The effectiveness of educational programmes in ventilator bundle implementation: a systematic review

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Abstract

Introduction

Ventilator-associated pneumonia (VAP) is the most frequent nosocomial infection encountered in critical care settings. Thus, several packages (ventilator bundles, VBs) have been designed to help reduce or eliminate VAP, promote adherence to evidence-based guidelines and thus improve clinical outcomes. The aim of this systematic review was to assess current literature regarding the effectiveness of educational programmes on their implementation.

Materials and methods

A comprehensive literature search strategy was formulated in association with an information specialist. We then reviewed studies published between 2003 and 2012 listed in seven multidisciplinary databases (Ovid MEDLINE®, the Cumulative Index to Nursing and Allied Health Literature, Cochrane Library, Scopus, Web of Science, Medic and Academic Search Premier). The study selection and quality assessment were carried out by two researchers independently and objectively.

Results

Six original studies were included in the final review. Educational programmes were linked to significant improvements in the overall

adherence to VBs and a significant decrease in adverse clinical outcomes such as the incidence of VAP, monthly use of sedatives, duration of mechanical ventilation and hospitalisation costs.

Conclusion

Education programmes about VBs can promote adherence to evidence-based guidelines and thus reduce the incidence of VAP. However, they are often inconsistently developed, implemented and evaluated. There are needs for both effective educational programmes and a universal method for evaluating their outcome.

Introduction

Ventilator-associated pneumonia (VAP) is the most frequent device-associated, nosocomial infection in critical care settings¹⁻³, causing substantial morbidity, a two-fold increase in mortality rates⁴, excess costs⁵ and prolonged use of ventilators⁴, intensive care unit stays and hospital stays^{4,6}.

According to previous literature, healthcare staff's adherence⁷⁻¹⁰ to infection control procedures is currently insufficient due to the lack of time^{11,12}, inaccessible supplies and a lack of knowledge¹¹⁻¹⁵, which may jeopardise patient safety, and thus the quality of care¹⁶.

The Institute for Healthcare Improvement¹⁷, the Centres for Disease Control and Prevention¹⁸ and Rello et al.¹⁹ have designed several 'packages' of evidence-based guidelines (EBGs), known as 'VAP bundles' (ventilator bundles, VBs), to promote adherence to EBGs, thereby reducing or eliminating VAP and improving clinical outcomes. The evidence-based interventions include combinations of sedation vacation and use

of weaning protocols^{17,19}, elevation of the head of the bed between 30° and 45°^{17,18}, daily oral care with chlorhexidine¹⁷⁻¹⁹, adequate hand hygiene¹⁷⁻¹⁹, and ulcer and deep vein thrombosis prophylaxis¹⁷.

The initiation of VBs is an effective method for VAP reduction when adherence is maintained²⁰⁻²². VB training can promote adherence to EBGs and thus reduce the incidence of VAP. However, it is often inconsistently developed, implemented and evaluated⁴. The aim of the present study was to assess the current body of literature regarding the effectiveness of educational programmes on the implementation of VBs, in order to identify ways to intensify current development-evaluation-implementation practices.

Materials and methods

Search strategy

A systematic review was conducted in the autumn of 2012 in accordance with the guidelines of the Centre for Reviews and Dissemination²³ and the Joanna Briggs Institute²⁴. A limited review of Medic, Ovid MEDLINE® and the Cumulative Index to Nursing and Allied Health Literature (CINAHL), was initially conducted to identify optimal search terms²⁴.

The final review focused on peer-reviewed empirical studies written in English, Swedish or Finnish (due to a lack of resources and facilities for translation of other languages) and was published during the past 10 years (2003–2012). The review (Table 1) covered seven multidisciplinary databases (Ovid Medline®, CINAHL, Cochrane Library, Scopus, Web of Science, Medic and Academic Search Premier). A comprehensive literature search strategy was formu-

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Table 1. Databases and number of original studies.

Database	Number of original studies
Ovid Medline®	54
CINAHL*	40
Cochrane Library	1
Scopus	93
Web of Science	68
Medic	0
Academic Search Premier	54

*CINAHL, Cumulative Index to Nursing and Allied Health Literature.

Table 2. Review questions and inclusion criteria .

Review questions	Inclusion criteria
Population	Critical care, critical care unit Intensive care, intensive care unit Adults
Intervention	Education: continuing education, ongoing education, clinical education, inter-professional education
Adverse outcomes	Incidence of VAP, mortality, morbidity, adverse events, length of stay, complica- tions, errors, readmission, admission
Study design	RCT, case control and intervention studies published between 2003–2012 in English, Swedish or Finnish

RCT, randomised controlled trial; VAP, ventilator-associated pneumonia.

lated in association with a library information specialist, based on comparison of outputs of advanced and basic searches with appropriate permutations of terms^{23,24}. The search terms were as follows: 'ventilator-associated pneumonia', 'pneumonia ventilator associated', or 'VAP' and educate* or teach* (* denotes that the used search terms were shortened to obtain more studies in which these terms had been used).

Inclusion criteria and study selection

The study selection process was carried out by two researchers independently and objectively^{23,24}. Studies were included if they met the inclusion criteria (Table 2) based on the research questions, populations (registered critical nurses or

intensive care nurses), intervention (educational intervention used with or without other educational strategies in implementing VBs), type of the outcome (clinical outcome) and the study design (intervention studies). Reviews and studies that did not meet the inclusion criteria or did not include VBs were excluded.

Studies were selected in three stages (Figure 1) to minimise the risk of errors and bias and to ensure that all relevant studies were included. The study selection process was carefully documented to ensure reproducibility using RefWorks®, a web-based research management tool^{23,24}.

In the first stage ($n = 310$), duplicate publications ($n = 130$) in the seven databases were excluded from the

review to reduce publication bias^{23,24}. In the second stage, potentially relevant studies were assessed by two reviewers independently by comparing the titles ($n = 180$) and abstracts ($n = 40$) against the pre-determined inclusion criteria^{23,24}. In the third stage, the full texts ($n = 7$) of studies that appeared to meet the inclusion criteria were obtained for detailed assessment against the inclusion criteria^{23,24}. There was complete agreement between the reviewers' final selections.

Quality assessment

The widely used, standardised, Critical Appraisal Checklist for Cohort/Case Control Appraisal²⁵ was used to assess the quality of the relevant studies ($n = 7$) prior to their inclusion in the final review. The quality of the studies was assessed by two reviewers independently, a content expert and a methodological expert^{23,24}, using a scoring system in which one point was awarded for the inclusion of each relevant criterion (quality score range, 0–9). Studies, with ≥ 5 points were included in the final review.

Data extraction and analysis

The extracted data included specific details about the study designs, settings and participants, and interventions and results, which were extracted by both primary and secondary reviewers and cross-checked (Table 3). A p-value of less than 0.05 was considered statistically significant. Further analysis was limited because of the lack of available data. One study was excluded due to poor quality.

Results

Six out of the seven original studies (85.7%) were included in the final review (Figure 1). The quality of each included study was assessed as high ($\geq 50\%$ of maximum possible score).

Study characteristics

Most (66.7%) published studies were single-centre studies, conducted in Canada²⁶, Germany²⁷ and the UK^{28,29}. The most commonly used (100%)

Figure 1: Flow-chart of the study selection process.

research design was a prospective, observational intervention study including pre- and post-measurements (Table 3). The other included studies were quasi-experimental observational intervention studies, comparing pre- and post-intervention outcomes from different units in a single hospital or between multiple hospitals^{30,31}.

Ventilator bundles

The VBs considered in the examined studies consisted of modified

Institute for Healthcare Improvement bundles^{27,29} and other protocols including three to five evidence-based interventions that have been shown to improve clinical outcomes^{26,28,30,31}. These include combinations of sedation vacation and use of weaning protocols^{28,29,31}, elevation of the head of the bed^{26,27,29,30}, daily oral care with chlorhexidine²⁸⁻³⁰, ulcer^{26,27,31} and/or deep vein thrombosis prophylaxis^{27,31}, adequate hand hygiene^{26,30} and glove

use³⁰, nutrition²⁶, lung protective ventilation²⁷ and management of ventilator tubing condensate^{26,28,30}.

Educational interventions

Educational programmes addressed in the studies consisted of self-study modules³⁰, repeated lectures²⁷, workshops²⁸ and several brief²⁶ or standardised sessions²⁹. All the included intervention studies considered other complementary interventions: teaching materials²⁸⁻³⁰, multidisciplinary education meetings^{28,30}, storyboards³⁰ and reminders, such as e-mails³⁰, posters^{26,29} or other visual aids²⁶⁻²⁹. Moreover, training was supplemented with feedback²⁷⁻³⁰, VAP rate reports^{30,31} and reinforcement at the bedside²⁸. In addition, DePalo et al.³¹ identified hazards, learned from defects and implemented teamwork tools (Table 3).

Critical care nurses' adherence to VBs

Fifty percent of the included studies found that educational interventions increased overall VB adherence significantly^{27,28,31} and the others found that the interventions extremely significantly ($p = 0.000$) increased observed hand hygiene practices and glove use (Table 3)³⁰. Two or three studies found that they significantly increased adherence to elevation of the head of the bed²⁷⁻²⁹, daily oral care with chlorhexidine^{28,29} and documented adherence to weaning protocols^{28,29}. In addition, Bloos et al.²⁷ reported that they significantly increased the use of ulcer and deep vein thrombosis prophylaxis ($p = 0.048$), but Omrane et al.²⁶ detected no significant change in adherence to prophylaxis.

Clinical outcomes

Following educational interventions, 66.7% of the included studies found that the incidence of VAP decreased significantly^{26,28,29,31} and one study³¹ reported that the long-term effects were maintained over 48 months of follow-up (Table 3). In addition, Morris et al. found that rates of methicillin-resistant *Staphylococcus aureus* acquisitions decreased significantly ($p < 0.001$)²⁹.

Table 3. The study characteristics of included original studies with quality scores $\geq 50\%$ ($n = 6$).

Study	Sample and settings	Design	Interventions	Results
Abbot et al. 2006	Conducted in five ICUs in two medical centres among all hospital staff and adult mechanically ventilated patients ($n = 106$) admitted to the ICUs before and after intervention in the USA	Prospective, observational, quasi-experimental design with pre- (from April, May and June 2002) and post-intervention (from April, May and June 2004) measurements	Ventilator bundle: elevation of the head of the bed, oral care, condensate removal, hand hygiene, glove use Educational interventions: self-learning packets, educational materials, and storyboards, one-on-one teaching with clinicians Reminders: E-mails Feedback: VAP* rate reports, feedback on guideline adoption	No statistically significant reduction in the overall VAP* rates in a two-year follow-up ICU length of stay declined resulting in costs savings of approximately \$23000–40000 Observed hand hygiene practices improved ($p = 0.000$) Observed use of gloves increased ($p = 0.000$)
Bloos et al. 2009	Conducted in an ICU in a tertiary care university hospital among hospital and post-surgical staff in charge and all adult mechanically ventilated patients admitted to the ICU before ($n = 133$) and after ($n = 141$) intervention in Germany	A prospective, cohort study with pre- (from June to September 2005) and post-intervention (from March to June 2006) measurements	Modified IHI bundle: elevation of the head of the bed, lung protective ventilation, ulcer and deep vein thrombosis prophylaxis Educational interventions: daily seminars (the scientific background and technique of the bundle) for a two-month period Reminders: red marks were attached on the walls to indicate a correct semi recumbent position Feedback: monitoring daily adherence to the treatment bundles and individually trained nurses and residents if the bundle was not correctly applied for a two-month period	Overall bundle adherence increased from 15% to 33.8% ($p < 0.001$) Elevation of the head of the bed was achieved in 24.9% of patient days before and 46.9% of patient days after ($p < 0.001$) Admission of deep vein thrombosis prophylaxis increased from 89.5 to 91.5% ($p = 0.048$) Ulcer prophylaxis was achieved in both groups Median tidal volume remained unaltered Days of mechanical ventilation reduced from 6 to 4 days ($p = 0.017$) ICU length of stay, ICU mortality and rate of VAP** remained unaffected In patients with VAP, the median ICU length of stay was reduced by 9 days ($p = 0.04$) Significantly less patients received propofol ($p = 0.01$)

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Study	Sample and settings	Design	Interventions	Results
DePalo et al. 2010	Conducted in 23 ICUs in 11 hospitals among ICU staff and all adult ICU patients admitted to the ICUs before and after intervention in the USA	A prospective, cohort study design with pre- (from January to March 2006) and post-intervention (from January 2006 to June 2008) measurements	Ventilator bundle: daily assessment for liberation from mechanical ventilation, elevation of the head of the bed, following commands as an indication of appropriate sedation, ulcer and deep vein thrombosis prophylaxis Educational interventions: educating staff on the science of safety, identifying hazards, identifying senior executive partners, learning from defects and implementing teamwork tools Feedback: VAP* rate reports	Overall bundle adherence increased significantly ($p < 0.0001$) VAP* rates decreased from 3.44 to 2.92 per 1000 ventilator days VAP rate reduced as ventilator bundle adherence increased
Hawe et al. 2009	Conducted in a medical-surgical ICU among ICU staff and all adult mechanically ventilated patients ($n = 1068$) admitted to the ICU before ($n = 675$) and after ($n = 393$) intervention in the UK	Quasi-experimental study with pre- (from 1 September 2005 to 27 September 2007) and post-intervention (from 27 September 2007 to 31 September 2007) measurements	Ventilator bundle: elevation of the head of the bed, oral antisepsis with chlorhexidine, use of sub-glottic suction/drainage endotracheal tubes, daily sedation breaks, daily assessment of readiness to wean and 'tubing management' Educational interventions: workshops (definition, epidemiology, pathogenesis, risk factors, consequences of VAP), written material, multidisciplinary education meetings; barriers affecting delivery of care were identified and iteratively improved Reminders: laminated copies of the bundle, charts Feedback: feedback of process measurement and feedback of outcome measurement Other: organisational change, multi-disciplinary morning rounds	Adherence to all VB elements increased significantly after active implementation ($p < 0.0001$) VAP*** rates reduced from 19.2 to 7.5 per 1000 ventilator days There was a trend towards a lower unit mortality ($p = 0.06$)
Morris et al. 2011	Conducted in mixed medical-surgical ICU in a teaching hospital among all adult patients admitted to the ICU for 48 h or more during the periods before ($n = 1460$) and after ($n = 501$) intervention in the UK	A before-after intervention study VAP surveillance*** data from January 2005 to February 2008 were used as baseline data, from September 2008 to August 2009 as the 'post-VAP prevention bundle implementation' period	Modified IHI bundle: elevation of the head of the bed, oral chlorhexidine gel, sedation holds, weaning protocol implementation Educational interventions: nurse and medical champions, education sessions, teaching materials Reminders: changing the 24-h observation charts, bedside cues Feedback: feedback on adherence at meetings by e-mails and posters	Adherence to elevation of the head of the bed and the use of oral chlorhexidine gel were 95%–100% Documented adherence to 'wake and wean' elements was 70% Overall bundle adherence to VB was 70% Incidence of VAP*** reduced from 32 to 12 days per 1000 ventilator days ($p < 0.001$) Rates of MRSA decreased from 10% to 3.6% ($p < 0.001$)

Study	Sample and settings	Design	Interventions	Results
Omrane et al. 2007	Conducted in an ICU in a tertiary care teaching hospital among ICU staff and all adult mechanically ventilated patients admitted to the ICU before ($n = 349$) and after ($n = 360$) intervention in Canada	Pre- (from November 2003 to May 2004) and post-intervention (from November 2004 to May 2005) observational study	Ventilator bundle: nutrition, hand hygiene, patient positioning, ulcer prophylaxis, the ventilator circuits Educational interventions: 12 education sessions (regarding aetiology, morbidity and mortality of VAP, prevention protocol) Reminders: in service programmes during the study period, posters; a plastified copy of the protocol was incorporated into every patient medication Kardex	Hospital length of stay remained unaffected ($p = 0.35$) Total duration of mechanical ventilation remained unaffected ($p = 0.2$) Antibiotic treatment duration remained unaffected ($p = 0.23$) Use of stress ulcer prophylaxis remained unaffected ($p = 0.08$) Early-onset VAP* decreased from 31 to 18.5 per 1000 ventilator-days ($p < 0.001$) Incidence of late-onset VAP* increased from 21.9 to 24.1 5 per 1000 ventilator days ($p < 0.001$)

* The definition of VAP was derived from the National Nosocomial Infections Surveillance system, ** The definition of VAP was derived from the Clinical Pulmonary Infection Score, *** The definition of VAP was derived from the Hospitals in Europe Links for Infection Control Surveillance.

ICU, intensive care unit; IHI, Institute for Healthcare Improvement; MRSA, methicillin-resistant *Staphylococcus aureus*; VAP, ventilator-associated pneumonia; VB, ventilator bundle.

Increased adherence to VBs did not affect the mean duration of hospital stay^{26,27}. However, Bloos et al.²⁷ found that it significantly decreased the median length of stay of patients with VAP ($p = 0.04$). These authors also reported that it significantly ($p = 0.017$) reduced the total duration or median tidal volume of mechanical ventilation, but not Omrane et al.²⁶, who found no change in this variable. Bloos et al.²⁷ and Abbot et al.³⁰, respectively, found that it significantly reduced the monthly use of sedatives and hospitalisation costs (Table 3). However, the monthly use of antibiotics remained unaffected^{26,29}. Two of the studies detected a trend towards lower mortality associated with adherence to VBs^{28,29}.

Discussion

A comprehensive literature search strategy was formulated, studies were selected and their quality was assessed in accordance with the

guidelines of the Centre for Reviews and Dissemination²³ and Joanna Briggs Institute²⁴. According to our findings, active implementation strategies (i.e. educational programmes) were linked to significant improvements in the overall adherence to VBs and a significant decrease in clinical outcomes: incidence of VAP, monthly use of sedatives, duration of mechanical ventilation and hospitalisation costs.

VBs are an important component of patient safety. Implementation of a VB can support and improve the quality and delivery of care of mechanically ventilated patients in critical care settings. However, the average adherence to VBs in the baseline measurements was insufficient, which is in line with previous studies^{4,7-10}. Overall, the use of active implementation strategies led to a significant increase in adherence to VBs in 50% of included studies^{27,28,31}.

However, according to Klompas⁴, the adherence to VB components must be >95% to realise the bundle's full potential.

A significant reduction in the incidence of VAP following educational programmes was observed in most of the included studies^{26,28,29,31}, but Abbot et al.³⁰ and Bloos et al.²⁷ found no statistically significant reduction in the overall VAP rates. The variability of results in the included studies might be due to the wide range of definitions of VAP applied and the lack of a universal method of outcome evaluation⁴. The definitions of VAP were derived from the National Nosocomial Infections Surveillance³⁰, the Clinical Pulmonary Infection Score^{26,27,31} and Hospitals in Europe Links for Infection Control Surveillance^{28,29} systems. The lack of a universal method of outcome evaluation (i.e. variations in the research

designs, lack of standardised instruments, measurements and follow-up times) raises questions about the validity of estimated effects and limits generalisability^{32,33}.

Variations in the implementation strategies (i.e. in the execution and frequency of education), VBs (various complementary interventions, e.g. reminders, feedback etc.) and endpoints, make intrahospital comparisons and trend determinations difficult or even impossible. In addition, the development-evaluation-implementation processes addressed in the included studies were often inadequately reported. Moreover, the effects of extraneous factors or other potential sources of bias²⁵ on their findings were inadequately reported resulting in both practical and methodological difficulties in the evaluation of their findings.

The search strategy focused only on peer-reviewed empirical studies written in English, Swedish or Finnish and published during the past 10 years (2003–2012), which may have led to publication or language bias^{23,24}. However, the results clearly show that further research is needed to design multi-centre, parallel or cluster randomised controlled, follow-up trials. The development of a universal method of outcome evaluation and a more objective surveillance definition for VAP is required to facilitate further evaluation of the relationship between educational implementation strategies and clinical outcomes. Regular auditing and active implementation strategies (i.e. adequate support) for critical care nurses are required to assess and improve their professional capabilities and current practice.

Conclusion

Educational programmes about VBs can promote adherence to evidence-based guidelines and thus reduce the incidence of VAP. However, they are often inconsistently developed, implemented and evaluated. There are needs for both effec-

tive educational programmes and a universal method for evaluating their outcome.

Abbreviations list

CINAHL, Cumulative Index to Nursing and Allied Health Literature; EBGs, evidence-based guidelines; VAP, ventilator-associated pneumonia; VB, ventilator bundles.

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