

# Ventilator Bundle Compliance: Report from a Neurosurgical Intensive Care Unit

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## Abstract

**Objective and Setting:** Ventilator associated pneumonia (VAP) is the leading cause of mortality of hospital-acquired infections. One strategy for addressing this issue has been the ventilator bundle. This intervention was implemented in the University District Hospital (UDH) as part of an initiative to improve health care in the neurosurgical intensive care unit (NSICU) of an academic centre.

**Design and Interventions:** From July 2007 to December 2007 educational strategies consisting of monthly lectures, bed pamphlets and card reminders were used to educate the health care team. Ventilator bundle intervention compliance was evaluated daily in random shifts during a 14-day period during July-August 2007 and December 2007.

**Measurements and Results:** Pre-educational compliance was recorded at 6%. Individual component compliance was (1) Head of bed (HOB) $>30^\circ$  - 14%, (2) Withdrawal of sedation - 67%, (3) Peptic ulcer (PUD) prophylaxis - 93%, (4) Deep venous thrombosis (DVT) prophylaxis - 87%. Post-educational compliance was 59% with individual compliances of 74%, 72%, 95%, 92% respectively. A statistically significant increase in compliance was observed in ventilator bundle compliance and HOB elevation ( $p<0.01$ ).

**Conclusions:** A simple educational strategy can improve compliance of the ventilator bundle. This in turn and although not demonstrated can subsequently effect the mortality of patients. Collaborative work between team members of the unit is the key to compliance.

**Key words:** Ventilator bundle, pneumonia, compliance, education.

## Introduction

Respiratory failure caused by a deficit in ventilation, is characterized by an increased arterial carbon dioxide tension, or lack of oxygenation, and by decreasing the arterial oxygen

tension. The treatment for respiratory failure includes augmentation of the patient's alveolar ventilation, oxygen supplementation and reversing the cause of this condition. By the other hand invasive or non-invasive mechanical ventilation can also be used. In doing so, patients may become in risk not to have only air, but also microorganisms, or foreign particles into their lungs. Weaning a patient from full or partial ventilatory support to unassisted spontaneous ventilation requires a meticulous evaluation of various factors. (1) First, the nature and severity of the underlying disease leading to respiratory failure; second, the type of ventilatory mode used to support the respiratory failure episode, and third, the methods of weaning ventilation from full support to unassisted ventilation. Even for experts in the

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field in many cases the transition to unassisted spontaneous ventilation seems difficult, leading to a ventilatory support greater than 48 hours. Post-anesthetic phase, chronic cardiopulmonary disorders, significant trauma, multisystem organ failure, psychological factors and ventilator-associated pneumonia are among the factors contributing to extended mechanical ventilation.

Ventilator-associated pneumonia (VAP) is an infection of the lung parenchyma following intubation and mechanical ventilation for at least 48 hours. (2,3) The number of VAP per 1000 ventilator days is the standard measure for surveillance by the CDC, and are outlined in the CDC Guidelines: MMWR Mar 26, 2004; 53(RR-3): 1-179. The exact incidence varies based on the population evaluated; (4) in heart surgery patients the frequency was reported as 34.5, on a coronary care unit 45.3, on a burns intensive care unit (ICU) 26, on a pediatric ICU 18.7, and between 8.0 and 46.3 episodes per 1000 days of mechanical ventilation on mixed medical/surgical ICUs. Ventilator-associated pneumonia occurs in 9-27% of all intubated patients (5,6) and 28 to 40% of patients with brain injury develop this condition. (7) The risk of VAP is higher in the early course of hospital stay, is estimated to be 3%/day during the first 5 days, decreasing to 2% during days 5-10 of mechanical ventilation and to 1% afterwards. (8)

Among hospital-acquired infections VAP is the leading cause of death, exceeding the rate of death due to central line infections, severe sepsis, and respiratory tract infections in the non-intubated patient. (9) Hospital mortality of ventilated patients who develop VAP is 46%, in comparison with the 32% of ventilated patients who do not develop VAP. (6,9,10) It has been reported that patients with VAP have significantly longer stays in the ICU (26 vs 4 days) and in the hospital (38 vs 13 days) than uninfected patients. (6,11) Consequently, patients with VAP have higher crude hospital costs (US\$ 70,568 vs US\$ 21,620) than uninfected patients, even after adjusting for the underlying severity of their illness (attributable cost of VAP is approximately US\$ 11,897). (3)

Prevention strategies for VAP are concerned with minimizing invasive mechanical ventilation. For those needing long term ventilator use, VAP prevention has brought up

controversies, in part because there is so much debate over which clinical interventions are effective. Also, there are various differences on prevention based on health systems and hospital preferences.

Care bundles, in general, are groupings of best practices supported by evidence strategies with respect to a disease process that individually improves care, but when applied together result in substantially greater improvement. Based on publications from the Centers for Disease Control and Prevention in 1994 (12) and the American Thoracic Society in 1995, (13) The National Canadian ICU Patient Safety Collaborative began promoting bundles of interventions. (14) Later, a Boston-based group bundled four interventions that combined could improve outcomes for mechanically ventilated patients. (15)

The key components of the ventilator bundle are:

1. Elevation of the head of the bed (HOB).
2. Daily sedation vacation and assessment of readiness to extubate.
3. Peptic ulcer disease (PUD) prophylaxis.
4. Deep venous thrombosis (DVT) prophylaxis.

Various healthcare organizations have begun to promote the use of bundles, including the ventilator bundle, to reduce the morbidity and mortality in health facilities. The Institute for Healthcare Improvement (IHI) has placed VAP as one of six areas that hospitals can address to reduce inpatient morbidity and mortality. (15) The adequate total compliance according to IHI is 95%. Recent data observed an average 45% reduction in the incidence of VAP in a recent ICU collaborative improvement project at IHI. (16) Some hospitals have even reported no VAP for several months. To our knowledge, there is no available data concerning the implementation of the ventilator bundle in a NSICU. Our goal, and based on IHI ventilator bundle protocols, is to assess compliance for all elements of the ventilator bundle in the NSICU. This intervention was implemented in the University District Hospital (UDH) as part of an initiative to improve health.

## Materials and Methods

At UDH, they count with an 18-bed state of the art NSICU providing critical care services for patients admitted to the neurosurgery service of a tertiary care academic referral center. The hospital currently operates 232 beds and is part of a large government based medical centre, which includes a level I trauma centre. Care in the NSICU is provided concurrently by the neurosurgery service which counts with 11 neurosurgeons, 1 critical care attending, 1 neurosurgical resident, 1 internal medicine resident, approximately 6-7 dedicated registered nurses and 3-4 licensed practice nurses per shift, a clinical pharmacist, one registered dietician, and a respiratory therapist who provides 24 hr coverage. This study had the approval of the Institutional Review Board.

### *Team preparation*

The NSICU team was first educated on the ventilator bundle protocols via lectures, pamphlets and reminder cards for a period of 1 week. The following month, compliance of ventilator bundle was assessed weekly on random days and alternate shifts. Days and shifts assessed were rotated. Feedback via graph reports was given to the nursing staff and their supervisor.

### *Patient population*

A total of 188 interventions were recorded; 102 pre-educational and 86 post-educational. All patients in the NSICU who were on mechanical ventilation during the study time were included with the exception of patients on barbiturate coma, paralyzing agents and cervical traction. Patients on barbiturate coma and paralyzing agents could have had a negative effect in their management if the full bundle was applied. On the other hand, patients with cervical traction are not allowed to have the head of bed elevated because of the instability caused by this strategy. For those patients only partial application of the bundle was performed.

### *Data collection pla*

During a period of 2 weeks, from July-August 2007 and

December 2007, patients on mechanical ventilation were assessed for full compliance with the ventilator bundle. Assessments were performed for 14 consecutive days prior to promoting the bundles and for 14 days after the educational promotion of the bundle. The time between pre and post-educational assessments was 4 months. One missing component made the case non compliant with the bundle. Evaluation was performed from observation at the bedside, and reviews of the medication records and medical chart.

Calculations of weekly measures were made as follows:

(Number of ICU patients on mechanical ventilation who received all four elements of the ventilator bundle) / (Total number of eligible NSICU patients on mechanical ventilation on the day of the week of sample).

Statistical analysis was performed using a Pearson Chi-Square test with statistics program of MatLab Software.

## Results

### *Ventilator bundle compliance*

Ventilator bundle compliance pre-educational was 6%. The ventilator bundle was followed adequately in 59% of the cases post-educational. This represents a 53% increase ( $p < 0.01$ ) with a relative risk (RR) of 0.43 and an Odd's ratio (OR) of 0.04 (**Table 1, Figure 1**).

### *Head of bed elevation*

In the pre-educational component we found that 14% of cases evaluated were compliant with the elevation of the bed at or more than 30° from the horizontal plane. Following the educational strategies 74% of the cases were compliant to HOB elevation with an increase in 60% ( $p < 0.01$ ). The RR and OR for head of bed elevation non-compliance was 0.30 and 0.05 respectively (**Table 1, Figure 1**).

### *Sedation vacation*

Sedation vacation compliance was noticed to be 67% pre-

educationally and 72% showed compliance post educational with 5% increase ( $p>0.05$ ). A RR of 0.84 and OR of 0.77 was calculated (**Table 1, Figure 1**).

#### *PUD prophylaxis*

PUD prophylaxis was 93% pre-educational and 95% post educational, with an increase of 2% ( $p>0.05$ ). The RR was 0.68 and OR of 0.66 (**Table 1, Figure 1**).

#### *DVT prophylaxis*

DVT prophylaxis 87% pre-educational and post-educational compliance of 92%, a 5% increase ( $p>0.05$ ). The RR was 0.64 and OR of 0.61 (**Table 1, Figure 1**).

### **Discussion**

After the education sessions, the team performed better on all of the items tested. The area with most significant improvement was the elevation of the HOB that increased 60%, from a compliance of 14% to a post-educational of 74%, ( $p<0.01$ ). This result is similar to the results from Tolentino-Delosreyes et al, (17) who also found HOB elevation to be the one with the most post-educational improvement. The rest of the items evaluated did not have a significant change in compliance.

The experience of IHI teams has demonstrated improvement when the process is more frequent. The IHI defines compliance as the percentage of intensive care patients on mechanical ventilator for whom all four of the elements are daily documented. If a bundle element is contraindicated for a particular reason, it should be documented, making the patient compliant for that particular case. We did not include the patients that were in barbiturate coma or in paralyzing agent for the management of increased intracranial pressure because holding these agents might have led to a detrimental outcome of the primary condition. On the other hand, we did not want to include a “default” compliance to our initial implementation and education phase as suggested by the IHI. This led us to obtain a “true” compliance on the initial phase.

The success of ventilator bundle is highly linked to adherence and compliance from every part of the team to every element of the bundle. Health care team compliance rates vary between 30 and 64%. (8) In our experience 6% pre education compliance and 59% post education compliance was observed which represent a 53% increase with educational strategies. The focus should be addressing modifiable risk factors. Through our study, we found that there was a lack of knowledge in regard to the bundle education, and adequate charting from both medical and nursing staff are among the most common factors that could be modified. Other factors that can contribute to decrease compliance in a setting like ours are the economic limitations of our health care system. Compliance has not only been linked to decrease incidence of VAP, but also protecting patients from developing peptic ulcers, and deep venous thrombosis.

Post educational results demonstrate a considerable ( $p<0.01$ ) improvement in all aspects of the ventilator bundle that signifies the efficacy of educational strategies in the implementation of care bundle in an ICU. Even though total compliance was sub optimal as the adequate threshold is 95% total compliance, a 53% increase that is statistically significant ( $p<0.01$ ) in total compliance is in adequate pace for more improvement with time (**Figure 1**). In Youngquist et al, a 1 year period was needed for 100% compliance in an intensive care unit. We improved up to 59% of total compliance within 4 months.

The elevation of the head of bed is an integral part of the ventilator bundle. The reason for this positioning is to allow the lungs to expand more easily and discourage the pooling of secretions. (18) Also, patients should be cared for in the semi-recumbent position to reduce the extent of aspiration, especially while receiving enteral feedings. Radionuclide studies revealed increased tracheal penetration of gastric contents when intubated patients are supine. (19-21) Some studies suggest the head of bed to be  $>45^\circ$  from the horizontal plane. In our unit the head of bed positioning, on intubated patients, is ordered to be  $>30^\circ$  at all times. Some exceptions are the patients that were kept on traction for the management of cervical spine instability. Patients on cervical traction are kept flat on bed. In view on the effect on HOB compliance and the total compliance these patients were withdrawn from the study as mentioned above.

The initial results presented a worrisome fact that the ventilator bundle was not being implemented adequately to its full extent. These results may represent the lack of adequate knowledge and its consequence on ventilator bundle compliance. We found that via education of the team, the awareness and compliance of the bundle improved considerably. Of interest, the area of head of bed elevation that in neurosurgical units is of extreme importance due to improvement of adequate cerebrospinal fluid (CSF) circulation allowing adequate pressure gradients for dural sinuses drainage into the internal jugular vein. Thus, pressure gradient may help improve not only the mental status but also the respiratory function.

Daily sedation vacation and assessing the readiness to extubate have become an integral part of the ventilator bundle. Two trials conducted in adult patients on mechanical ventilation, where randomized interruption of sedation irrespective of clinical status, resulted in significant reduction in time on mechanical ventilation. (22,23) We found that sedation vacation increased 5%, from a compliance of 67% to 72% ( $p > 0.05$ ). Unnecessary sedation predisposes the patient to a longer ventilator dependent period as deconditioning ensues and extubation capacity diminishes. Stressing adequate daily ordering and charting from both medical and nursing staff is of weight for the full compliance of this item.

Peptic ulcer disease prophylaxis in critically ill patients is necessary for the adequate maintenance of the gastric mucosa and barrier. Disruption of this delicate homeostasis could lead to translocation of bacteria that could eventually predispose the patient to sepsis and multiple organ failure. (24) Despite the small improvement in compliance, only 2% increase on compliance, this was the only component of the bundle to have reached the 95% threshold. The small percentage of non compliance was due to unavailability of the medication. This brings the point of how much does an institution influences the compliance of a bundle and hence the cost of the management of a critical patient.

Deep venous thrombosis (DVT) is of utmost importance in mechanically ventilated patients. The emergence of a DVT in neurosurgical patients represents a complex dilemma as sometimes these patients cannot be started on anticoagulant therapy due to its inherent risks. DVT prophylaxis' main purpose is to prevent a pulmonary embolism that although is

not always mortal, interfering with the adequate ventilation-perfusion match that exists in the pulmonary system. Any disruption whatsoever of this delicate balance presents a perfect environment for the development of poor perfusion and subsequent complications in mechanically ventilated patients. In our institution we observed an improvement of 5% ( $p > 0.05$ ). Although a not statistically significant change is seen, DVT prophylaxis was adequate in a single point in time reflecting that this point is being acknowledged as an integral part by the care team. It is imperative to stress that all neurosurgical patients must receive DVT prophylaxis. In our institution non-compliance was the result of delay in properly acquiring the DVT garments for patients and not due to lack of personnel knowledge. At our institution DVT garments are bought at expenses of patients or family members, some of which have economic limitations. Lately and to counteract this fact, we have started to be more aggressive and implement earlier the use of prophylactic anticoagulants on selected patients.

Although all 4 components of the ventilator bundle showed increased compliance after educational strategies, 3 of them (sedation vacation, PUD prophylaxis and DVT prophylaxis) were not statistically significant changes. In the more broad statement the utmost importance is the compliance of the ventilator bundle as a whole that demonstrated a statistically significant change of 53%. Also a risk ratio of 0.43 demonstrated that the likelihood of non-compliance after intervention remains low. An odds ratio (OR) for ventilator bundle compliance showed an OR of 0.04 which also shows that it is highly unlikely that non-compliance of the ventilator bundle occurs.

Thorough analysis of the study demonstrate how simple educational strategies such as conferences and poster reminders improved the ventilator bundle compliance and as result it reduced the incidence of ventilator associated pneumonia in an intensive care unit. A more directed strategy could be employed for an optimization of compliance such as pre-entered orders with the components of the ventilator bundle and multiple independent daily checks for assessment of unit compliance.

Changing behavioral culture of all team members helps to the improvement in reducing the rate of VAP. Education of nurses, residents, and attending physicians as well as

frequent reinforcement and reeducation are a must in the process to improve the rates of VAP and maintain the momentum for change.

### Conclusions

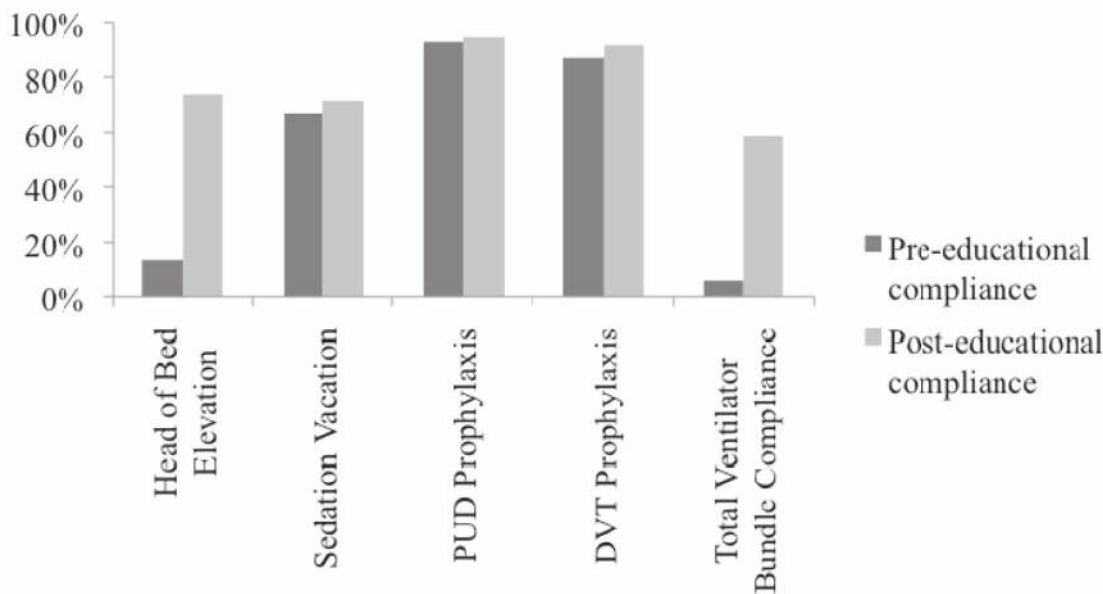
The ventilator bundle represents an innovative approach towards prevention rather than treatment of an entity. Furthermore, the prevention of such complication in a NSICU would prevent a “second hit” scenario in patients with significant morbidity. Analysis of the present results indicates that a simple educational strategy could improve the compliance of the ventilator bundle in an ICU. It is

essential to state that the adequacy of a care bundle requires a multi-disciplinary approach and demands the development of teamwork necessary to improve reliability. Ventilator associated pneumonia represents a potentially disastrous consequence of mechanical ventilation. Although measuring VAP incidence was not the scope of this study, our ultimate goal is to evaluate the influence on the incidence of VAP. This task requires a concerted effort on the part of hospital administration, physicians, and ICU personnel. As part of an ongoing effort to establish the ventilator bundle, unit protocols and educational strategies must be developed to improve knowledge and acceptance from collaborative team and hence, enhance total compliance. Our next step is to evaluate the impact of compliance to the ventilator bundle on VAP in the neurosurgical intensive care unit.

**Table 1.** Ventilator Bundle Compliance

<b>Component</b>	<b>Pre-Educational Compliance</b>	<b>Post-Educational Compliance</b>	<b>Δ</b>	<b>RR</b>	<b>OR</b>	<b>p value</b>
HOB>30°	14%	74%	+60%	0.30	0.05	<0.01
Sedation vacation	67%	72%	+5%	0.84	0.77	>0.05
PUD prophylaxis	93%	95%	+2%	0.68	0.66	>0.05
DVT prophylaxis	87%	92%	+5%	0.64	0.61	>0.05
Total compliance	6%	59%	+53%	0.43	0.04	<0.01

**Figure 1. Ventilator Bundle Compliance**



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