



# Evaluation of the effects of applying the ventricular care bundle (VCB) method for reducing ventilator-associated pneumonia (VAP) in the intensive care unit of a general Chinese tertiary hospital

Weiping Liu, Yongfang Yang, Yueying Jiao, Kai Zhang, Yunting Hai, Haoxue Li, Huimin Xing, Binbin Xu, Haibo Bai, Yuping Zhao, Huan Bao, Shuai Zhang, Wei Ren, Lifang Yang, Huijun Yang, Junwei Tian, Meng Wang, Tianhui Guo

Department of Nosocomial Infection control, Inner Mongolia People's Hospital, Hohhot, China

**Contributions:** (I) Conception and design: W Liu, T Guo; (II) Administrative support: W Liu, Y Jiao, H Xing; (III) Provision of study materials or patients: K Zhang, Y Hai, J Tian, H Yang; (IV) Collection and assembly of data: B Xu, H Bai, S Zhang, H Bao, M Wang, L Yang; (V) Data analysis and interpretation: Y Zhao, Y Yang, H Li, W Ren; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

**Correspondence to:** Tianhui Guo, MPH. Department of Nosocomial Infection Control, Inner Mongolia People's Hospital, No. 20 of Zhaowuda Street, Saihan District, Hohhot 010017, China. Email: tianhui0409@126.com.

**Background:** Ventilator-associated pneumonia (VAP) is a severe complication that occurs within patients who must use ventilators in the intensive care unit (ICU). Ventilator care bundles (VCB) have been applied across many developed regions and have produced positive results in controlling VAP. In this study, we report on the implementation and effects of using VCBs to manage VAP in a general tertiary hospital in the Inner Mongolia Autonomous Region of China.

**Methods:** A targeted surveillance method was used to survey all the patients (n=4,716) in the ICU from June 1, 2017 to May 31, 2019. Patients from June 1, 2017 to May 31, 2018, and June 1, 2018, to May 31, 2019, were respectively divided into 2 groups: the control group (2,029 patients) and intervention group (2,687 patients). These dates were selected because VCB was implemented from June 1, 2018, in our institution. The variables that were associated with VCB and observed were the head-of-bed elevation, oral care, maintenance of the pressure for the cuff of the endotracheal tube, aspiration of subglottic secretion, daily sedation vacation protocol, daily extubation assessment results, and hand hygiene. After collecting the data, the compliance of VCB, ventilator use ratio, and the incidence rate of VAP in these 2 groups were compared.

**Results:** We observed that compliance with all of the intervention measures for VCB improved results in the intervention group compared to the control. Furthermore, the compliance rate of hand hygiene increased from 71.99% to 91.97%, and the head-of-bed elevation of 30°–45° increased from 62.02% to 85.96%. All differences between these two groups were statistically significant, according to the  $\chi^2$ -test. The ventilator use ratio was statistically and significantly lower in the intervention group (34.86%) compared to the control group (40.29%) ( $\chi^2=95.513$ ,  $P<0.001$ ). The incidence rate of VAP was statistically and significantly lower in the intervention group (13.70‰) compared to the control group (18.85‰) ( $\chi^2=5.471$ ,  $P=0.019$ ).

**Conclusions:** Our results show that VCB prevents VAP. Therefore, personnel training, clinical supervision, and surveillance feedback could promote a reduction in intervention measures.

**Keywords:** Bundle intervention; intensive care unit (ICU); incidence rate; ventilator-associated pneumonia (VAP)

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## Introduction

A ventilator is a commonly used medical device in the intensive care unit (ICU), and one of the most severe complications for a patient on a ventilator is ventilator-associated pneumonia (VAP). VAP increases medical costs and extends the hospital length of stay (LOS) of ICU patients (1-3). While the length of ventilator use is a risk factor for VAP, the longer hospital LOS, patient age, and chronic disease are also risk factors (4). VAP is one of the most common types of healthcare-associated infections (HAI). Patients in the ICU usually have a significantly higher chance of having HAI than non-ICU patients. It is speculated that this is because most of them have severe conditions or decreased immune function. Among all of the HAI cases in the ICU, VAP accounts for 36–60% of all of cases (5). Furthermore, 9–27% of patients on a ventilator will have VAP, and the infection rate of VAP is 1.2–8.5 cases per 1,000 days of ventilator use (6). Moreover, VAP infections can lengthen the LOS by 7–9 days (7).

VAP prevention interventions, such as oral care (5) and modified endotracheal tubes (8), could effectively reduce the chance of a VAP infection. Despite ICU patients only constituting 8% of all of the inpatients, a study conducted abroad revealed that 45% of all HAI occurred in the ICU (9). According to Vincent *et al.*, 16% of ICU patients will get infected with VAP (10). The death rate of VAP patients ranges from 24–76%, which is 2–10 times the death risk compared to non-VAP patients. As a result, VAP has become the main reason for HAI death (11). For this reason, reducing the prevalence of VAP in the ICU is a critical step for reducing HAI, improving the prognosis of patients on a ventilator in the ICU, and improving medical quality.

In 2001, the Institute for Healthcare Improvement (IHI) started to combine 4 VAP prevention interventions for ICU ventilator patients. Afterward, the ventilator bundle emerged in some studies conducted in developed countries. In 2005 Then the IHI formally published the ventilator care bundle (VCB) guidelines, which comprised 4 evidence-based VAP prevention interventions. These four methods included (I) elevating the head-of-bed by 30–45 degrees, (II) the conducting of daily sedation vacations, daily intubation and ventilation assessments, (III) peptic ulcer prevention, and (IV) deep venous thrombosis prevention (12). Bundle interventions can effectively prevent VAP infection, and these have already been broadly implemented worldwide, following the substantial results of a large number of previous studies (13–15). However, VCB has not been

accepted by healthcare practitioners in the Inner Mongolia Autonomous Region, which is a border region of China. Inner Mongolia People's Hospital has required clinical healthcare practitioners to use VCB in all 6 ICUs since June 1, 2018. Our study is observational and compares the data from and before and after VCB implementation. We also concluded the value of implementing the bundle method.

In this study, 6 ICUs from different departments of a general tertiary hospital were selected for study to discuss the clinical value of the bundle intervention method in VAP prevention. The rates of interventions in the bundle before and after implementation were compared.

We present the following article in accordance with the STROBE Reporting Checklist (available at <http://dx.doi.org/10.21037/apm-20-289>).

## Methods

### *Surveillance objectives*

Surveillance was performed on all patients in the 6 ICUs (general ICU, cardiovascular medicine ICU, neurology ICU, respiratory ICU, neurosurgery ICU, and cardiovascular surgery ICU) of a general tertiary hospital in the Inner Mongolia Autonomous Region of China from June 1, 2017 to May 31, 2019. Patients from June 1, 2017 to May 31, 2018, were assigned as the control group, while patients from June 1, 2018 to May 31, 2019, were assigned as the intervention group. The study was approved by the Ethics Board of Inner Mongolia People's Hospital (No. 202000103L) and conducted in accordance with the Declaration of Helsinki. Since this study did not involving any patient's personal information and only medical record has been used in this study, informed consent is not required in this study.

### *Surveillance method*

As a result of VCB not being widely accepted in the Inner Mongolia People's Hospital or the coverage regions, adverse medical care consequences for ventilator patients had occurred. Therefore, Inner Mongolia People's Hospital decided to require the clinical implementation of VCB since June 1, 2018. The implementation included the condition of requiring a medical quality assessment in the ICU department, which is managed by HAI practitioners.

The target surveillance method was used to perform a daily survey of all mechanical ventilator patients in the

6 ICUs, according to the hospital-associated infection surveillance standards guidelines (16). A patient discharged from the ICU would be followed up for 48 hours after. All surveillance procedures were completed by the HAI practitioners from the Nosocomial Infection Department. They conducted an on-site observation of the performance conditions of the VAP intervention strategy in the ICU twice a week and recorded the findings. ICU nurses were responsible for filling in the ICU patient's daily record and the HAI case questionnaire based on the HAI patient's actual condition. The VAP diagnosis standard was based on the "VAP prevention, diagnosis and treatment guideline" published by the Intensive Care Branch of the Chinese Medical Association in 2013 (17).

### *Intervention measure*

The VCB used in the present study was based on the "HAI prevention and control guidelines in ICU" (WS/T509-2016) and other related evidence (18,19). The VCB used in the present study included 8 interventions: head-of-bed elevation of 30–45 degrees, oral care with chlorhexidine 3–4 times per day, adherence to aseptic technique operations and hand hygiene guidelines, continuous evaluation of aspiration of subglottic secretion, maintenance of the cuff of the endotracheal tube with 25–30 cm of H<sub>2</sub>O, the conducting of daily sedation vacation, and the conducting of daily intubation and ventilation use assessments.

### *Evaluation indicator*

- (I) The demographic information, including age, gender, chronic disease status, and surgical operations performed on the patient, in the intervention and control groups, were collected.
- (II) Appendix D of the "Standard for nosocomial infection surveillance" published by the Ministry of Health (16) was used in the data collection strategy to calculate the patient's acute physiology and chronic health evaluation II (APACHEII) scores. Data on the ratio of ventilation use and incidence rate of VAP were also collected. The calculation equations are listed below:
  - ❖ The ratio of use of ventilation = total number of ventilation use days/the total LOS of the patient ×100%;
  - ❖ The incidence rate of VAP = VAP infected patient number/the total number of ventilation use days ×100%;

- ❖ Hand hygiene compliance = actual times of hand hygiene performance/supposed times of hand hygiene performance ×100%;
- ❖ Performance ratio of a head-of-bed elevation of 30° = person-days of a head-of-bed elevation of 30°/the total number of ventilation use days ×100%;
- ❖ Performance ratio of oral care >3 times = person-day of oral care >3 times per day/total number of ventilation use days ×100%;
- ❖ Performance ratio of continuous aspiration of subglottic secretion = person-days of continuous aspiration of subglottic secretion/the total number of ventilation-use days ×100%;
- ❖ Performance ratio of extubation assessment = person-days of extubation assessment/the total number of ventilation-use days ×100%.

### *Statistical analysis*

SPSS 19.0 software was used to conduct the statistical analysis, while an  $\chi^2$ -test was used to compare the enumeration data between the 2 groups. A P value <0.05 was considered statistically significant.

## **Results**

### *Demographic information*

Four thousand seven hundred and sixteen patients underwent surveillance. Two thousand six hundred and eighty-seven patients were assigned to the intervention group, and 2,029 patients were assigned to the control group. The differences in gender, age, chronic disease, and surgical operation of patients in these two groups were not statistically significant ( $P>0.05$ ); therefore, these two groups are comparable (*Table 1*).

### *Compliance of VCB*

Hand hygiene compliance, the performance ratio of head-of-bed elevation of 30–45 degrees, performance ratio of oral care >3 times per day, the performance ratio of adhering to the management of the cuff of the endotracheal tube, the performance ratio of continuous aspiration of subglottic secretion measurement, the performance ratio of undergoing sedation vacation, and the performance ratio of extubation assessment all increased after the VCB was

**Table 1** Demographic information of the patient in two groups

Demographic information	Intervention group	Control group	$\chi^2$	P
Gender				
Male	1,436	1,047	1.571	0.210
Female	1,251	982		
Age (years old)				
>65	1,462	1,138	1.314	0.252
≤65	1,225	891		
Chronic disease				
Yes	1,447	1,122	0.975	0.323
No	1,240	907		
Operation				
Yes	1,378	1,019	0.522	0.470
No	1,309	1,010		

**Table 2** Compliance comparison of before and after VCB implementation

Measure	Intervention group, n (%)	Control group, n (%)	$\chi^2$	P
Hand hygiene	2,665/3,702 (71.99)	2,634/2,864 (91.97)	413.982	<0.001
Head-of-bed elevation	1,148/1,851 (62.02)	1,231/1,432 (85.96)	231.964	<0.001
Oral care	1,238/1,876 (65.99)	1,232/1,450 (84.97)	154.054	<0.001
Maintain endotracheal tube cuff pressure	1,088/1,860 (58.49)	1,225/1,442 (84.95)	270.994	<0.001
Aspiration of subglottic secretion	1,458/1,870 (77.97)	1,330/1,446 (91.98)	119.556	<0.001
Sedation vacation	1,243/1,866 (66.61)	1,350/1,444 (93.49)	151.735	<0.001
Extubation assessment	1,344/1,868 (71.95)	1,343/1,445 (92.94)	234.291	<0.001

VCB, ventricular care bundle.

implemented. All differences between the two groups were statistically significant ( $P < 0.001$ ), according to the  $\chi^2$ -test (Table 2).

### Ventilation use and VAP infection

The ventilation use ratio in the intervention group was 34.86%, which was statistically lower than in the control group (40.29%) ( $\chi^2 = 95.513$ ,  $P < 0.001$ ). Furthermore, the incidence rate of VAP in the intervention group was 13.70‰, which was statistically lower than in the control group (18.85‰) ( $\chi^2 = 5.471$ ,  $P = 0.019$ ; Table 3).

## Discussion

### VAP prevention and control measures

The VCB method is a collection of evidence-based interventions that focus on ventilator patient care and treatment. The VCB used in the present study was based on the detailed guidelines set domestically and internationally that factored in the variables of the study's hospitals. Improving the prognosis and reducing the incidence rate of VAP is the goal of VCB. The surveillance of the VCB implementation process and increasing the compliance to VCB was achieved during its implementation. A study

**Table 3** Before and after intervention ventilation use and VAP infection rates

Group/statistics	Surveillance case	LOS (stays)	Ventilation use days	Ventilation use ratio (%)	VAP incidence rate (‰, case)
Intervention group	2,687	1,8838	6,567	34.86	13.70 [90]
Control group	2,029	12,598	5,076	40.29	18.85 [98]
$\chi^2$	–	–	–	95.513	5.471
P	–	–	–	<0.001	0.019

VAP, ventilator-associated pneumonia; LOS, length of stay.

revealed that compliance to VAP prevention compared to the control, bundle intervention strategy increased the results from 82.06% in 2012 to 96.88% in 2013, and the VAP infection rate decreased from 32.72% in 2012 to 24.60% in 2013 (20). In this study, the full-time professionals from the Nosocomial Management Department, the director of the ICU, and the head nurse supervised compliance to VCB implementation. Feedback on its implementation was communicated to all healthcare workers (HCWs) of the ICU Department to improve the VCB implementation conditions. As a result, the compliance rate of all measures significantly increased after this implementation strategy.

Hand hygiene is always accompanied by other measures for preventing and controlling VAP. According to a study on basic prevention measures, including hand hygiene, in eight pediatric intensive care unit (PICUs) in five developing countries, the compliance of hand hygiene increased from 48.9% to 67.1% after implementing a series of prevention measures. As a result of this implementation, the incidence rate of VAP decreased from 11.7 per 1,000 ventilation use days to 8.1 per 1,000 ventilation use days (13). The increased compliance of hand hygiene is beneficial for reducing the incidence rate of VAP. As well as being an important variable in HAI prevention, hand hygiene is also a vital variable in VAP.

The patient's body position is also an important variable for VAP infection. A prospective study on VAP prevention from 1966 to 2001 revealed that the half supine position is the best position for VAP prevention. The evidence for this is strong, and all ventilator patients should choose the half supine position when there are no contraindications (21). These guidelines require that the cephalothorax of the patient should be elevated at 30°–45° when there are no contraindications. During the present implementation period, the HCWs found a convenient method for easily meeting this elevation requirement. The method was done by conspicuously marking the 30°

and 45° elevation position on one side of the head-of-bed previously measured by a protractor. The HCWs elevated the head-of-bed between two marks on the side of the bed, achieving an elevation angle within 30°–45°. Through this approach, HCWs do not need to measure the elevation angle every single time the head needs to be elevated. The mark that was previously made could also help other HCWs easily find the right angle of the head-of-bed elevation quickly. The reasons for the low compliance of head-of-bed elevation included a lack of awareness of the benefits of the half supine position, the lack of execution responsibility, and the lack of practice feasibility and ignorance of this strategy. As for the nurses, they concluded that the doctors did not provide clear enough instructions for adjusting the head-of-bed elevation, which is the main reason for the low compliance since nurses always adhere strictly to the instructions of the doctor. Therefore, doctors should provide clear instructions for setting the head-of-bed elevation during the execution of this strategy. Although the importance of the head-of-bed elevation being constantly pushed during the complement period, the compliance rates were still not high since this intervention burdened the workload of the nurses, in which the half supine position of the patient required more care work than the supine position. Therefore, the nurses on duty should all take responsibility for executing the head-of-bed elevation and reprimand non-executing nurses for ensuring compliance.

The establishment of artificial airways breaks the oral and nasal vessel's natural barriers against bacteria. Hence, strict, and effective oral care in ventilation is needed for the patient to protect their airway. Substantial evidence has revealed that comprehensive oral care, a part of the VCB, could reduce the incidence rate of VAP. A meta-analysis of 2,341 adult patients across 12 studies using chlorhexidine to prevent VAP in their oral care procedure had a reduced risk of VAP (22). Oral care >3 times per day using chlorhexidine was required in the present study. Chlorhexidine has low



irritation and strong broad-spectrum bactericidal effects, which is effective against gram-negative and positive bacteria. Furthermore, chlorhexidine has a positive charge, which can absorb the negative charge in dental plaque and other bacteria in the oral mucosa surface during oral care procedure producing a gradual and persistent anti-bacterial effect.

Aspiration prevention is also an important strategy for preventing VAP. Presently, the maintenance of endotracheal tube cuff pressure is a widely used clinical prevention strategy. According to the “Practical guidelines for mechanical ventilation published by the Society of Critical Care Medicine, Chinese Medical Association” in 2006 (23), the pressure of the artificial airway of the endotracheal tube should undergo routine surveillance. The pressure should be maintained between 25 to 30 cmH<sub>2</sub>O, and high-volume low-pressure should be maintained. These would enclose not only the airway, but it would simultaneously also maintain a pressure that is not higher than the perfusion pressure of the airway mucous blood capillary. Furthermore, this could also prevent airway mucosa ischemic injury, trachea-esophageal fistula, tracheostenosis after extubation, and other complications. It has been demonstrated that under-inflation of the balloon and low pressure cannot effectively enclose the space between the balloon and airway, leading to secretions above the balloon. The secretions would enter the lower respiratory tract and increase the risk of a pneumonia infection. Another study revealed that compared to staggered surveillance, constant surveillance of the endotracheal cuff pressure and maintaining it at 25 cmH<sub>2</sub>O could effectively reduce the incidence rate of VAP (24). Equipping an endotracheal pressure detector in the ICU and having constant surveillance allowed for the compliance of endotracheal cuff pressure to increase from 65.99% to 84.97%.

For patients using an indwelling ventilator catheter, secretions in the upper respiratory tract could gather above the balloon of the ventilator catheter leading to local bacteria reproduction. Then, secretions could follow the respiratory tract and enter the lungs, causing a pulmonary infection. Therefore, aspiration of subglottic secretion could effectively reduce pulmonary infection rates (25-27). Another study showed that constant subglottic secretion aspiration could reduce the incidence rate of VAP, shorten the length of ventilation use time, shorten the LOS while having no obvious adverse reactions, and good patient tolerance (28).

Constant intravenous injection sedation could increase

ventilation use time and LOS. Therefore, a sedation vacation is recommended, including the VCB for VAP prevention. A clinical randomized control trial of 128 patients receiving mechanical ventilation in ICU showed that the implementation of awakening the patients daily as a sedation vacation in the morning and extubation every day resulted in the reduction of the average ventilation use time from 7.3 to 4.9 days ( $P=0.004$ ) and shortened the LOS from 9.9 to 4.9 days ( $P=0.02$ ). The incidence rate of VAP and medical costs was also reduced due to daily awakening (29). Sedation vacation is useful in preventing VAP and is a necessary component of the VCB.

Invasive ventilation needs to open the airway resulting in a higher chance of pathogen bacteria being introduced to the lower respiratory tract. Prolonged ventilation use time also increases the risk of lower respiratory tract infections that causes a VAP infection. A study showed that the chance of VAP infection increased with longer ventilation use time. Further, it has been demonstrated that ventilation use time is an independent risk factor in VAP infection (30). The reason for this could be longer ventilation use time, longer airway open time, more invasive of operation, a higher chance of infection by a contaminated ventilator, and a higher risk of getting ventilation related complications. Therefore, the doctor should assess daily the necessity of ventilation and intubation use. Extubation should be performed as soon as the patient meets the extubation requirement to reduce ventilation use time.

### *Obvious effects of VCB in preventing VAP*

VCB is a group of intervention measures based on evidence-based guidelines. The implementation of these strategies altogether has better VAP prevention effects compared to only single intervention measure implementation. An American multi-center cohort study of mechanical ventilation bundle intervention measures showed that compliance with the bundle techniques increased from 32% to 84% and the overall incidence rate of VAP reduced from 5.5% to 0.0% after 30 months. These techniques included head-of-bed elevation, stress ulcer prevention, deep venous thrombosis prevention, sedation vacation, and extubation assessment (15). The choice of using all interventions of the VCB in this study is based not only on literature evidence but also on real clinical situations. The head-of-bed elevation, oral care techniques, maintaining endotracheal tube cuff pressure, the aspiration of subglottic secretion, daily sedation vacation, daily extubation assessment, and

hand hygiene supervision surveillance were chosen in our VCB. After one year of implementation, the incidence rate of VAP and the ventilator-used ratio had a significant reduction compared to before implementation showing that VCB in this study has a significant effect of reducing VAP infection in ICU.

### *VCB promotion by personnel training and supervision feedback*

VCB is a new strategy for VAP prevention and control, and it could significantly reduce the incidence rate of VAP based on the existing evidence. However, HCW's compliance in using VCB methods should be paid more attention to enhancing the effectiveness of every step in achieving prevention purposes (31). Therefore, training the related HCWs before implementation is suggested to educate them on the importance of VCB and to implement it better. Detailed quality control standards should be made before implementation, and efficient managers should be in charge as the director of the department and as the chief nurse. The Director of the department and chief nurse should regularly evaluate the situation, gain valuable feedback, and improve the implementation as needed (32). During the VCB implementation period, a supervision evaluation chart should be used to record the implementation and the conditions of every intervention measure for achieving explicit purposes and significant effects. Continued surveillance and feedback could also significantly improve HCW's awareness and help them to execute HAI prevention and control methods better. A Chinese study investigated VAP patients in general ICUs when compliance with VCB increased, mechanical ventilation use days decreased after training the ICU HCW (33). In this study, clinical HCW received HAI surveillance data every month and compared the reported data from home and abroad, which let HCW quantize the effect of prevention and control, and see the difference in real-time. These reports give the HCWs a direct understanding of VAP's urgent status in their department and to further enhance awareness for prevention and control.

### **Conclusions**

In conclusion, head-of-bed elevation, oral care, maintaining endotracheal tube cuff pressure, aspiration of subglottic secretion, daily sedation vacation, daily extubation assessment, hand hygiene, and supplemented surveillance

feedback and supervision of the VCB implementation could effectively reduce the incidence rate of VAP in our studied hospital. However, this study is only limited to one hospital. Since every hospital has different basic measures of VAP prevention and control in their ICU, extrapolating this result in larger scenarios needs further research.

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### **Footnote**

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was

approved by the Ethics Board of Inner Mongolia People's Hospital (No. 202000103L) and conducted in accordance with the Declaration of Helsinki. Since this study did not involving any patient's personal information and only medical record has been used in this study, informed consent is not required in this study.

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