A care bundle approach for prevention of ventilator-associated pneumonia

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Abstract

Implementation of care bundles for prevention of ventilator-associated pneumonia (VAP) and its impact on patient outcomes requires validation with long-term follow-up. A collaborative multi-centre cohort study was conducted in five Spanish adult intensive-care units. A care bundle approach based on five measures was implemented after a 3-month baseline period, and compliance, VAP rates, intensive-care unit length of stay (ICU LOS) and duration of mechanical ventilation were prospectively recorded for 16 months. There were 149 patients in the baseline period and 885 after the intervention. Compliance with all measures after intervention was <30% (264/885). In spite of this, VAP incidence decreased from 15.5% (23/149) to 11.7% (104/885), after the intervention ($p < 0.05$). This reduction was significantly associated with hand hygiene (OR = 0.35), intra-cuff pressure control (OR = 0.21), oral hygiene (OR = 0.23) and sedation control (OR = 0.51). Use of the care bundle was associated with an incidence risk ratio of VAP of 0.78 (95% CI 0.15–0.99). We documented a reduction of median ICU LOS (from 10 to 6 days) and duration of mechanical ventilation (from 8 to 4 days) for patients with full bundle compliance (intervention period). Efforts on VAP prevention and outcome improvement should focus on achieving higher compliance in hand and oral hygiene, sedation protocols and intracuff pressure control.

Keywords: Care bundles, intensive-care unit outcomes, patient safety, respiratory care, ventilator-associated pneumonia prevention
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Introduction

Implementing care bundles in clinical practice has been widely advocated in mechanically ventilated patients admitted to an intensive-care unit (ICU) and is associated with a reduced risk of ventilator-associated pneumonia (VAP) [1]. A care bundle identifies a set of key interventions deriving from evidence-based guidelines that, when implemented, are expected to improve patients' health outcomes [2]. The aim of care bundles is to improve health outcomes by facilitating and promoting changes in patient care and to encourage guideline compliance.

The scientific evidence used during the development of the current care bundle package was derived from European hospital-acquired pneumonia guidelines [3]. This study is a validation of the usefulness of care bundles for the prevention of VAP. We have hypothesized that consistent implementation of the evidence-based bundles can improve patient health outcomes. Therefore, the primary objective was to determine the impact of implementing a care bundle package for VAP prevention on VAP rates and duration of mechanical ventilation (days of mechanical ventilation; DMV). Secondary objectives included the determination of any existing relationship between care bundle compliance and other outcomes, such as ICU length of stay (ICU LOS), as well as the assessment of compliance levels and impact of each individual measure on the risk of VAP.

Materials and Methods

This intervention was part of a Catalonian quality improvement collaborative strategy, led by the Department of Health, Generalitat de Catalunya, in collaboration with the local Society of Intensive Care (Societat Catalana de Medicina Intensiva i Critica—SOCMIC) to promote patient safety in the ICU, known as the FADO project.

A pan-European committee developed a care bundle based on the findings of a previous review of the hospital-acquired pneumonia and VAP guidelines across Europe [3]. The details of how best to implement particular interventions were tailored to the local situation, with practical details being specified for each intervention to ensure deliverability. The approach encouraged participation from all individuals involved in patient care [4,5]. Details of the care bundle have been reported elsewhere [6].

The strategies for prevention and management of VAP were scored, after being evaluated by a European expert and a multidisciplinary panel. The highest scored strategies were ranked, selected and presented to a local committee to build a VAP care bundle on prevention (see Supplementary material, Data S1). The SOCMIC invited five hospitals to implement the intervention after an observational baseline period of 3 months. The data collection period was conducted using designated paper forms and lasted from March 2007 to December 2008. Standard data collection forms were distributed across centres.

Potential measures were reviewed and discussed in detail by the steering committee and those considered most appropriate for inclusion as VAP care bundle recommendations were: (i) not implementing ventilator circuit changes unless clinically indicated [7,8]; (ii) the incorporation of sedation control protocols into patient care [9–11]; (iii) the use of strict hand hygiene using alcohol-based antiseptic before manipulating the airways [12]; (iv) oral care with chlorhexidine 0.12% every 8 h [13]; and (v) intra-cuff pressure control to reduce leakage of oropharyngeal secretions to the lower airways tract [14]. The protocol was standardized across different centres (Data S2).

Each variable was recorded as dichotomous (yes/no) for every 8-h period and transferred to an electronic database. Compliance with measures was self-recorded through a checklist at the end of each nursing shift. As compliance with individual measures in the care bundle inevitably varied between shifts, over a 24-h period, the lowest level of compliance achieved for each variable was recorded in the daily log to facilitate inter-variable analysis for each patient. It was predetermined that a selected collaborator would randomly observe the manner in which measures were followed and recorded, and we expected this to have minimized the bias in self-reporting. Interventions such as maintaining optimal hand hygiene comprised the standard of general infection control procedures [15]. However, its inclusion in the VAP care bundle represents an opportunity to audit its compliance and optimize the quality of hand hygiene practices. In addition, the requirement of not changing ventilator circuits unless indicated represented an accepted care practice. Nonetheless, the steering committee believed that including this established intervention remained appropriate because it had a high degree of evidence and was associated with cost-containment.

A local ICU improvement team was established and both the medical leader and the nurse manager were included. The teams were trained through conference seminars led by the study investigators, for standardization of care and education purposes. The ICU teams were provided with cards, brochures and posters to educate their staff. Feedback on VAP rate was provided in the form of posters, detailing cumulative incidence of VAP and measure compliance in the different centres. Every centre was allowed access to their own data and the coordinating centre owned the overall data. Teams from each centre attended feedback meetings where results were exposed; data from all centres were shown but the identity of the centres was not disclosed. This model of institutional change emerged from the existing literature on practical approaches to evidence-based practice [16]. The study was approved by the Ethics Committee of the coordinating institution (Joan XXIII University Hospital, Tarragona: ref. 2006) and informed consent was waived. VAP was defined as early onset when it developed in the first four DMV, and as late onset when it appeared after the fourth DMV [17].

Ventilation-associated pneumonia was diagnosed by the attending physician team, based on standardized definitions and methods provided by the CDC [18,19] (see Supplementary material, Data S3). An independent investigator (intensivist), who was not part of the team caring for the patient made the final diagnosis of pneumonia, using quantitative respiratory cultures, using standardized thresholds [20–23]. Finally, there was no other infection control programme implemented concomitantly to this study in any of the centres.

Variables

Variables were recorded prospectively. The severity of illness was assessed by the application of an Acute Physiology and Chronic Health Evaluation (APACHE II) [24] within 24 h of ICU admission. The attending nurse recorded, every 8 h,

TABLE 1. Demographic background of the study population (baseline and intervention)

	Baseline	Intervention
Demographic details		
n (patients)	149	885
Age, years (mean ± SD)	59 ± 18	66 ± 18
Sex, male (%)	69	65
APACHE II at admission mean ± SD	18 ± 8.6	17 ± 3.5
Co-morbidities (%)		
Chronic obstructive pulmonary disease	N/A	15
Cardiomyopathy	N/A	11
Chronic renal failure	N/A	4
Background on admission (%)		
Medical	51	52
Surgical	38	33
Trauma*	11	15

APACHE II, Acute Physiology and Chronic Health Evaluation; N/A, not available.
*Only referring to some centres.

the compliance for each variable included in the care bundle. All other variables were collected by the study coordinator.

Statistical analysis

Data were analysed using statistical software (Version 15.0 for Windows; SPSS, Chicago, IL, USA). Continuous variables were described as mean values, medians and SDs, and were compared with Student's *t* test or Mann–Whitney *U* test as appropriate according to distribution. Categorical variables were compared with Pearson and, if appropriate, Fisher exact tests. The significance level was defined as $p \leq 0.05$. Compliance rates were calculated as (number of cases where compliance with measure *X* was observed / total number of intubated patients in the same period of time) × 100.

Results

The final study included a total of 3845 ventilator-days, 149 patients in the baseline period and 885 patients after the intervention. Characteristics of the study population are summarized in Table 1. There were no significant differences from the baseline period and intervention period in terms of percentages of each specialty for all centres. Hence, we did not relate any decreases in VAP incidence to an altered population mapping in terms of admission diagnosis.

During the baseline period, there was a VAP incidence of 12.9/1000 ventilator-days (a rate of 16 cases per 100 patients), which decreased to 9.28/1000 ventilator-days (a rate of 11 cases per 100 patients) after the intervention period ($p < 0.05$). DMV decreased from 11.1 to 6.4 days from the baseline period to the intervention period ($p < 0.05$).

The use of the full bundle was associated with an incidence risk ratio of VAP of 0.78 (95% CI 0.15–0.99), delaying onset of VAP from a median of 6–9 days.

Compliance for each variable of the care bundle varied for all patients included in the study (Fig. 1). The highest compliance was achieved regarding not changing ventilator circuits unless necessary (34%; 301/885) and performing sedation control (27%; 239/885) (p 0.20). On the other hand, intracuff pressure control was consistently performed only in 18% (159/885) of opportunities, followed by oral care (21%; 186/885) and hand hygiene (19%; 188/885), which revealed the lowest levels of compliance. When only significant variables were taken in account, excluding all the cases where compliance was not recorded and including only variables with an OR < 1, overall compliance in VAP patients was reduced to 9.3% (82/885).

In the intervention period, the risk of developing VAP was significantly reduced, when hand hygiene was performed (OR 0.35; 95% CI 0.11–0.68), and the same association was found with intra-cuff pressure control (OR 0.21; 95% CI 0.25–0.92) and oral hygiene (OR 0.23; 95%CI 0.17–0.75). The bundle variable that appears to have less impact on the risk of developing VAP is not changing the ventilator tubings unless necessary (Fig. 2).

When analysing the number of VAP cases through time (see Supplementary material, Data S4), one can observe a majority of cases (60%) occurring before the seventh DMV.

In the intervention period, where full adherence to the five evidence-based interventions of the care bundle was recorded, the DMV was considerably reduced, as well as ICU LOS (Fig. 3).

In all, 10.5% (93/885) of daily compliance records were mssing. Early-onset VAP cases were to some extent affected by the care bundle compliance (Fig. 4). A rate of 0.7% (6/885) was observed, of which 0.5 episodes/1000 ventilator-days

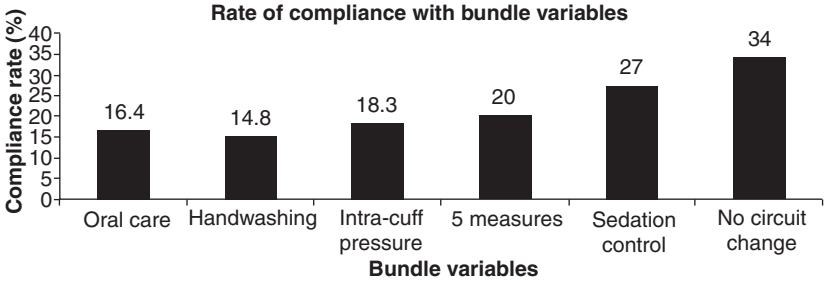

FIG. 1. Rates of compliance with bundle variables in the intervention period.

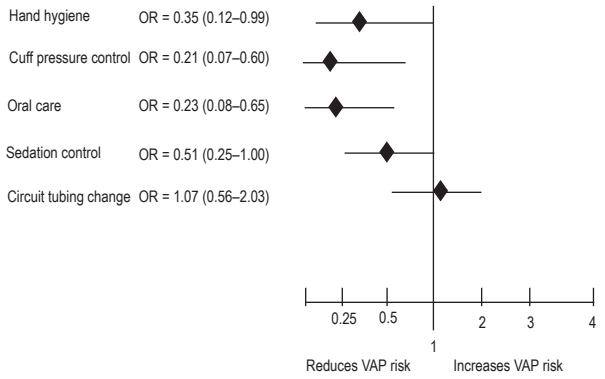

FIG. 2. Ventilator-associated pneumonia (VAP) risk odds ratio for each preventive measure.

occurred with full compliance and 1 episode/1000 ventilator-days with partial compliance of the prevention care bundle. Late-onset VAP, on the other hand, with a rate of 9.4% (83/885), had an incidence of 2.9 episodes/1000 ventilator-days for patients with the full care bundle. For cases with only partial bundle compliance (less than five measures), a VAP incidence of 19.5 episodes/1000 ventilator-days was observed.

Discussion

This is the first study to validate a European care bundle for VAP prevention [6]. In a long-term follow up, it was difficult to maintain high levels of compliance (see Supplementary material, Data S5), demonstrating the importance of continuous education of healthcare workers. Multidisciplinary efforts combining doctors and other healthcare workers are required.

The five specific care bundle variables used in our approach were selected by an expert multidisciplinary group, and each of them has been found in a previous study to be associated with a decrease in the rate of VAP [6]. Our findings demonstrate a reduction of 4 days in ICU LOS and

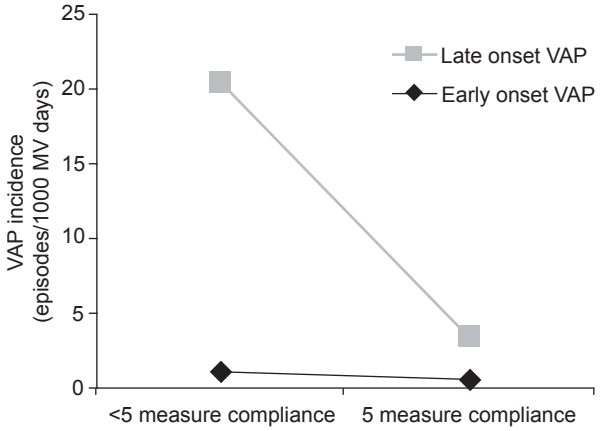

FIG. 4. Ventilator-associated pneumonia (VAP) incidence (episodes/1000 mechanical ventilation days) for early-onset and late-onset VAP according to measure compliance—figures after the intervention.

DMV, when compliance was highest, and during the intervention period. The VAP rate and DMV decreased after the intervention, when performing a comparative analysis of the available data in the pre-intervention and post-intervention periods.

These findings are particularly relevant, because it has been reported that the occurrence of VAP increases the duration of hospital stay by approximately 6 days [25] and that costs have been estimated to be above $40 000 [26].

Wip and Napolitano [27] have reviewed the value of care bundles to prevent VAP. They concluded that, although the 'ventilator bundle' is an effective method to reduce VAP rates, it should be modified towards introducing specific preventive strategies with proven effect in reducing VAP.

We have scrutinized the different bundle variables independently and related them to VAP risk (Fig. 2). This enabled us to suggest that some variables may have more impact on improving outcomes than others, even though they seem to be the ones with lowest compliance rates. Hand hygiene before manipulating airways, for example, has shown a strong impact on reducing VAP risk, but it revealed a compliance of

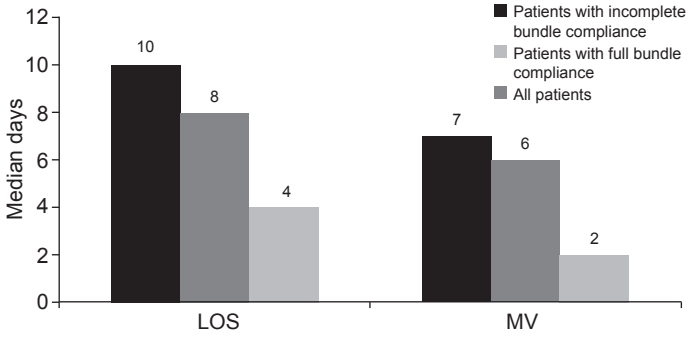

FIG. 3. Intensive-care unit length of stay (LOS) and duration of mechanical ventilation (MV), in days, according to measure compliance—figures after the intervention.

only 19%. Because we have used a method essentially based on self-registration of compliance by the attending nurse, biases in reporting should be taken into account.

A major strength of our study is that its design has allowed the assessment of individual measures over a long follow-up period. Four out of five preventive measures were found to have benefit in VAP prevention. Not changing the ventilator circuits revealed no significant impact in reducing the rate of VAP, whereas the rest of the preventive strategies contributed to the decline of VAP incidence. Although an 'all-or-nothing' approach is the main rule of bundle application [6], a close relationship was established between the number of compliant variables and VAP rates. During the intervention period, the measures that most impacted on the risk of developing VAP were hand hygiene (OR = 0.35) and oral care (OR = 0.23). Our evidence also suggests higher impact of the care bundle on late-onset VAP than on early-onset VAP.

Similar to the before-and-after study by Morris *et al.* [28], our work acknowledges the importance of a quality-improvement programme in embedding practice change within the culture of a unit or organization. Morris *et al.*' results [28] have shown levels of compliance with the care bundle that are close to 100% and also that this led to clear benefits to patients. Our approach, on the other hand, advocates the possibility lower thresholds for compliance with a care bundle still obtaining benefit in patient outcomes. In the Resar *et al.* study [29], the bundle was based on measures that were checked three times every day. Our accomplishment of hand hygiene is in accordance with other studies [30].

The decision of assuming the lowest compliance levels for each day, and each patient, might have had a strong impact on the overall compliance. A Hawthorne effect may have represented potential bias. In general, it is commonly accepted that a heavy change in daily practice would take a while until it achieves its final goal. Indeed, our study may confirm what was suggested by Resar *et al.* [29] that a 'changed delivery system' and 'chain reaction' of increased attention to the patients leads to benefits in patient outcomes. Hence, even though we acknowledge that external factors can be present, one can still explain why such a low compliance level was still associated with a decrease in the rate of VAP, DMV and ICU LOS.

Conclusions

Significant improvements in outcomes can be achieved with high compliance in implementing a care bundle package for VAP prevention. This study shows that even though the bundle approach was difficult to maintain long term, significant benefits were documented, even with low degrees of compliance. Efforts should be concentrated in continuous education of healthcare workers to maintain high levels of compliance.

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Author Contributions

JR designed the research protocol and wrote the first draft of the manuscript. EA, TL, MR, BB, AR, JV and ED contributed to the acquisition of data, contributed to the revised versions of the manuscript and the analysis of data. ED coordinated the study investigator sites. All authors read and approved the final manuscript.

Transparency Declaration

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Data S1. Ranking of evidence-based bundle variables.

Data S2. Summary of protocol for bundle implementation.

Data S3. Algorithm used for VAP diagnosis.

Data S4. Cumulative percentage of VAP cases according to days of mechanical ventilation, during the intervention period.

Data S5. Cumulative cases of full and incomplete bundle compliance, according to days of mechanical ventilation, during the intervention period.

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Appendix 1

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