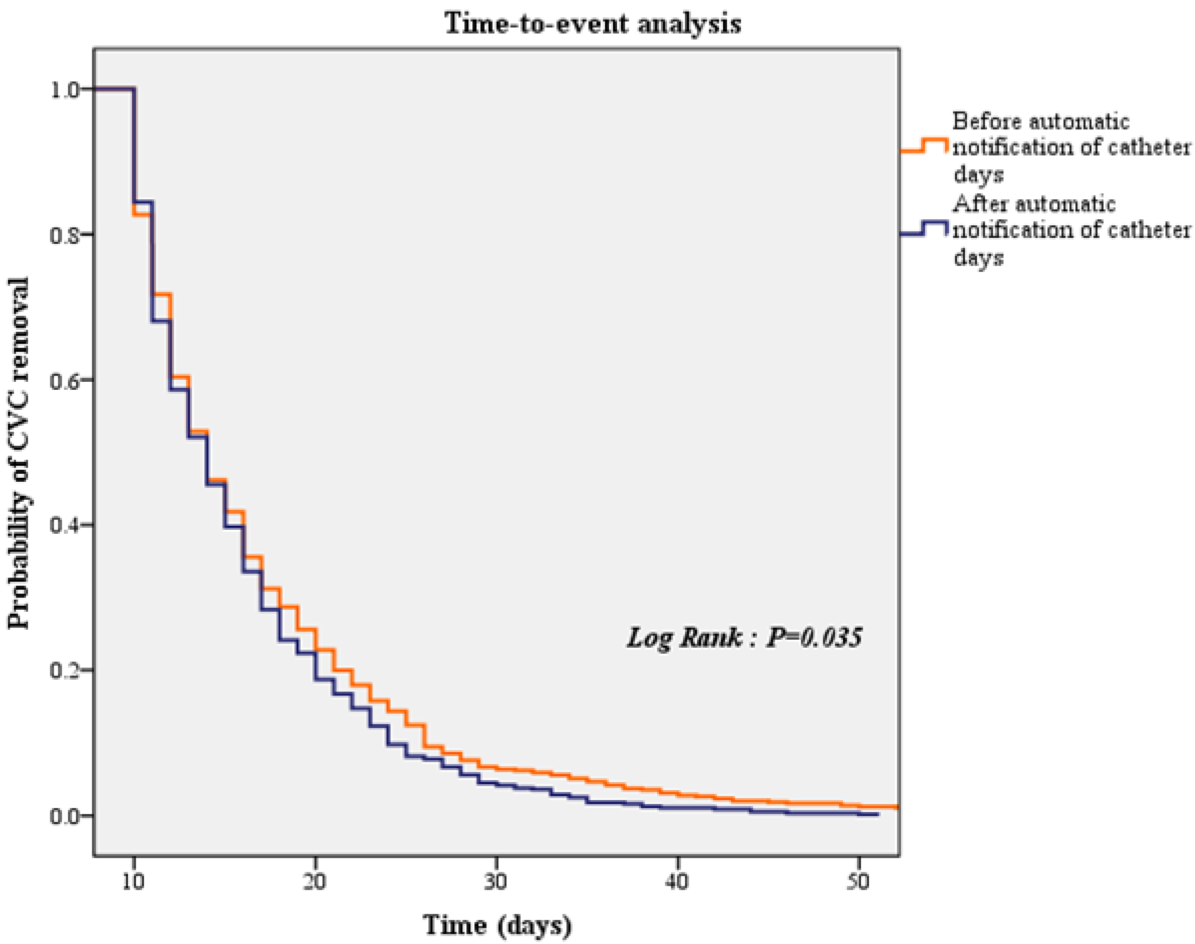

Figure 3

Time-to-event analysis for central venous catheter removal