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Research paper

Ventilation bundle compliance in two Australian intensive care units: An observational study

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A B S T R A C T

Background: The ventilation bundle has been used in adult intensive care units to decrease harm and improve quality of care for mechanically ventilated patients. The ventilation bundle focuses on prevention of specific complications of mechanical ventilation; ventilator-associated pneumonia, sepsis, barotrauma, pulmonary oedema, pulmonary embolism, and acute respiratory distress syndrome. The Institute for Healthcare Improvement ventilation bundle consists of five structured evidence-based interventions: head of the bed elevation at 30–45°; daily sedation interruptions and assessment of readiness to extubate; peptic ulcer prophylaxis; deep vein thrombosis prophylaxis; and daily oral care with chlorhexidine.

Objectives: The objective of the study was to evaluate the use of the ventilation bundle in two intensive care units in Victoria, Australia.

Methods: This is a 3-month prospective observational study in two intensive care units. Patient medical records were reviewed on days 3, 4, and 5 of mechanical ventilation using a prevalidated ventilation bundle checklist.

Results: A total of 96 critically ill patients required mechanical ventilation for more than 2 d. Patients had a mean age of 64.50 y (standard deviation = 14.89), with an Acute Physiology, Age, Chronic Health Evaluation (APACHE) III mean score of 79.27 (standard deviation = 27.11). The mean ventilation bundle compliance rate was 88.3% on the three consecutive mechanical ventilation days (day 3 = 79.4%, day 4 = 91.1%, and day 5 = 96.7%). There was a statistically significant difference in the mean APACHE III score between patients who had head of bed elevation and those without head of bed elevation, on days 3 (p < 0.001) and 4 (p = 0.007).

Conclusion: The ventilation bundle elements were used in Australian intensive care units. The likelihood of having all ventilation bundle elements on day 3 was low if the patient’s APACHE III score was high. However, the ventilation bundle compliance rate increased with mechanical ventilation days.

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1. Introduction

Use of a ventilation bundle has been shown to decrease harm and improve quality of care for mechanically ventilated patients in adult intensive care units (ICUs) across a number of countries.1,2 The Institute for Healthcare Improvement (IHI) ventilation bundle consists of five core sets of interventions grouped in an attempt to
achieve the best patient care and outcome: head of the elevation at 35–45°, sedation interruption and readiness to extubate, peptic ulcer prophylaxis, deep vein thrombosis (DVT), and use of chlorhexidine for oral care. Four of the IHI ventilation bundle elements that were in the FASTHUGS medical checklist (Feeding, Analgesia, Sedation, Thromboembolic prophylaxis, Head of the Bed elevation, Ulcer [peptic] prophylaxis, Glucose control, and Spontaneous breathing trial) were used in the prevention of mechanical ventilation complications. It includes four IHI ventilation bundle elements, except for the use of chlorhexidine for oral care, which was added to the bundle in 2010 after the development of the FASTHUGS checklist. However, there is contradicting research on the benefits of chlorhexidine for oral care in mechanically ventilated patients. The bundled care has been adapted by many organisations, resulting in varied elements of the ventilation bundle. The use of FASTHUGS shows that there was more than one bundle used in preventing mechanical ventilation complications. The aim of care bundles is to promote consistency, relying on the grouped evidence-based guidelines and the use of a multidisciplinary approach. The ventilation bundle helps achieve better care delivery and improved patient outcomes when all elements of the bundle are implemented. However, previous studies have reported poor uptake and compliance with the ventilation bundle by healthcare professionals. The ventilation bundle is used in the prevention of ventilator-associated events (VAEs): ventilator-associated pneumonia, sepsis, barotrauma, pulmonary oedema, pulmonary embolism, and acute respiratory distress syndrome. VAEs are specific complications of mechanical ventilation that may develop if a patient is mechanically ventilated for more than 48 h. These complications lead to a prolonged hospital stay, lead to increased hospital costs, and are associated with doubling the risk of death compared with patients without the complications. Despite focused efforts for more than a decade to reduce morbidity and mortality among ventilated patients, VAEs remain a significant healthcare challenge. Between 5.8 and 16 events per 1000 mechanical ventilation days have been reported across several countries internationally. In Australia, VAEs have been reported to be higher, with up to a quarter of mechanically ventilated patients affected. The evaluation of the implementation of a ventilation bundle to prevent VAEs is understudied in Australia.

2. Aim

The aim of this study was to evaluate the use of the ventilation bundle in two ICUs in Victoria, Australia.

3. Methods

This is a 3-month, prospective observational study conducted in two ICUs in large health services in Victoria, Australia.

4. Sample and setting

Medical records of patients who were mechanically ventilated for more than 48 h in two ICUs were reviewed. The medical records comprised patient progress notes, drug charts, observation charts, and the FASTHUGS checklist, which were used for the care of mechanically ventilated patients. Contextual data were collected for all patients in the unit during the time of data collection; this comprised daily patient case-mix reports, daily admission and discharge information, and Acute Physiology, Age, Chronic Health Evaluation (APACHE) III scores. The two ICUs were of different sizes and case mix, which facilitated diverse participant characteristics. ICU A had 24 beds with >2500 admissions per annum and provided specialised cardiothoracic, renal, neurology, obstetric, surgical, and general medical services. ICU B had 15 beds, provided specialised surgical and medical services, and admitted >1200 patients per annum.

5. Data collection

An existing IHI ventilation bundle checklist was used. The checklist has been used in several studies worldwide. The checklist consists of five elements to be checked on the documentation: (i) head of bed elevation (HoBE) at 30–45°, (ii) daily sedation interruptions and daily assessment of readiness to extubate, (iii) peptic ulcer prophylaxis, (iv) DVT prophylaxis, and (v) daily oral care with chlorhexidine. Only one of the two ICUs used chlorhexidine for oral care; hence, these data are reported for the single ICU. The checklist was used to examine the medical and nursing documentation for compliance with each element of the ventilation bundle in both ICUs. The checklist was given to three associate nurse unit managers and two nurse unit managers who worked in ICUs in nonparticipating hospitals for assessment of face validity. They recommended splitting the elements daily sedative interruptions and daily assessment of readiness to extubate on the basis that the two elements required different actions to achieve the objective. In a previous study by Klompas et al., the two elements were assessed separately, and the checklist was amended accordingly. Therefore, our checklist had five elements. Readiness to extubate was assessed as switching mechanical ventilation to a mode of ventilation that facilitated spontaneous breathing or having daily ventilation orders with a weaning plan or ventilating patient on continuous spontaneous ventilation mode. Daily sedation interruption was assessed as cessation of sedation for a certain period of time or no sedation or titration of sedation to a lower level.

All medical records of patients who were mechanically ventilated for more than 48 h were reviewed on days 3, 4, and 5 of mechanical ventilation. The three days of records per patient facilitated analysis of any trends in practice within the two ICUs. There were occasions when a patient was extubated before day 5, and three days of records per patient were not collected; data were still used but not for trend analysis. Comments and reasons were noted if the patient did not have the three datasets collected. Data were collected from October 2018 to January 2019 (3 months). Only one ICU used chlorhexidine for oral care, so this element was excluded in the combined data analysis. Each element was scored as either compliant (yes) or noncompliant (no).

6. Data analysis

Data were analysed using IBM SPSS, Statistics for Windows version 25, (IBM Corp: Armonk, NY). Descriptive statistics (frequencies, means, and standard deviations) were used to summarise the data, and inferential statistics were used to explore relationships and differences between the study variables. The data met the assumptions of normality, so parametric tests were used. An independent samples t-test was conducted to compare the APACHE III scores and compliance with ventilation bundle elements. A p-value of <0.05 was considered statistically significant. Compliance with each element of the bundle was analysed to identify the elements of weakness or strength.
7. Ethical considerations

Approval was obtained from the hospital Human Research Ethics Committee (HREC) before the study commenced (reference: HREC/18/MoH/417). The research project was also approved by the University HREC (project number: 14750). Consent from individual patients was not required as information reviewed was routinely recorded for patient care without consenting the individual person. Identifiable patient data were available to authors at each site but were collated into a de-identified dataset for analysis and reporting purposes.

8. Results

A total of 989 patients were admitted to the participating ICUs during the study period. Of these, 96 critically ill patients required mechanical ventilation for more than 48 h, and their medical records were included in the analysis. Of the 96 patients, 15 were extubated on day 4 and 8 were extubated on day 5; these patients were retained in the study as per the eligibility criteria. Postcardiac arrest was the most common reason for admission (n = 4, 4.2%), followed by ‘sepsis with shock other than urinary tract infection’ (n = 10, 10.4%). The mean age was 64.50 y (standard deviation = 14.89), and the APACHE III mean score was 79.27 (standard deviation = 27.11).

8.1. Peptic ulcer and DVT prophylaxis

On day 3 of mechanical ventilation, all patients (n = 96, 100%) were receiving peptic ulcer and DVT prophylaxis. The mean compliance over the 3 d of mechanical ventilation was 97.6% and 99.6%, respectively. These were the most adhered to ventilation bundle elements. However, compliance with peptic ulcer prophylaxis decreased with the number of mechanical ventilation days (Table 1).

8.2. Head of bed elevation

The majority of the patients (n = 78, 81.3%) had the HoBE on day 3 (Table 1). The mean HoBE compliance for the 3 days of mechanical ventilation was 92%. The patients who did not have the HoBE were as follows: (i) those receiving high doses of inotropes, (ii) those diagnosed with postcardiac arrest, or (iii) those who underwent postspinal surgery, with HoBE contraindicated. There was a statistically significant difference in the mean APACHE III score between patients who had HoBE and those without HoBE on day 3 (p < 0.001) and on day 4 (p = 0.007) (Table 2). The higher the APACHE III score, the lower the likelihood of HoBE on days 3 and 4.

8.3. Sedation interruption

More than half (n = 58, 60.4%) of the patients had sedation interruption on day 3. The mean sedation interruption compliance for the 3 days of mechanical ventilation was 78.8%. The patients who had no sedation interruption were diagnosed with intracerebral haemorrhage (n = 4, 4.2%), postcardiac arrest (n = 4, 4.2%), seizure (n = 4, 4.2%), and sepsis (n = 3, 3.1%). However, there was no statistically significant difference in APACHE III scores between patients who had sedation interruptions and those who did not have on day 3 (p = 0.542) and day 4 (p = 0.594) (Table 2). There was a significant positive association between sedation interruptions and HoBE (χ^2 = 4.293, df = 1, p = 0.038).

8.4. Readiness to extubate

More than half (n = 53, 55.2%) of the patients were assessed for readiness to extubate on day 3 (Table 1). The mean readiness to extubate compliance for the 3 days of mechanical ventilation was 73.3%. Most of the patients who were not assessed for readiness to extubate were diagnosed with postcardiac arrest (n = 7, 7.3%), sepsis (n = 5, 5.2%), intracerebral haemorrhage (n = 4, 4.2%), and stroke (n = 3, 3.1%). There was no difference in the APACHE III mean score for patients who were assessed for readiness to extubate and those who were not assessed on day 3 (p = 0.108) and day 4 (p = 0.270) (Table 2).

The patients who had sedation interruption were significantly more likely to be assessed for readiness to extubate (χ^2 = 17.541, df = 1, p = <0.001). There was higher compliance with readiness to extubate on day 5 than on days 3 and 4 (Table 1).

8.5. Overall bundle compliance

Across all five ventilation bundle elements, the mean compliance per mechanical ventilation day was as follows: day 3 = 79.4%, day 4 = 91.1%, and day 5 = 96.7%. The compliance rate increased with the number of mechanical ventilation days (Table 1). The overall bundle compliance over the three days of mechanical ventilation was 88.3%. In ICU B, chlorhexidine was documented as a solution used for oral care most of the time (95.3%).

9. Discussion

This study evaluated the use of the ventilation bundle in two Australian metropolitan ICUs. The overall ventilation bundle compliance was 88.3%. Compliance with HoBE, sedation interruption and readiness to extubate increased with the number of ventilation days. There was a significant negative association between the HoBE and APACHE III score on days 3 and 4 of mechanical ventilation. The most adhered to elements were DVT prophylaxis and peptic ulcer prophylaxis. However, the use of peptic ulcer prophylaxis decreased with the number of mechanical ventilation days. The mean compliance with the use of chlorhexidine for mouth care in one ICU was 95.3%. However, the other ICU did not use chlorhexidine, which might be related to the available contradictory evidence on its use.26

| Table 1 | Adherence rates as per the ventilation bundle element. |
|---------|--------------------------------------------------------|
| Ventilation bundle elements | Day 3 (N = 96), n (%) | Day 4 (N = 81), n (%) | Day 5 (N = 73), n (%) |
| DVT prophylaxis | 96 (100) | 80 (98.8) | 73 (100) |
| Peptic ulcer prophylaxis | 96 (100) | 80 (98.8) | 68 (93.2) |
| Head of bed elevation | 78 (81.3) | 79 (97.5) | 73 (100) |
| Sedation infusion interruptions | 58 (60.4) | 68 (84) | 71 (97.3) |
| Readiness to extubate | 53 (55.2) | 62 (76.5) | 68 (93.2) |
| Average adherence | 381 (79.4) | 369 (91.1) | 353 (96.7) |

DVT (deep vein thrombosis).
Most of the patients (>80%) had the HoBE, and compliance increased with the number of mechanical ventilation days. Previous studies reported 53–95% compliance.24–26 This study found a statistical difference in the APACHE III score and HoBE.

The higher the APACHE III score, the lower the chance of HoBE on days 3 and 4 of mechanical ventilation. The progressive increase in compliance over mechanical ventilation days might be explained by the changes in the patient’s condition as the APACHE III score is measured on admission. These results confirm the results of previous studies, which reported that patient diagnosis, the severity of patient illness as per the APACHE III score, and haemodynamic instability were associated with low compliance with HoBE.27–29 However, the results of this study are contrary to an observational study of 33 Chinese ICUs, which reported 27.8% of 8647 measurements complied with HoBE.30 The compliance rate reported was not associated with the APACHE III score or use of inotropes, but nurse workload was identified as the critical factor of noncompliance.31 This shows that there are various factors that influence compliance with ventilation bundle elements.

This study found that a mean of 78.8% patients had sedation interruptions over the 3 days of mechanical ventilation, and there was a significant association between HoBE and sedation interruption. These results are better than the previous results of an Australian and New Zealand intensive care practice cross-sectional survey by O’Connor et al.,24 in which 62% of participants reported they used daily interruption of sedation. Mehta et al.,32 reported a similar rate of daily sedation interruption (60%) in 2006. When our results and previous study results are viewed together, there appears to be a slow progression in the uptake of sedation interruption in Australian ICUs over the years. However, there is contradictory research as to whether sedation interruptions facilitate early extubation. A randomised control trial found no difference in mechanical ventilation duration after comparing daily sedation interruption and protocolised sedation that targeted light sedation. Mehta et al.,32 and Weishrodt et al.,34 reported no difference in mechanical ventilation days after implementing sedation interruptions. Mehta et al.,33 stated that sedation interruption was associated with an increase in nurse workload, higher than the intended decrease in the mechanical ventilation period. The ventilation period was the same for those who had sedation interruption and those who were on light sedation. This shows that there is more than one factor that facilitates early extubation.

In nearly three quarters (73.3%) of the medical records reviewed, patients were assessed for readiness to extubate. These results were lower than previously reported results in the United States of America as in the studies by DuBose et al.,35 (78%) and Bird et al.,24 (94%). This study found a significant association between sedation interruption and readiness to extubate. These results confirm the results of Klompas et al.,9 who reported that there was association between the two elements, and they were associated with a decrease in mechanical ventilation time and decreased mortality rate. Some previous studies confirm Klompas et al.,9 results were Lim et al.,12 and Rello et al.,36

In most of the medical records reviewed (97.6%), the patients were on peptic ulcer prophylaxis. This finding demonstrates an improvement on previous studies in ICUs, which reported 53–78% compliance with peptic ulcer prophylaxis in similar populations.35,37 The results of this study are consistent with the Surviving Sepsis Campaign guidelines, which strongly recommend peptic ulcer prophylaxis in mechanically ventilated patients.38,39 These results demonstrate an increase in ventilation bundle element uptake over the years. However, this study found a decrease in the use of peptic ulcer prevention as the number of mechanical ventilation days increased, despite compliance of more than 90%. This finding is supported by Sesler,40 who suggested that peptic ulcer prophylaxis should be reviewed daily and recommended discontinuing if the patient’s condition improves. However, the IHI recommended universal use of peptic ulcer prophylaxis for mechanically ventilated patients.41 There is no consensus on the best time to cease peptic ulcer prophylaxis, i.e., (i) when the patient tolerates enteral feeding, (ii) when there is no risk of factors for peptic ulcers, (iii) at extubation, or (iv) at discharge from the ICU.52,41 The variability of the available literature on when to discontinue the use of peptic ulcer prophylaxis might have influenced the use of it in the two ICUs.

Reynolds and MacLaren41 claimed that a large randomised trial was required to demonstrate the importance of peptic ulcer prophylaxis in all mechanically ventilated patients.

The ventilation bundle element that had the highest compliance (99.6%) was the use of DVT prophylaxis. This finding confirms the results of previous studies.35,45 In response to the burden of venous thromboembolism (VTE) in the Australian healthcare system, the Australian Commission on Safety and Quality in Health Care included VTE prevention in clinical care standards.46 The recommended VTE prophylaxis is similar to DVT prophylaxis in the ventilation bundle. The availability of the Australian Commission on Safety and Quality in Health Care VTE standard at the time of data collection could have helped with ventilation bundle compliance.

The overall ventilation bundle mean compliance rate was 88.3% for the three consecutive mechanical ventilation days. These results confirm previous study findings; Baldwin et al.,47 reported >85%

### Table 2

Elements of the ventilation bundle and APACHE III score means.

| Characteristics          | Number of patients | APACHE III, mean | SD | Mean difference | 95% confidence interval | p value |
|--------------------------|--------------------|------------------|----|-----------------|-------------------------|---------|
| Day 3 (N = 96)           |                    |                  |    |                 |                         |         |
| Head of bed elevation    | Yes 78             | 74.74            | 24.00 | -24.145        | -37.40 to -10.89        | <0.001  |
|                          | No 18              | 98.89            | 31.54 |                 |                         |         |
| Sedation interruption    | Yes 58             | 77.90            | 22.73 | -3.47           | -14.74 to 7.80          | 0.542   |
|                          | No 38              | 81.37            | 32.91 |                 |                         |         |
| Readiness to extubate    | Yes 53             | 75.26            | 23.49 | -8.95           | -19.90 to 2.01          | 0.108   |
|                          | No 43              | 84.21            | 30.55 |                 |                         |         |
| Day 4 (N = 81)           |                    |                  |    |                 |                         |         |
| Head of bed elevation    | Yes 79             | 80.10            | 26.79 | -53.40          | -91.57 to -15.23        | 0.007   |
|                          | No 2               | 133.50           | 26.16 |                 |                         |         |
| Sedation interruption    | Yes 67             | 80.04            | 26.54 | -4.46           | -21.04 to 12.13         | 0.594   |
|                          | No 14              | 84.50            | 36.48 |                 |                         |         |
| Readiness to extubate    | Yes 60             | 78.63            | 25.22 | -7.85           | -21.91 to 6.22          | 0.270   |
|                          | No 21              | 86.48            | 35.16 |                 |                         |         |

SD, standard deviation.

* Sum difference as some patients were extubated on day 4. Day 5 cannot compute the difference as the compliance rate was approximately 100% or 100%.
compliance, and Bird et al., 24 reported 86% compliance. The use of the care bundle was reported as effective in preventing hospital-acquired infections in different settings. 10 However, compliance with the ventilation bundle has been reported to be low over the years. Rello et al., 36 reported that significant benefits were recorded, even with low compliance. Daily auditing and continuous education of healthcare workers might help to increase awareness and prompt compliance. 36, 48 This study did not examine the relationship between bundle compliance and patient outcome; however, high bundle compliance has been significantly associated with decreased hospital stay and decreased VAE rates in previous studies. 3, 49

In this study, ICU B used chlorhexidine for oral care, and the mean compliance was 95.3%. This result is contradictory to a previous Australian survey study by Madhuvu et al., 50 in which just less than two-thirds reported adhering to the use of chlorhexidine for oral care. The higher compliance rate in this study might be because of their unit policy.

Other ICUs might not be using chlorhexidine for oral care owing to the available contradictory literature. 7, 22 Bouadma and Klompas 7 made a worldwide call to stop using chlorhexidine for mouth care as a precautionary measure until further research has been conducted. However, Ricard and Lisboa 7 stated that more studies were required before stopping using chlorhexidine for mouth care in mechanically ventilated patients.

10. Limitations

This study has limitations. The current VAE prevention policy and procedures of the two units were not reviewed before the evaluation. The sample size was small. The bias related to underreporting or overreporting by healthcare professionals could not be eliminated in indirect data collection. 51 The study did not examine patient outcome of those who had high or low compliance. 52 However, the study was conducted prospectively and therefore reflected practice in each of the ICUs. The study was conducted at two different-sized ICUs, with different case mix, which facilitated diversity in patients for whom medical records were reviewed. Therefore, the results can inform our understanding of the IHI ventilation bundle use in two Australian ICUs.

11. Conclusion

The results of this study demonstrate that ventilation bundle elements were used in Australian ICUs to prevent mechanical ventilation complications. The compliance rate increased with the number of mechanical ventilation days in most of the ventilation bundle elements. These results will help increase awareness of VAE prevention in Australia. It remains essential to promote high compliance with the ventilation bundle until further research proves futility. Future research to investigate facilitators and barriers to compliance with the ventilation bundle would be crucial in clinical practice.

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Auxillia Madhuvu: Conceptualisation, Methodology. Investigation, Software, Data curation, Formal analysis, Writing - original draft, Visualisation, Funding acquisition. Ruth Endacott: Supervision, Methodology. Formal analysis, Writing - review & editing.

Virginia Plummer: Supervision, Methodology, Formal analysis, Writing - review & editing. Julia Morphet: Supervision, Methodology, Formal analysis, Writing - review & editing

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