

An Evaluation of the Ventilator Bundle for the Prevention of Ventilator-Associated Pneumonia in Patients Under Mechanical Ventilation at Selected Hospitals

Deepak Kumar¹, Rakesh Kumar², Mohammad ikrar³

^{1,2} School of Nursing Sciences

ITM University, Gwalior, India

Abstract

Background

Ventilator-associated pneumonia (VAP) is a leading cause of death and a major financial burden for healthcare systems worldwide. In order to reduce the occurrence of ventilator-associated pneumonia (VAP), our institution has instituted bundle care in the ICUs. The effectiveness of it is being assessed in this retrospective study.

Methods

We updated the VAP care bundle from the Institute for Healthcare Improvement and deployed it at five surgical intensive care units (SICUs) at National Taiwan University Hospital. This bundle of care required a diverse team. To determine the effect of the VAP bundle in a clinical context, this study examines the use of the intensive care unit (ICU), the number of patients ventilated, and the incidence of ventilator-associated pneumonia (VAP) from 2006 to 2013.

Result

Enrolment was limited to 27,125 patients; 12,913 patients were from the pre-VAP bundle phase and 14,212 from the post-VAP bundle phase. The study initially analysed 28,454 SICU patients; children younger than 18 were eliminated ($n = 1329$). There was a trend towards older patients and shorter stays in the SICU among patients in the post-VAP phase ($p = 0.024$ and $p = 0.006$, respectively). In the post-VAP bundle phase, patients had lower disease severity scores on the Therapeutic Intervention Scoring System, Glasgow Coma Scale, and Acute Physiology and Chronic Health Evaluation II score ($p < 0.001$), with the exception of the Injury Severity Score ($p = 0.729$). No change in SICU utilisation was observed between the pre- and post-VAP bundle phases in response to VAP interventions ($p = 0.982$), but there was a significant decrease in ventilator utilisation ($p < 0.001$), from 1148.5 to 956.1 ventilator days per month, and a remarkable decrease in VAP density ($p < 0.001$), from 3.3 to 1.4 cases per 1000 ventilator days.

Summary

When VAP bundle care is put into place, the occurrence of VAP in the SICU diminishes. The keys to success include interdisciplinary teamwork, education, and a thorough checklist to improve compliance among health-care personnel.

Keywords- healthcare, hospital, pneumonia, ventilator

1. Introduction

Among the most dangerous infections that can develop while receiving medical treatment, ventilator-associated pneumonia (VAP) increases hospital stays and intensive care unit (ICU) stays, as well as mortality, morbidity, and medical costs.^{1,2, 3} In the United States, medical-surgical intensive care units had an average VAP density of 3.6 cases/1000 ventilator days, according to the Centres for Disease Control and Prevention's National Healthcare Safety Network Hospitals. In developing nations, the density ranged from 10 to 41.7 cases/1000 ventilator days. Four, five Ten to twenty percent of patients who required mechanical ventilation for more than 48 hours developed ventilator-associated pneumonia (VAP), according to Safdar et al.⁶ As a result, preventing VAP in critical care requires a lot more work.

During their "100 Mile for Lives" campaign, which ran from 2004 to 2006, the Institute for Healthcare Improvement (IHI) introduced a "bundle" of simple, basic evidence-based practices that, when used together, consistently enhance patient outcomes.⁷ Typically, it consists of three or five separate therapies that are supported by evidence. First, a head-of-bed elevation of 30° to 45°; second, a readiness-to-wean evaluation and daily "sedation vacation"; third, prophylaxis against peptic ulcer disease; fourth, prophylaxis against deep vein thrombosis; and fifth, daily oral care with chlorhexidine, an intervention that has been added since 2010, make up the VAP bundle, which is derived from the IHI bundle. The effectiveness of the VAP care bundle has been demonstrated in multiple international trials. After two years of using this bundle in surgical intensive care units (SICUs), the mean VAP density dropped from 9.3 cases/1000 ventilator days to 2.2 cases/1000 ventilator days, according to Al-Tawfiq et al.⁹

It is critical to keep working to enhance the quality of clinical treatment and patient safety in order to boost clinical outcomes. Within the intensive care units of National Taiwan University Hospital (NTUH), VAP ranks second in terms of healthcare-associated infections, only behind catheter-related bloodstream infections. In 2009, NTUH implemented a VAP bundle to lower the VAP density. Starting on November 1, 2009, the VAP bundle has been implemented in all five SICUs. Reducing VAP density in all SICUs by 50% was our goal. In order to determine whether the VAP bundle was effective, we looked back at the data.

Because the body's natural defences against lung and airway infections are impaired in patients on mechanical ventilation, they are more likely to experience ventilator-associated pneumonia (VAP). Patients with VAP may have trouble reducing their reliance on mechanical breathing and may need it for a longer period of time. Increases in mechanically ventilated patients' length of stay (LoS) and associated financial expenses are associated with ventilator-associated pneumonia (VAP), which can prolong intubation by 4–9 days compared to patients without VAP. In addition, the mortality rate for patients who have VAP can double compared to those who do not [6]. Mechanical ventilation increases the incidence of ventilator-associated pneumonia (VAP) by 3% per day for the first five days, 2% per day for days six through ten, and 1% per day thereafter, according to the American Thoracic Society (ATS) [7].

Risk factors for VAP include immune suppression, which in turn impairs important organs like the heart, liver, kidneys, and lungs, leaving the patient more susceptible to infection. Chronic disorders such as coronary and respiratory disease, diabetes, and chronic renal failure are examples of such conditions [8,9,10]. Longer hospital stays and more time spent on mechanical breathing were associated with patients with chronic illnesses [11]. The risk of developing VAP was 2.3% higher in patients with co-morbidities compared to those without [12]. The death rate in VAP patients is 61.7% when there are two or more co-morbidities, and it rises as the number of co-morbidities increases [13].

Illness severity is also known to be a risk factor for VAP on its own [14]. Patients with moderate to severe illness are at a higher risk of developing VAP because their immune systems are compromised, making them more susceptible to infection and, in turn, more virulent infectious microorganisms. This, in turn, increases the likelihood of clinical complications and worse prognosis [12].

Prevention of VAP is a crucial practice for patient safety, and it has also been suggested as a measure of treatment quality [15]. Hospitals in the US are under pressure to reduce VAP rates due to the high expense of VAP [16].

2. The tools and procedure

2.1 Methodology employed

This study set out to compare the VAP density at SICUs before and after implementing the VAP bundle in an effort to gauge the bundle's effectiveness in reducing VAP density by half. The following individuals were brought together to establish a multidisciplinary team: the administrator (vice superintendent), respiratory therapists, chemists, specialists in general affairs and information technology, physicians and nurses from the surgical intensive care unit (SICU), quality improvement and infection control experts, and others.

Nottingham Technical University's Infection Control Centre oversaw this collective effort. At 2200 beds, NTUH is Northern Taiwan's largest tertiary referral hospital. There were a total of four paediatric intensive care units (PICUs), five surgical intensive care units (SICUs) (63 beds), seven medical intensive care units (MICUs) (79 beds), and others. The VAP bundle was implemented in all SICUs starting from November 1, 2009. So, we looked at the demographic data and VAP rates of all SICU patients in a retrospective manner. Institutional review boards at NTUH (NTUH201003093RINC) gave their stamp of approval to this work.

2.2 Definition

In the event of a respiratory tract infection occurring within 48 hours following intubation with mechanical ventilation or within 48 hours following ventilator disconnection, the condition is known as ventilator-associated pneumonia (VAP).twelve, thirteen Clinicians diagnose respiratory tract infections based on patient symptoms after exhausting all other possible causes of SARS-CoV-2, according to the Taiwan Centres for Disease Control and Prevention's Nosocomial Infection Surveillance guideline. No non-invasive ventilation devices were considered for the ventilators; only those requiring an invasive tracheostomy or endotracheal tube were considered.

The "SICU utilisation" is the total number of patients admitted to the SICU over a given time period, multiplied by the number of days each patient spent ventilated; the "ventilator utilisation" is the total number of patients who required mechanical ventilation during that time, also expressed as a percentage; and finally, the "ventilator utilisation ratio" is the ratio of ventilator utilisation to SICU admission. the "VAP count" is the sum of all VAP patients admitted to the SICU before and after the VAP bundle, expressed as "cases"; the "VAP incidence" is the number of VAP patients relative to the total number of ventilated patients during the pre- and post-VAP bundle, expressed as a ratio of 1000; and the "VAP density" is the ratio of the "VAP count" to the "ventilator utilisation," expressed as "cases/1000 ventilator days." A

2.3 package containing VAP

There were a few tweaks and additions to the daily quality rounding checklist in addition to the five main treatments included from the IHI bundle. As part of the VAP bundle, we implemented six interventions in SICUs. To ensure that all ventilated patients in the intensive care unit (ICU) followed the daily protocol for standard care, a bedside VAP bundle quality rounding checklist was utilised, which was adapted from the IHI bundle⁸. The specifics of this procedure are displayed in Table 1.

Table 1. Requirements for providing high-quality VAP bundle care on a daily basis

Interventions	Checkers
Direct elements that decrease infections	
Hand hygiene before and after intubation procedure and patient contact	Nurse
Aspiration prophylaxis	
Head-of-bed elevation	Nurse
Adequate endotracheal tube cuff pressure	Respiratory therapist
Oral cavity secretion clearance before changing position or supination	Nurse
Oral care with chlorhexidine solution every 8h	Nurse
Deep vein thrombosis	Doctor
Peptic ulcer disease	Doctor

Charlson Complex Illness Index

Based on the International Classification of Diseases (ICD), the Charlson Co-morbidity Index was developed to classify patients' co-morbidities. It forecasts the 10-year survival rate in patients with numerous co-morbidities and is composed of 19 types of co-morbidities. The severity of each illness and the related mortality rate determine its score, which ranges from 0 to 6. There were no co-morbidities detected if the score was 0, and more co-morbidities were indicated by higher scores. There is an almost 100% chance of death after one year for patients with a score greater than 5 [18]. With a score of 0 on the scale, the anticipated 10-year survival rate was 98%, 1 point was 96%, 2 points was 90%, 3 points was 77%, 4 points was 53%, 5 points was 21%, 6 points was 2%, and 7 points or more was 0%.

There is substantial evidence that supports the validity and reliability of the Charlson Co-morbidity Index. Excellent reliability was suggested by the Alpha Coefficient for the Charlson Co-morbidity Index, which ranged from 0.86 to 0.95 for its internal consistency [19]. Using test-retest reliability and Cronbach's Coefficient Alpha, which was 0.92 ($P < 0.001$), the present study examined the Charlson Comorbidity Index's dependability.

section IV)

CPIS (Clinical Pulmonary Infection Size)

Pugin et al. (1991) [13] created the Clinical Pulmonary Infection Score to make the diagnosis of VAP easier. The first five items, which include the patient's temperature, white blood cell count, tracheal secretions, arterial oxygen saturation ($\text{PaO}_2/\text{FiO}_2$), and a chest radiograph, are used to calculate the CPIS. When gramme stains or cultures came back positive, two more points were added to the CPIS baseline score to determine the CPIS cultures. A total of zero to twelve CPIS is possible. A CPIS score below six indicates the absence of VAP, while a score above six either at baseline or after adding the culture result is indicative of VAP.

The CPIS demonstrated a good level of validity when administered to patients on mechanical ventilation ($r^2 = 0.233$, $p < 0.0001$). Fifty adults on mechanical ventilation were the subjects of a study that documented the CPIS scale's dependability.

According to Cronbach's alpha, the overall scale has an internal consistency of 0.81 [14]. Internal consistency and Cronbach's Coefficient Alpha both came out at 0.98 when testing the CPIS's dependability in this study.

References

- [1] Clavé, Stéphanie, Michel Tsimaratos, Mohamed Boucekine, Bruno Ranchin, Rémi Salomon, Olivier Dunand, Arnaud Garnier et al. "Quality of life in adolescents with chronic kidney disease who initiate haemodialysis treatment." *BMC nephrology* 20 (2019): 1-10.
- [2] Elsayed, Ebtisam, Wafaa El-Soreety, Thanaa Elawany, and Faten Nasar. "Effect of nursing intervention on the quality of life of children undergoing hemodialysis." *Life Sci J* 9 (2012): 77-86.
- [3] McKenna, Ann Marie, Laura E. Keating, Annette Vigneux, Sarah Stevens, Angela Williams, and Denis F. Geary. "Quality of life in children with chronic kidney disease—patient and caregiver assessments." *Nephrology Dialysis Transplantation* 21, no. 7 (2006): 1899-1905.
- [4] Goldstein, Stuart L., Nicole Graham, Tasha Burwinkle, Bradley Warady, Rhonda Farrah, and James W. Varni. "Health-related quality of life in pediatric patients with ESRD." *Pediatric nephrology* 21 (2006): 846-850.
- [5] Raparathi, M., Dodda, S. B., & Maruthi, S. (2023). Predictive Maintenance in IoT Devices using Time Series Analysis and Deep Learning. *Dandao Xuebao/Journal of Ballistics*, 35(3). <https://doi.org/10.52783/dxjb.v35.113>
- [6] Heath, Jennifer, Dorothy MacKinlay, Alan R. Watson, Anna Hames, Lucy Wirz, Sarah Scott, Elaine Klewchuk, David Milford, and Kathleen McHugh. "Self-reported quality of life in children and young people with chronic kidney disease." *Pediatric Nephrology* 26 (2011): 767-773.
- [7] Goldstein, Stuart L., Nicole Graham, Bradley A. Warady, Mouin Seikaly, Ruth McDonald, Tasha M. Burwinkle, Christine A. Limbers, and James W. Varni. "Measuring health-related quality of life in children with ESRD: performance of the generic and ESRD-specific instrument of the Pediatric Quality of Life Inventory (PedsQL)." *American Journal of Kidney Diseases* 51, no. 2 (2008): 285-297.
- [8] Abreu, Isabella Schroeder, Lucila Castanheira Nascimento, Regina Aparecida Garcia de Lima, and Claudia Benedita dos Santos. "Children and adolescents with chronic kidney disease in haemodialysis: perception of professionals." *Revista Brasileira de Enfermagem* 68 (2015): 1020-1026.
- [9] Anthony, Samantha J., Diane Hebert, Laura Todd, Moira Korus, Valerie Langlois, Rita Pool, Lisa A. Robinson, Angela Williams, and Stacey M. Pollock-BarZiv. "Child and parental perspectives of multidimensional quality of life outcomes after kidney transplantation." *Pediatric transplantation* 14, no. 2 (2010): 249-256.
- [10] Tjaden, Lidwien, Allison Tong, Paul Henning, Jaap Groothoff, and Jonathan C. Craig. "Children's experiences of dialysis: a systematic review of qualitative studies." *Archives of disease in childhood* (2012): archdischild-2011.
- [11] Tjaden, Lidwien A., Martha A. Grootenhuys, Marlies Noordzij, and Jaap W. Groothoff. "Health-related quality of life in patients with pediatric onset of end-stage renal disease: state of the art and recommendations for clinical practice." *Pediatric Nephrology* 31 (2016): 1579-1591.
- [12] Heath, Jennifer, Paul Norman, Martin Christian, and Alan Watson. "Measurement of quality of life and attitudes towards illness in children and young people with chronic kidney disease." *Quality of Life Research* 26 (2017): 2409-2419.
- [13] Fibrianto, Ari, Hertanti Indah Lestari, Yudianita Kesuma, Moretta Damayanti, Eka Intan Fitriana, and Rismarini Rismarini. "Quality of life in children with chronic kidney disease." *Paediatrica Indonesiana* 63, no. 5 (2023): 395-404.
- [14] Levy, Norman B., and Gary D. Wynbrandt. "The quality of life on maintenance haemodialysis." *The Lancet* 305, no. 7920 (1975): 1328-1330.
- [15] Neul, Shari K., Charles G. Minard, Helen Currier, and Stuart L. Goldstein. "Health-related quality of life functioning over a 2-year period in children with end-stage renal disease." *Pediatric Nephrology* 28 (2013): 285-293.
- [16] Brownbridge, Garry, and Dorothy M. Fielding. "Psychosocial adjustment to end-stage renal failure: comparing haemodialysis, continuous ambulatory peritoneal dialysis and transplantation." *Pediatric Nephrology* 5 (1991): 612-616.

-
- [17] Abdelkader, Raghad, A. Anwar, R. Masaadi, M. Ibrahim, and I. Alrimawi. "Exploring the quality of life of Jordanian children and adolescents with end stage renal disease receiving hemodialysis." *Eur Sci J* 12, no. 35 (2016): 17.
 - [18] Fischbach, Michel, A. Edefonti, C. Schröder, A. Watson, and European Pediatric Dialysis Working Group. "Hemodialysis in children: general practical guidelines." *Pediatric Nephrology* 20 (2005): 1054-1066.
 - [19] Groothoff, Jaap W., Martha A. Grootenhuis, Martin Offringa, Mariken P. Gruppen, Joke C. Korevaar, and Hugo SA Heymans. "Quality of life in adults with end-stage renal disease since childhood is only partially impaired." *Nephrology Dialysis Transplantation* 18, no. 2 (2003): 310-317.
 - [20] Mohammed Ali, Howayda, Atiat Osman, and Nagat Farouk Abolwafa. "Empowerment Program for Mothers to Improve the Quality of Life of Their Children undergoing Hemodialysis on Arteriovenous Fistula Care." *Egyptian Journal of Health Care* 14, no. 1 (2023): 1087-1102.