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# Successful Implementation of a Bundle Strategy to Prevent Ventilator-Associated Pneumonia in a Neonatal Intensive Care Unit

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## ABSTRACT

**Background:** We aimed to investigate the effectiveness of evidence-based bundle that we developed to reduce ventilator-associated pneumonia (VAP) rates and to assess the degree of compliance rates to this strategy in a tertiary neonatal intensive care unit.
**Methods:** This before–after prospective cohort trial divided into two periods was conducted. All neonates requiring ventilation were enrolled in the study. VAP incidence, compliance rates to bundle components and the contribution of each bundle component to VAP rates were compared between the periods.
**Results:** Throughout the study period, 13 VAP episodes were observed. Full adherence to all six components of the bundle doubled in the active-bundle period (12.8 vs. 24.3%, $p < 0.01$). The mean VAP rate decreased from 7.33/1000 to 2.71/1000 ventilator days following intervention ($p = 0.083$).
**Conclusion:** This study showed that reliable implementation of a neonate-specific VAP prevention bundle can produce sustained reductions in VAP rates.

KEYWORDS: bundle, newborn, ventilator-associated pneumonia

## INTRODUCTION

Ventilator-associated pneumonia (VAP) is pneumonia that develops ≥48 h after mechanical ventilation is given via an endotracheal tube or tracheostomy and is the second most common hospital-acquired infection among patients in a neonatal intensive care unit (NICU) [1]. Different NICUs have found incidence of VAP between 0 and 52 infections per 1000 ventilator days [1–3].

VAP in NICU is an important issue, as it leads to significant morbidity and economic consequences. Therefore, prevention of VAP is a key issue to be dealt with. To decrease the VAP rates, a group of interventions called 'bundle' has been used for almost 10 years in adult intensive care units [4–6]. After the Institute for Healthcare Improvement has modified the recommendations for paediatric patients, decreases were achieved in VAP rates in paediatric intensive care units [7].

VAP prevention studies have demonstrated that strategies such as caregiver education, hand hygiene and minimizing days of ventilation decreased the VAP rates in NICUs [8, 9]. Change of ventilator circuits when there is a visibly solid contamination, instead of changing them regularly and more frequently, has been proved to decrease intensive care costs and the rate of tracheal colonization without increasing VAP rates [9, 10]. Ventilator circuit condensation has been shown to be a potential for development of resistant microorganisms [11, 12]. To date, the role of bed head elevation, which has significant importance in adults, has not been evaluated in VAP rates in NICU. Clinical trials should be conducted to find out the best position to prevent VAP in ventilated neonates. However, risk of VAP development has been shown to be lower in semirecumbent position and 10–13 degree elevation of bed head can be applied in NICUs without any adverse effects [13, 14].

In addition, oral hygiene with chlorhexidine has been shown to be beneficial in the adult population, but because gingivitis or dental problems are not observed in neonates, so implementation of suctioning and oral care when necessary are sufficient in this patient group [6, 15].

This is a prospective study evaluating VAP prevention studies and the recommendation of Centers for Diseases Control and Prevention (CDC). It also investigated the effectiveness of evidence-based bundle that we have developed, a new bundle consisting of six interventions in reducing VAP rates and assessed the compliance rates to this strategy in a tertiary NICU.

## MATERIAL AND METHODS

### Study design

This before–after prospective cohort trial divided into two periods (pre-bundle and active-bundle) was conducted between January 2011 and December 2011 in the NICU of Zekai Tahir Burak Maternity Teaching Hospital. Our hospital is a tertiary care centre specializing in obstetrics and neonatology, with about 20 000 live births per year.

The duration of the pre-bundle period was 6 months, and the actual status of the unit was observed and recorded in this period. The nurses and physicians were educated with regard to the VAP bundling (VAPB) strategies for a month at the end of the pre-bundle period. The active-bundle period was in progress during the following 6 months. This study was approved by the Zekai Tahir Burak Maternity Teaching Hospital local ethical committee (Date: 07/12/2013; No: 08).

### VAP prevention bundle strategies

The VAPB components were as follows: (i) adherence to hand hygiene guidelines; (ii) readiness to wean assessment; (iii) ventilator circuit evaluation and changing the circuit only when visibly soiled or malfunctioning; (iv) periodical draining and discarding of ventilator circuit condensate; (v) bed head elevation to 10–13 degrees; (vi) oral care.

Alcohol-based disinfectants were used for hand hygiene. Standard Isolette C2000 incubators that allow bed head elevation up to 13 degrees were used. The babies were wrapped in coverlet like mother's lap to prevent sliding down. Saline was used twice a day for oral care, and oral suctioning was performed when necessary.

### Data collection

Two registered nurses from infection control and prevention committee evaluated all patients requiring mechanical ventilation either with an endotracheal tube or tracheostomy, and recorded compliance to the bundle between 08:00 and 16:00 am every day. Evaluation in the evening was performed by the chief NICU nurse in the 04:00 pm to 08:00 am shift. Bed head elevation, presence of visibly solid contamination in the breathing circuits, implementation of oral care and hand hygiene strategies were directly observed and evaluated. The physician in charge was asked to assess readiness for extubation. Neither advice nor notification to staff was given in the pre-bundle period. In the active-bundle period, structured observation tools were performed at regularly scheduled intervals as in the pre-bundle period, but the staff was warned when there was a misapplication of any bundle component. The data, including adherence to VAPB strategies and the VAP rates, were shared with the staff on a monthly basis.

### Definitions and outcome

The CDC definitions for infants ≤12 months were used for VAP [16]. VAP is indicated in a patient receiving mechanical ventilation who has chest radiograph findings that show new or progressive infiltrates, consolidation, cavitation or pleural effusion. The patient must also meet at least one of the following criteria: new onset of purulent sputum or change in character of sputum; organism cultured from blood; or isolation of an aetiological agent from a specimen obtained by tracheal aspirate, bronchial brushing or bronchoalveolar lavage. The VAP rate per 1000 ventilator days was calculated by dividing the number of VAPs by the number of ventilator days and multiplying the result by 1000. The ventilator utilization ratio was calculated by dividing the number of ventilator days by the number of patient days. The primary outcome measure was assessment of VAPB compliance and VAP incidence, while secondary outcomes were the effect of each bundle component on the VAP incidence and the correlation between full adherence to the VAPB and VAP incidence.

### Statistical analysis

Clinical and demographic characteristics of patients were compared between the pre-bundle and active-bundle period patients using a Student's *t*-test and a chi-square test for the continuous and categorical variables, respectively. The compliance rates in the two study periods were compared using a Student's *t*-test. Independent sample *t*-test was used to evaluate the difference in VAP rates between the two study periods. Multinomial logistic regression analysis was performed to evaluate the effect of each bundle component to VAP incidence, and Spearman's correlation test was used to assess the relationship between VAP incidence and full adherence to VAPBs. The Statistical Package for the Social Sciences for Windows 13.0 (SPSS Inc. Chicago, Illinois, USA) was used to evaluate the data.

## RESULTS

A total of 3038 newborns were admitted in NICU between 1 January 2011 and 31 December 2011, 431 required mechanical ventilation via endotracheal intubation or tracheostomy. Pre-bundle period 195 and active-bundle period 236 patients were included into the study. Patient's baseline characteristics were similar in the two groups except for gender (Table 1).

Throughout the study period, 13 VAP episodes were recorded. Five patients had concomitant blood culture positivity. *Klebsiella pneumoniae* was detected in three patients, and *Acinetobacter baumannii* and *Staphylococcus warneri* were each detected in one patient. Nine of the 13 VAP episodes were observed in the pre-bundle period, with four occurring in the active-bundle period. VAP rate was decreased by 63% in the active-bundle period (7.33/1000 ventilator days and 2.71/1000 ventilator days, respectively), but this decrease was not statistically significant ($p = 0.083$). The total number of ventilation days recorded, ventilator utilization, VAP incidence and VAP rates per 1000 ventilator days are summarized in Table 1.

Compliance rate at the night shifts was unexpectedly higher compared with daytime shifts (Table 2). The total compliance rates in the pre-bundle and active-bundle periods were 12.8% and 24.3%, respectively. When the compliance rates of each bundle parameter were compared, the difference was statistically significant ($p < 0.001$). The compliance rates of all parameters were significantly higher in the active-bundle period, with the exception of the 'readiness to extubation' assessment (Table 2).

Full adherence to all six bundle components was inversely related with VAP incidence ($r = -0.04$, $p = 0.02$). Furthermore, the VAP incidence was inversely correlated with the number of components implemented in the VAPB ($r = -0.07$, $p < 0.001$).

The regression analysis revealed that only the oral care component significantly decreased VAP incidence (Table 3).

## DISCUSSION

This before and after prospective cohort trial demonstrated that effective implementation of VAPB strategies leads to a 63% reduction in the VAP incidence in a tertiary NICU. Furthermore, a significant relationship was observed between full adherence to each bundle component and VAP incidence, although each component did not individually contribute to VAP incidence, with the exception of the oral care.

Evidence-based practices of bundle programmes are essential in preventing VAP in NICUs. To date, there are a number of trials on this topic for the

**Table 1. Demographic characters of both groups**

| Demographic factor | Pre-bundle period ($n = 195$) | Active-bundle period ($n = 236$) | $p$ |
|---|---|---|---|
| Gestational age, mean ± SD, week | 30.9 ± 5.3 | 30.7 ± 5.3 | 0.45 |
| Birth weight, mean ± SD, g | 1688 ± 997 | 1697 ± 995 | 0.095 |
| Gender, male, $n$ (%) | 107 (54.9) | 153 (64.8) | 0.03 |
| Caesarean section, $n$ (%) | 119 (61) | 149 (63.1) | 0.22 |
| Total number of ventilator days, mean, day | 1227 | 1475 | |
| Ventilator utilization rate | 0.07 | 0.08 | 0.23 |
| Duration of mechanical ventilation, mean, day | 6.29 | 6.25 | 0.30 |
| VAP rate per 1000 ventilator days | 7.33 | 2.71 | 0.08 |
| VAP incidence, $n$ (%) | 9 (4.6) | 4 (1.7) | 0.07 |
| NICU admission, $n$ | 1363 | 1675 | |

**Table 2 . Bundle compliance in day shift and night shift**

| Bundle component | Pre-bundle period (%) | | Active-bundle period (%) | | $p$ |
|---|---|---|---|---|---|
| | Day shift | Night shift | Day shift | Night shift | |
| Hand hygiene | 48.4 | 71.3 | 61.2 | 88.6 | <0.001 |
| Daily readiness to wean assessment | 98.5 | 99.3 | 99.1 | 99.2 | 0.15 |
| Absence of visibly solid contamination in breathing circuits | 93.9 | 98.3 | 97.5 | 97.5 | <0.001 |
| Periodically drain and discard of ventilator circuit condensate | 40.5 | 38.9 | 51.8 | 45.3 | <0.001 |
| Head of the bed elevation | 67.3 | 73.1 | 83.9 | 78.7 | <0.001 |
| Oral care | 67.0 | 53.0 | 78.5 | 68.4 | <0.001 |
| Total bundle compliance | 12.8 | 17.3 | 24.3 | 31.8 | <0.001 |

**Table 3. The contribution of each bundle component to VAP incidence**

| Bundle component | RR | CI (95%) | $p$ |
|---|---|---|---|
| Hand hygiene | 0.9 | 0.7–1.1 | 0.34 |
| Daily readiness to wean assessment | 0.8 | 0.28–2.3 | 0.7 |
| Absence of visibly solid contamination in breathing circuits | 1.5 | 0.6–2.4 | 0.08 |
| Periodically drain and discard of ventilator circuit condensate | 1.1 | 0.9–1.47 | 0.13 |
| Head of the bed elevation | 1.28 | 0.99–1.63 | 0.05 |
| Oral care | 1.56 | 1.23–1.96 | <0.001 |

adult intensive care units, but number of trials for NICUs is scarce. We tried to choose consistent and easily applicable bundle elements to have effective results in our trial. The compliance rate was doubled in the active-bundle period; however, full adherence to all six components remained at a low level (24.3%). This may have been associated with inadequate service assessments. However, there are studies in the literature showing decreased VAP rates despite low compliance rates like our study [16–18].

Our trial was conducted during both day and night shifts. Results from the daytime shifts were evaluated. The compliance rate was unexpectedly higher at night shifts. This was probably related to the fact that the control in the night shift is carried out by the NICU nurse in charge, but control in the daytime shifts was conducted by the infection control nurses. In most of the bundle trials, the records were taken from either day or night shifts, or this information was not stated [17, 18].

The CDC recommends a comprehensive oral hygiene programme in patients at high risk for healthcare-associated pneumonia [19]. In a meta-analysis, Pineda *et al.* [20] showed a reduction in VAP among adult patients treated via decontamination with oral chlorhexidine, although the reduction in VAP did not reach statistical significance. A meta-analysis by Chlebicki and Safdar [21] revealed a similar protective effect with chlorhexidine rinse. However, the CDC has made no recommendation with regard to the use of an oral chlorhexidine rinse for the prevention of VAP. Surprisingly, in our study, we demonstrated that implementation of oral care according to recommendations of the American Dental Association significantly reduced VAP incidence (RR; relative risk 1.56, $p < 0.001$). This may be the result of a reduction in oral bacterial colonization; however, these findings should be confirmed with further investigations.

Several studies have reported a relationship between nosocomial pneumonia and mortality in adult ICU patients [22–24]. It is unclear whether VAP contributes to higher mortality in NICU patients. Apisarnthanarak *et al.* [25] reported that VAP is a significant risk factor for mortality in preterm infants. In this study, only one death was attributed to VAP and most of the patients died because of prematurity and related morbidities in early postnatal life.

There are general and unavoidable limitations for such bundle studies. In preterm infants, a diagnosis of VAP is difficult because CDC definitions are not specific for this population. Isolated positive tracheal culture or gram staining of tracheal aspirate does not distinguish between bacterial colonization and respiratory infection [26]. Clinical and laboratory signs of VAP, mostly non-specific, can also be found in other conditions such as bronchopulmonary dysplasia and patent ductus arteriosus.

The current study is among few reports that effectively inspected compliance of each bundle component during both day and night shifts. It was conducted in a hospital and therefore may not be fully transferable to other hospitals, although we believe that the interventions and methods are straightforward and inexpensive, and can therefore be easily reproduced. The other weakness of the current study is that the knowledge and skill levels of the healthcare providers, with regard to the application of VAP prevention strategies, were not evaluated before or after the education period.

## CONCLUSIONS

In summary, this study found that reliable implementation of a neonate-specific VAP prevention bundle can produce sustained reductions in VAP rates. We recommend the inclusion of recent knowledge and evidence-based guidelines for VAP prevention in the education of nurses, physicians and other healthcare providers who have leading roles in the critical care setting.

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