American Journal of Infection Control 48 (2020) 1184–1188

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Impact of a quality control circle on the incidence of catheter-associated urinary tract infection: An interrupted time series analysis

Xiao Zhong MPH [a,*], Li-Hua Xiao BSc [a], Dong-Li Wang MMed [b], Shan-Wen Yang BMed [a], Lan-Fang Mo BSc [a], Lan-Fang He BSc [a], Qing-Fei Wu BMed [a], Yan-Wei Chen BMed [a], Xiao-Feng Luo BSc [a]

[a] Department of Nosocomial Infection Control, Shenzhen Hospital, University of Chinese Academy of Sciences, Shenzhen, Guangdong, China
[b] Department of Nosocomial Infection Control, Inspection Center, Guangming District Center for Disease Control and Prevention, Shenzhen, Guangdong, China

Key Words:
Quality control circle
Interrupted time series analysis
Catheter-associated urinary tract infection
Quality improvement activity
Catheter use ratio
Prevention measures

Background: To report a quality control circle (QCC) activity on the theme of reducing the incidence of catheter-associated urinary tract infection (CAUTI), and used an interrupted time series analysis to evaluate the impact of the QCC.

Methods: In a general tertiary hospital in Shenzhen, China, we carried out a QCC activity with the theme of reducing CAUTI from April 2017 to December 2017. Before the QCC, we carried out the routine measures; during the QCC, we implemented usual measures and the countermeasures of QCC, and after the QCC, we performed the routine measures and adhered to the core measures of QCC. The interrupted time series analysis method was used to analyze the changes in the CAUTI incidence during the 3 stages.

Results: Before, during, and after the QCC activities, the catheter use ratios and mean indwelling time both had a downward trend; meanwhile, the compliance rate of CAUTI prevention measures showed an upward trend. After the interventions, the CAUTI incidence decreased by 1.317‰ immediately, then gradually decreased by 0.510‰ per month. After the completion of QCC, the CAUTI incidence increased by 0.266‰ immediately and increased by 0.070‰ over time, but the difference was not statistically significant.

Conclusions: The CAUTI incidence is reduced through QCC, providing a useful reference for the prevention of CAUTI and the development of medical quality improvement activities.

Catheter-associated urinary tract infection (CAUTI) refers to the urinary tract infection (UTI) that occurred during the indwelling of the catheter, and within 48 hours after the catheter was removed. In the United States, UTIs are common hospital-acquired infections (HAIs), accounting for 15% of HAIs, and approximately 70% are associated with an indwelling urethral catheter.[1,2] Similarly, in China, UTIs accounted for 20.8%-31.8% of nosocomial infections, following respiratory infections,[3,4] and 80%-85% related to the use of catheters.[5] The incidence of CAUTI is one of the essential indicators to measure the quality and safety of medical care.[6] At present, there are many quality improvement activities about reducing CAUTI in the domestic and overseas. However, the use of quality control circle (QCC) to reduce the morbidity of CAUTI is rarely reported.

Moreover, QCC is a management tool for quality improvement. It was founded in Japan in 1962 and introduced to Chinese medical institutions in 2001 to improve and solve medical quality and problems.[7-9] Based on the theory of the plan-do-check-act cycle, it fully mobilizes the enthusiasm, initiatives, and creativity of participants to explore and improve problems together. Currently, the application of QCC in the improvement of medical quality is more and more widespread and popular in China.[10] Our country has also established the "China Quality Management Alliance" and regularly holds the nationwide QCC competitions for medical establishments.

In the activities of the QCC, the χ^2 test or t test are often used to evaluate the effect of interventions,[11] which are not rigorous enough in some situations, for example, the data may contain a secular trend before the interventions, therefore exaggerating the effect of interventions. However, interrupted time series analysis (ITSA) can balance the trends of the data before the interventions and examine the real impact of countermeasures.

* Address correspondence to Xiao Zhong, MPH, Department of Nosocomial Infection Control, Shenzhen Hospital, University of Chinese Academy of Sciences, Shenzhen, 518106, Guangdong, China.
E-mail address: 187197283@qq.com (X. Zhong).

Conflicts of interest: All authors report no conflicts of interest relevant to this article.

https://doi.org/10.1016/j.ajic.2020.01.006
0196-6553/

From April 2017 to December 2017, our hospital carried out a QCC activity to reduce the incidence of CAUTI, and ITSA was conducted to test the impact of countermeasures. It was the first time in our hospital used the QCC to reduce the morbidity of CAUTI. Therefore, we aim to introduce this successful case to peers, provides a useful reference for the prevention of CAUTI and the development of medical quality improvement activities.

METHODS

Study setting and design

We performed this study in a general tertiary hospital with 1,200 beds, 1,115 doctors, and 1,334 nurses in Shenzhen, China, from January 2016 to March 2019. There are 45 clinical departments involving various specialties, and each department has set up a nosocomial infection control team composed of the department director, head nurse, and infection control doctors and nurses.

There were 3 stages in the study. At stage 0 (January 2016-April 2017), we carried out the routine CAUTI combination prevention measures.[12] At stage 1 (May 2017-December 2017), we implemented usual measures and the countermeasures of QCC themed at reducing CAUTI, such as a regular organization of circle meetings, continuous hierarchy training, verification of CAUTI prevention measures for patients with indwelling urinary catheters, and regular feedback. At stage 2 (January 2018-March 2019), the period after the completion of QCC activities, we performed the routine measures and adhered to the core measures of QCC (verification and feedback). Using the ITSA, we compared the changes of CAUTI incidence before, during, and after the interventions to evaluate the effect of QCC.

The QCC of reducing the incidence of CAUTI

We carried out the activities strictly accordance with the steps of QCC[13]: Group circle, themes selection, making activity plans, status grasping, target value setting, cause analysis, countermeasures formulation, countermeasures implementation and review, effect evaluation and confirmation, standardization, and review and improvement.

In April 2017, we established a QCC team consisting of 7 infection control professionals and 4 head nurses of some clinical departments. Because the incidence of CAUTI in our hospital was much higher than the average level of China's 649 public hospitals in 2015 (1.43‰), we chose to reduce the incidence of CAUTI as the theme of the QCC activity. According to the QCC activity process, we made the Gantt chart of the activity plan. The whole QCC activity lasted from April 2017 to December 2017.

In the status grasping stage, the 12 investigators verified the defects in 188 patients with indwelling catheters and made the Pareto chart. According to the 80/20 rule, we determined the 2 major deficiencies, which were the indwelling catheter without indication and the prolonged indwelling time without timely extubating, they accounted for 74.3% of the total defects. According to the formula of the target value, the target value = current value − improvement value = current value − (current value × value of focus × ability of circle).[14] The target value was calculated to be 3.00‰. Using the brainstorming method, the QCC members selected the principal causes according to the 80/20 rule. Then we went back to the wards to check the frequencies of the primary causes. According to the 80/20 rule, we finally determined the root causes as insufficient training of medical staff and inadequate supervision of the implementation of CAUTI prevention measures.

We developed the countermeasures according to the 2 root causes with the brainstorming method. Then we graded them and chose those with high scores to put into effect in the end. As a result, the final countermeasures were as follows: (1) Strengthening the knowledge of health care workers (HCWs) for CAUTI prevention by hierarchy training. (2) Monitoring and feeding back the compliance rate of CAUTI prevention measures. During the implementation period of countermeasures, we held monthly QCC meetings to review the deficiencies in the process of implementation and used plan-do-check-act cycles for continuous improvement. Since the data of monthly changes for CAUTI incidence were time-series data, we applied ITSA to assess the impact of the interventions on the incidence of CAUTI.

At last, the effective countermeasures were written into the hospital systems or processes to be implemented for a long time, to ensure the prolonged stability of the improvement effect. Moreover, the residual problems were reviewed and developed improvement plans.

Definition of diagnostic criteria and monitoring indicators

CAUTI mainly refers to the urinary system infection occurring within 48 hours after the indwelling of the catheter or the removal of the catheter. The definition of CAUTI and diagnostic criteria followed the guidelines for the prevention and control of CAUTI from the ministry of health of the People's Republic of China.[4]

The incidence of CAUTI is defined as the number of UTIs per 1000 catheter days. The catheter use ratio (CUR) is the percentage of days used catheters per 1000 hospitalization days. The compliance rate of CAUTI prevention measures is defined as the percentages of the measures that have been put into effect in which should be applied.

Data collections

The CUR and the incidence of CAUTI came from the nosocomial infection monitoring system of our hospital, which has data interface with other information systems, such as hospital information system, laboratory information system, radiology information system, mobile nurse system and operating room anesthesia information system. When the clinicians find CAUTI, they will report them to the infection control department through the system, then 2 professionals of the infection control department will verify whether they are CAUTI or not according to the diagnostic criteria. When the 2 professionals disagree, the decision is made by the third professional. Besides, the system will give an early warning of possible nosocomial infection cases according to the patient's temperature, microbial culture, inflammatory indicators, and the use of antibiotics, then the professionals of infection control will take the initiative to deal with the early warnings and judge whether they are nosocomial infections or not. Through this system, the inpatient information and nosocomial infection information can be obtained timely and accurately. Moreover, the compliance rate of various CAUTI prevention measures was derived from the verification of the CAUTI prevention measures on patients with indwelling catheters by the QCC members and the infection control practitioners in target departments.

Data analysis

The data were input into Excel 2016 to establish a database and analyzed by Stata 15.1 (Stata Corporation, College Station, TX) software. First, an actest[15] was carried out to verify whether there was autocorrelation of time series data and determined the maximum lag levels. Then monthly changes in the incidence of CAUTI were analyzed by the ITSA package in Stata software. The Newey-west model of ITSA was selected for analysis with the lags determined previously. Based on the method of ordinary least-squares regression, this model provides Newey-west standard error to solve the problems of autocorrelation and possible heteroscedasticity of data. Due to the limitation of data, there were no control groups, and we used a single time

Table 1
Comparison of baseline before and after QCC implementation

Variables	Stage 0	Stage 1	Stage 2	Statistics	*P* value
Total of LOS	519,699	282,563	566,964	–	–
NOs of indwelling catheter	9,177	4,910	8,536	–	–
Indwelling catheter days	24,472	12,139	21,295	–	–
Ages, mean (IQR)	36.44 (27-44)	37.13 (34-41)	37.72 (28-44)	356.895	.0001
Sex, male	3,907	1537	4072	2.99	.224
Indwelling times, mean (IQR)	2.67 (1-3)	2.58 (1-3)	2.43 (1-3)	305.716	.0001
CUR, %	4.71	4.30	3.76	−24.67	<.0001
Reasonable rate of indwelling, %	61.17*	92.34	90.64	−6.137	<.0001
Daily extubation evaluation rate, %	76.06*	93.54	91.60	−2.551	.0107
Compliance rate of CAUTI control measures, %	65.43*	90.82	87.48	−2.653	.008

CUR, catheter use ratios; *IQR,* interquartile range; *LOS,* length of stay.
*The data represents the rates in the status grasping stage of QCC activities.

series analysis model. The form of the model is as follows[16]:

$$Y\_t = Beta\_0 + Beta\_1(T) + Beta\_2(X\_t) + Beta\_3(TX\_t)$$

Where Y_t is the result variable measured at each interval point t, T is the time since the study begins, X_t is the dummy variable representing the intervention (0 before the intervention, 1 otherwise), and TX_t is the interaction term. Beta_0 represents the intercept of the outcome variable. Beta_1 is the slope of the outcome variable before the intervention. Beta_2 represents the change in the level of the outcome variable immediately after the introduction of the intervention (as compared to the counterfactual case). Beta_3 represents the difference in outcome variable slope before and after the intervention. Therefore, we looked for significant *P* values in Beta_2 to indicate immediate intervention effects, or for intervention effects over time in Beta_3. Finally, the Linear combinations of parameters (lincom) were performed to estimate the postintervention trend of CAUTI.

The continuous variables accord with normal distribution were described by the means with standard deviation (SD), and non-normal distribution data were defined by the medians with interquartile range. The difference between groups was compared with the t test or Kruskal-Wallis test. The categorical variables were described by frequencies and percentages, and the trends of the 3 stages were tested by the Cochran-Armitage trend test in R statistical software (3.2.0). Statistical significance was observed at an α level of 0.05.

RESULTS

This study lasted 39 months from January 2016 to March 2019, with a total of 236,636 inpatients, including 1,369,226 inpatient days, 57,906 indwelling catheter days, 4.23% CUR, 142 cases of CAUTI occurrence, and 2.45‰ incidence of CAUTI.

There was no difference in the gender of patients with urinary catheter indwelling between stages 0, 1, and 2, but the patients in stage 1 and 2 were slightly older. From stage 0 to stage 2, the mean indwelling time and CUR both had a downward trend (2.67 days vs 2.58 days vs 2.43 days, and 4.71% vs 4.30% vs 3.76%, respectively), meanwhile reasonable catheterization rate, daily extubation evaluation rate, and total compliance rate of CAUTI prevention measures all showed an upward trend (61.17% vs 92.34% vs 90.64%, 76.06% vs 93.54% vs 91.60%, and 65.43% vs 90.82% vs 87.48%, respectively), as shown in Table 1.

The actest showed no autocorrelation of time series data with a maximum lag level of two. Therefore, a Newey-west model with lag (2) was used to analyze the data, and the results showed as follows: Before the QCC activities, the incidence of CAUTI increased by 0.299‰ per month from 0.65‰ in January 2016 and gradually increased to 5.72‰ in April 2017. In the first month after the implementation of the interventions in May 2017, the incidence of CAUTI decreased by 1.317‰, and then gradually decreased by 0.510‰ per month (relative to the preintervention trend). When the QCC activities ended, the incidence of CAUTI increased by 0.266‰ immediately and increased by 0.070‰ per month during stage 2, but the difference was not statistically significant. From the lincom estimate, after carrying out the countermeasures, the incidence of CAUTI decreased by 0.212‰ per month. During stage 1 and 2, the incidence of CAUTI decreased by 0.142‰ per month, as shown in Tables 2-4 and Fig 1.

DISCUSSION

At present, ITSA is known as the most robust quasi-experimental design used when randomized controlled trials are infeasible.[17] Box and Tiao[18] firstly proposed the analysis method of ITSA. Since ITSA mostly uses the data collected by conventional means, the comparison before and after intervention does not need a parallel comparison, and it is widely used in policies of society, drug, health, and the

Table 2
Incidence of CAUTI before and after the QCC activity

CAUTI_I	Coef.	Newey-west Std. Err.	*t*	P>|*t*|	[95% CI]	
_*t*	0.299	0.029	10.300	0.000	0.240	0.358
_x2017m5	−1.317	0.307	−4.280	0.000	−1.942	−0.691
_x_t2017m5	−0.510	0.077	−6.640	0.000	−0.667	−0.354
_x2018m1	0.266	0.399	0.670	0.510	−0.546	1.078
_x_t2018m1	0.070	0.066	1.050	0.300	−0.065	0.205
_cons	0.512	0.332	1.540	0.133	−0.163	1.187

CI, confidence interval; *Coeff, β* coefficient of the regression; *m,* month; *CAUTI_I,* incidence of CAUTI;*_t,* time since start of study; *_x(trperiod),* dummy variable representing the intervention periods (preintervention periods 0, otherwise 1); *_x_t(trperiod),* interaction of _x and _t.

Table 3
Postintervention linear trend: 2017m5

Treated: _b[_t]+_b[_x_t2017m5]						
Linear trend	Coef.	Std. Err.	*t*	P>|*t*|	[95% CI]	
Treated	−0.212	0.063	−3.385	0.002	−0.339	−0.085

CI, confidence interval; *Coeff, β* coefficient of the regression; *m,* month; *_t,* time since start of study; *_x_t(trperiod),* interaction of _x and _t.

Table 4
Postintervention linear trend: 2018m1

Treated: _b[_t]+_b[_x_t2017m5]+_b[_x_t2018m1]						
Linear trend	Coef.	Std. Err.	*t*	P>|*t*|	[95% CI]	
Treated	−0.142	0.029	−4.968	0.000	−0.200	−0.084

CI, confidence interval; *Coeff, β* coefficient of the regression; *m,* month; *_t,* time since start of study; _x_t(trperiod), interaction of _x and _t.

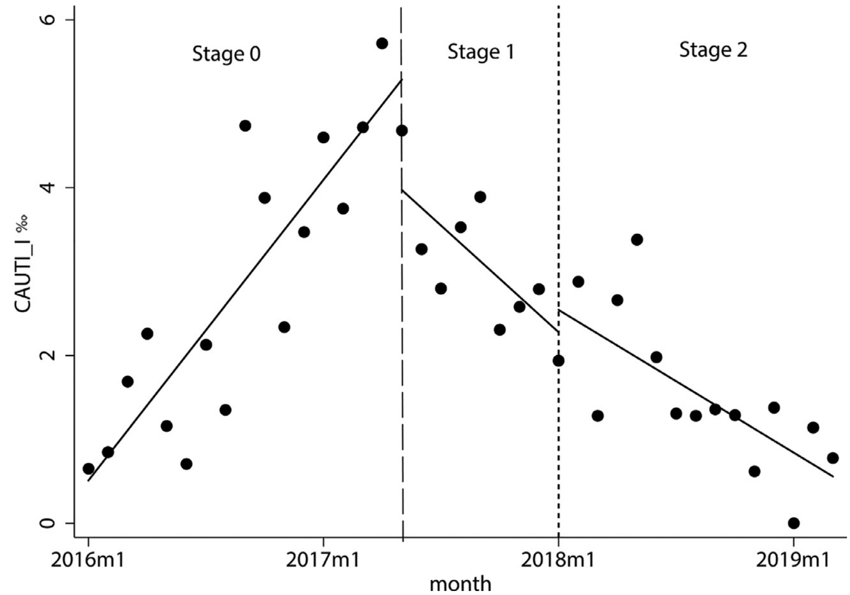

Fig 1. The monthly incidence of CAUTI from January 2016 to March 2019. The black spots show the actual incidence of CAUTI, and the full lines show the predicted trend of CAUTI incidence. The long dash vertical line represents the start of the QCC interventions (May 2017), and the short dash vertical line depicts the end of the QCC activities (Jan. 2018). The 2 vertical lines divide the time into 3 stages, which are stage 0, stage 1, and stage 2. Note. m, month; CAUTI_I, the incidence of CAUTI.

environment abroad.[19] However, in China, especially in the field of medical and health care, ITSA is still rarely known by a vast number of HCWs. Although it was a quasi-experimental study and no adequate control group was set, it controlled the rise and fall trend of the outcome variables before the interventions and still obtained relatively robust results.

In this study, the monthly incidences of CAUTI followed the characteristics of time series data,[20] and enough observations were available in both preintervention and postintervention periods. Consequently, we applied an ITSA to analyze the data. Compared with the traditional before and after comparison method of QCC effect confirmation, the ITSA can better evaluate the effectiveness of QCC interventions. Before carrying out the QCC activity, the incidence of CAUTI was in a rising trend. However, in May 2017, the QCC interventions began to apply, there was an immediate effect of 1.317‰ decrease in CAUTI, after balancing the trend before the interventions, there was a significant decrease over the time, proved that the impact of the QCC activity interventions was useful. After the QCC activity, the incidence of CAUTI increased by 0.266‰ immediately and increased by 0.070‰ over time, which may be related to the removal of some intervention measures, such as monthly review and improvement circle meeting and hierarchy training, leading to a decline in the department's attention to CAUTI. Compared with the period during the QCC activity, the declining trend of CAUTI incidence slowed down; however, we adhered to the core measures, such as monitoring and feedback. The increased tendency of CAUTI incidence after QCC activity was not statistically significant, and the general trend could still maintain declining. In addition to the gender balance, the patients in stage 1 and 2 were older than stage 0, indicating a higher risk of infection, but the incidence of CAUTI was still decreased, suggested the effectiveness of the interventions.

The use of catheters is the direct cause of CAUTI, so eliminating unnecessary indwelling catheters is the key to reduce CAUTI.[21] Current evidence-based studies reported some measures were used to minimize the CUR, such as education and training of HCWs, an automatic reminder of electronic medical orders, and automatic cessation of medical orders.[22-26] In this study, we trained the HCWs in the knowledge of CAUTI prevention through hierarchical training, and regularly monitored and verified whether the indwelling catheters were reasonable. The monitoring data showed that the reasonable indwelling rate increased from 61.17% in the status grasping stage to 92.34% at the end of the QCC activities.

Some studies indicated that indwelling catheters could form biofilms inside them, reducing the sensitivity of microorganisms to antibiotics and immune responses.[27] The longer the indwelling, the more likely that CAUTI will occur. The daily risk of CAUTI will increase by 3%-10%,[28] and about 40% of the indwelling catheter times are unnecessary.[29] Therefore, it is one of the most effective measures to reduce CAUTI to perform the daily extubation evaluation and avoid prolonged indwelling time. Thus, in addition to strengthening the training of HCWs, we enhanced the verification of evaluating extubation indications. The compliance rate of evaluation increased from 76.06% at the status grasping stage to 93.54% at the end of QCC activities. Menegueti, MG. et al[30] succeeded in reducing the incidence of CAUTI by training and daily checking the necessity of catheterization. It was similar to the interventions used in this study. Therefore, in this study, the CUR was reduced from 4.71% to 4.30% by reducing unnecessary catheter indwelling and daily evaluation of the extubation indicators to minimize the lasting time of indwelling catheters.

Monitoring the compliance rate of CAUTI prevention measures, and providing regular feedback to HCWs, were reported to be effective in reducing the incidence of CAUTI.[31-32] However, our hospital did not carry out a relevant survey previously. In this QCC activities, we used the checklists to verify the implementation of CAUTI prevention measures and fed back the results to relevant departments monthly. The compliance rate of CAUTI prevention measures increased from 65.43% to 90.82% from the status grasping stage to the end of the QCC activities. Through these countermeasures mentioned above, the incidence of CAUTI was controlled, and the target value of QCC had been reached, with the target completion rate of 107.9%. It could be said that this QCC activity achieved success.

STUDY LIMITATIONS

There are several shortcomings in this study: (1) The ITSA belongs to a quasi-experiment design. Although the trend of the outcome

variables before interventions was controlled, other confounding factors leading to the change of the outcome variables could not be controlled; (2) We administered a combination of interventions (such as a monthly review and improvement circle meetings, continuous hierarchy training, verification of CAUTI prevention measures, and feedback) that reduced the incidence of CAUTI, but it was not clear which interventions worked because they were applied at the same time; (3) This study is a single-center study, which affects the extrapolation of the research results. To further prove these measures are effective, a well-designed, multicenter, randomized controlled trial is needed.

CONCLUSIONS

In summary, this study finds the root causes of the high incidence of CAUTI through the QCC activities in our hospital. Moreover, the countermeasures are developed to deal with the causes. At last, ITSA is applied to evaluate the effect of the interventions, which proves that the implementation of QCC activities can reduce the incidence of CAUTI and provide a useful reference for the prevention and control of CAUTI and the development of medical quality improvement activities.

Acknowledgments

We want to thank the HCWs of our hospital for supporting and cooperating with our QCC activities.

References

1. Magill SS, Edwards JR, Bamberg W, et al. Multistate point-prevalence survey of health care-associated infections. *N Engl J Med*. 2014;370:1198–1208.
2. Septimus EJ, Moody J. Prevention of device-related healthcare-associated infections. *F1000Res*. 2016;5:65.
3. Ming-Hui L, Ting-Fang L. Research on the application of quality control circle in continuous improvement of medical quality. *Chin Hosp Manag*. 2012;32:38–39. [in Chinese].
4. General office of the ministry of health. *Guidelines for the Prevention and Control of Urinary Catheter-Related Infections, 2010*. 2010. Available at: http://www.gov.cn/gzdt/2010-12/14/content_1765450.htm. Accessed July 13, 2019.
5. Liu ZS, Jin DP, Chen ZH. *Management of Nosocomial Infection*. 1st ed. Bei Jin: Military Hospital Science Press; 2012. [in Chinese].
6. Fakih MG, Greene MT, Kennedy EH, et al. Introducing a population-based outcome measure to evaluate the effect of interventions to reduce catheter-associated urinary tract infection. *Am J Infect Control*. 2012;40:359–364.
7. Deng H, Shen L, Qin M, et al. A comprehensive intervention program on the long-term placement of peripherally inserted central venous catheters. *J Cancer Res Ther*. 2014;10:359–362.
8. Jiang Q, Zhang D, Majaw J, et al. Minimization of the perianal infection rate of hematological malignancies with agranulocytosis by quality control circle activity and patient-hospital-student win-win concept. *J Int Med Res*. 2018;46:2338–2345.
9. Chen P, Yuan T, Sun Q, et al. Role of quality control circle in sustained improvement of hand hygiene compliance: an observational study in a stomatology hospital in Shandong, China. *Antimicrob Resist Infect Control*. 2016;5:54.
10. Liu T. Review of QCC of Chinese hospitals. *J Chin Res Hosp*. 2015;2:24–28. [in Chinese].
11. Yan YZ, Yang HZ, Zhao JX, Xia R. A quality control circle process to reduce blood culture contamination rates. *Infect Control Hosp Epidemiol*. 2019;40:119–120.
12. Gould CV, Umscheid CA, Agarwal RK, et al. *Guideline for Prevention of Catheter-Associated Urinary Tract Infections, 2009*. 2009. Available at: https://www.cdc.gov/infectioncontrol/guidelines/cauti/index.html. Accessed January 13, 2019.
13. Feng H, Li G, Xu C, Ju C, Suo P. A quality control circle process to improve implementation effect of prevention measures for high-risk patients. *Int Wound J*. 2017;14:1094–1099.
14. Minxia XUE. Using quality control circle activities to reduce the incidence of breast distending pain in postpartum women. *Nurs Integr Tradit Chin West Med*. 2019; 5:184–187. [in Chinese].
15. Baum CF, Schaffer ME. *ACTEST: Stata module to perform cumby-huizinga general test for autocorrelation in time series*. 2013. Available at: http://ideas.repec.org/c/boc/bocode/s457668.html. Accessed January 15, 2019.
16. Linden A, Adams JL. Applying a propensity score-based weighting model to interrupted time series data: improving causal inference in programme evaluation. *J Eval Clin Pract*. 2011;17:1231–1238.
17. Penfold RB, Zhang F. Use of interrupted time series analysis in evaluating health care quality improvements. *Acad Pediatr*. 2013;13:S38–S44.
18. Hartmann DP, Gottman JM, Jones RR, et al. Interrupted time-series analysis and its application to behavioral data. *J Appl Behav Anal*. 1980;13:543–559.
19. Feng Z, Hong-Wei Y, Zhi-Zhong L, et al. Study on comparing the change of outpatient service between community health service centers and township health centers after the implementation of essential medicines system in a city of Guangxi Zhuang autonomous region. *Chin J Health Policy*. 2012;5:19–26. [in Chinese].
20. Owuor H, Amolo AS. Interrupted time series analysis of free maternity services policy in Nyamira County, Western Kenya. *PLoS One*. 2019;14: e0216158.
21. Tambyah PA, Oon J. Catheter-associated urinary tract infection. *Curr Opin Infect Dis*. 2012;25:365–370.
22. Magers, Tina L. Using evidence-based practice to reduce catheter-associated urinary tract infections. *Am J Nurs*. 2013;113:34–42.
23. Meddings J, Rogers MAM, Krein SL, et al. Reducing unnecessary urinary catheter use and other strategies to prevent catheter-associated urinary tract infection: an integrative review. *BMJ Qual Saf*. 2014;23:277.
24. Schwartz BC, Frenette C, Lee TC, et al. Novel low-resource intervention reduces urinary catheter use and associated urinary tract infections: role of outcome measure bias? *Am J Infect Control*. 2015;43:348–353.
25. Cho HJ, Khalil S, Poeran J, et al. "lose the tube": a choosing wisely initiative to reduce catheter-associated urinary tract infections in hospitalist-led inpatient units. *Am J Infect Control*. 2017;45:333–335.
26. Leis JA, Corpus C, Rahmani A, et al. Medical directive for urinary catheter removal by nurses on general medical wards. *JAMA Intern Med*. 2016;176:113–115.
27. Colomer-Winter C, Lemos JA, Flores-Mireles AL. Biofilm assays on fibrinogen-coated silicone catheters and 96-well polystyrene plates. *Bio Protoc*. 2019;9:e3196.
28. Chenoweth CE, Saint S. Urinary tract infections. *Infect Dis Clin North Am*. 2011; 25:103–115.
29. Saint S, Wiese J, Amory JK, et al. Are physicians aware of which of their patients have indwelling urinary catheters? *Am J Med*. 2000;109:476–480.
30. Menegueti MG, Ciol MA, Bellissimo-Rodrigues F, et al. Long-term prevention of catheter-associated urinary tract infections among critically ill patients through the implementation of an educational program and a daily checklist for maintenance of indwelling urinary catheters: a quasi-experimental study. *Medicine (Baltimore)*. 2019;98:e14417. Available at: https://insights.ovid.com/crossref?an=00005792-201902220-00022.
31. Jones LF, Meyrick J, Bath J, et al. Effectiveness of behavioural interventions to reduce urinary tract infections and Escherichia coli bacteraemia for older adults across all care settings: a systematic review. *J Hosp Infect*. 2019;102:200–218.
32. Navoa-Ng JA, Berba R, Rosenthal VD, et al. Impact of an International Nosocomial Infection Control Consortium multidimensional approach on catheter-associated urinary tract infections in adult intensive care units in the Philippines: International Nosocomial Infection Control Consortium (INICC) findings. *J Infect Public Health*. 2013;6:389–399.