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Caroline S. Hawe
Kirsteen S. Ellis
Chris J. S. Cairns
Andrew Longmate

Reduction of ventilator-associated pneumonia: active versus passive guideline implementation

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C. S. Hawe · K. S. Ellis · C. J. S. Cairns · A. Longmate (✉)
Department of Anaesthesia and Intensive Care Medicine, Stirling Royal Infirmary, Livilands Stirling FK8 2AU, UK
e-mail: alongmate@nhs.net
Tel.: +44-1786434476
Fax: +44-1786434476

C. S. Hawe
e-mail: hawecaroline@hotmail.com

Abstract *Purpose:* Ventilator-associated pneumonia (VAP) is associated with increased morbidity, mortality and costs. We describe an active, multifaceted implementation of a VAP prevention bundle designed to improve staff compliance with evidence-based actions and reduce the incidence of VAP. *Method:* A 'VAP prevention bundle' was designed then implemented, first passively, then actively, as defined by a multimodal programme incorporating staff education, process measurement and outcome measurement and feedback to staff and organisational change. *Results:* Compliance with the VAP prevention bundle increased after active implementation. VAP incidence fell significantly from 19.2 to 7.5 per 1,000 ventilator days. Rate difference (99% CI) = 11.6 (2.3–21.0) per 1,000 ventilator days; rate ratio (99% CI) = 0.39 (0.16, 0.96). *Conclusions:* An active implementation programme increased staff compliance with evidence-based interventions and was associated with a significant reduction in VAP acquisition.

Keywords Pulmonary nosocomial infections · Critical care organisation

Introduction

Ventilator-associated pneumonia (VAP) is the most frequent infection acquired by patients in intensive care [1]. It is associated with increased mortality, morbidity, length of stay and costs [2]. Prevention of VAP has been highlighted as a priority [3–5]. The incidence of VAP in our ICU appeared to be quite high, measured at 40/1,000 patient days in 2004 [6] and 15.9/1,000 ventilator days in the last quarter of 2005.

Several evidence-based interventions are known to reduce the incidence of VAP. These have been incorporated into guidelines by a number of organisations [7–9]. Translating evidence-based findings into consistent delivered care at the bedside remains a challenge. It is recognised that effective interventions are not always universally practiced despite evidence supporting their use [10–12], and this is no different when it comes to preventing VAP [13, 14]. Though the use of guidelines to promote consistency and reduce variation in clinical practice has been advocated, the successful implementation of any guideline is by no means guaranteed and is dependent upon many factors, including implementation strategies that need to be tailored to the local situation [15–18]. Knowledge of strategies for behaviour change is essential for successfully implementing evidence-based guidelines [19]. Active implementation strategies that include staff education, clinical reminder systems, audit and feedback, organisational change and multifaceted approaches are associated with improvements in care [20].

Educational interventions for staff have been shown to effectively reduce the incidence of VAP in several studies, though none have been performed in a European intensive care unit (ICU) [21–26]. Measurement of outcome ('Infection Surveillance') [27] has long been identified as an effective tool to reduce infections. The

importance of 'process measurement' (assessing provider behaviours) has also been emphasised more recently [28, 29] as a tool for improving quality. 'Care bundles' (groups of evidence-based interventions performed together) have been advocated as a means of improving outcomes for VAP, catheter-related blood stream infections and sepsis [3, 4, 30–32].

However, uncertainty remains regarding the optimal strategies to ensure that preventative interventions are translated into bedside practice. In addition, there remains the question of whether any specific 'bundle' can affect outcome when applied locally in the practical world of a busy intensive care unit.

We describe a quasi-experimental study that evaluated the effects of introducing a bundle of evidence-based interventions to reduce VAP. The bundle was introduced first in a 'standard' relatively 'passive' way and then later as part of an integrated 'active implementation program' involving a package of interventions including staff education, process and outcome measurement, feedback to staff and organisational change. This work has previously been published in abstract form [33] and presented at the Scottish Intensive Care Societies Scientific Meeting (Dunblane, UK, January 2008).

Method

Study location, patient population, VAP definitions and analysis

The adult surgical/medical ICU at Stirling Royal Infirmary serves a population of approximately 270,000 people. The activities described were performed as part of an infection surveillance and quality improvement programme that started in September 2005, in an ICU that has an ongoing culture supporting staff education. Ethical approval was therefore viewed as unnecessary, and this was confirmed by the chair of the local ethics committee. Hand hygiene and basic infection control techniques were emphasised at all times. A separate intervention designed to reduce catheter-related bloodstream infections was commenced in January 2007.

All patients admitted to the ICU between 1 September 2005 and 31 December 2007 were assessed for the occurrence of ventilator-associated pneumonia using 'Hospitals in Europe Links for Infection Control Surveillance' (HELICS) definitions [34].

Generating a VAP reduction protocol/bundle and passive implementation

In August 2005 the hospital's Critical Care Development Group reviewed evidence-based recommendations for VAP prevention [7–9] and finalised a local 'VAP prevention protocol' consisting of a "bundle" of six elements of care: semi-recumbent patient positioning (30–45° angle), oral antisepsis with chlorhexidine, use of sub-glottic suction/drainage endotracheal tubes, daily sedation breaks, daily assessment of readiness to wean and 'tubing management' (the default use of a dry ventilator circuit and use of a heat and moisture exchange filter (HMEF) positioned about the patient's head). Consultants and senior nursing staff developed the bundle and agreed to practice in accordance with it, and it was formally adopted as unit policy at our regular management meeting. Laminated copies of the bundle where displayed prominently by the bedside. Consultant staff and senior nurses gave verbal and written encouragement for its use at ward rounds and other times. This was defined as the "*passive implementation*" period from 1 September 2005 to 28 February 2007.

Assessment of compliance with six elements of the VAP prevention bundle

Compliance with the provision of each element of the bundle was assessed on three separate occasions for 50 consecutive ventilated patient episodes during November 2006, May 2007 and October 2007. Assessments were performed by one of two individuals (KE or CH) on daily visits between 16:00 and 18:00 h and results recorded on a standard form. A care element was judged to have been complied with if it was being performed, had been performed (in the previous 24 h) or if the intervention was contra-indicated.

Active implementation: education, feedback of process measurement and feedback of outcome measurement and organisational change

An educational intervention was commenced from March 2007. By April 2007 over 90% of the unit's medical and nursing staff had participated in workshops presenting the definition, epidemiology, pathogenesis, risk factors and consequences of VAP. The evidence base for the bundle was discussed. Written material was distributed to encourage further self-study. Staff knowledge was not objectively measured or tested.

The assessments of bundle element compliance were communicated to staff by means charts displayed on the walls and at multi-disciplinary education meetings. The pattern of VAP acquisition was displayed as frequently updated statistical process control (SPC) 'g charts' (see below) and discussed at educational meetings.

Barriers affecting delivery of care were identified and iteratively improved. Examples included: using a written prompt to initiate chlorhexidine prescription, later refined to pre-printing this prescription on the ICU drug charts, marking 30 and 45° on a revised bedside bundle chart,

agreeing to timing of sedation breaks and the re-introduction of a unified weaning plan tool.

Review of adherence to the bundle was promoted as an integral part of the morning multi-disciplinary ward rounds to enhance collective ownership. During the time period described the medical and nursing staff numbers and staffing ratios remained constant. The *active implementation period* was defined as the period from 1 March 2007 to 31 December 2007.

Statistical analysis

VAP rate was calculated per 1,000 ventilation days and compared between the passive and active implementation periods using rate difference and rate ratio tests. A ventilation day was defined as a patient receiving invasive ventilation for a whole or part ventilator day after 48 h of invasive ventilation had elapsed.

In addition, we performed continuous SPC analysis throughout the study period and regularly communicated infection patterns to staff. SPC combines time series analysis with graphical presentation of data, which can yield insights into the data in a quicker and more easily understandable form for the lay person. We analysed the number of ventilator days between episodes of VAP. The underlying statistical parameter is a geometric random variable and the plot is called a 'g chart'.

Analysis of outcome is complicated by the existence of natural or 'common cause' variation. For a stable process, the variation will be predictable as described by the relevant statistical distribution. 'Special cause variation' refers to unnatural variation due to circumstances or events that have not previously been typical or inherent in the process. If processes (in this case the occurrence of VAP) produce data with special causes, measured values will deviate in an observable way from the random distribution model. The SPC charts establish statistical limits with criteria to define whether data that deviate from predictions do indeed provide statistical evidence of change or 'special cause variation'. An advantage of using a 'g chart' over more traditional methods is that it takes advantage of each observed infection, yielding more plotted points at a faster rate rather than waiting until the end of a specific time period and aggregating measurements. This means there can be an almost immediate analysis, response and feedback as changes are seen [35–37].

Results

Demographics

Table 1 shows demographic data. A total of 1,068 patients were admitted over the 28-month period, 675 in the passive period and 393 in the active period; 374 patients were ventilated for more than 48 h in the passive period and 215 in the active period. The patients in the passive and active implementation cohorts were similar with respect to sex, ventilation rates, length of stay (LOS), illness severity, admitting diagnosis and source of admission.

Bundle compliance

Table 2 shows percent compliance for individual elements of the bundle. Compliance increased with active implementation.

Table 1 Patient demographics

All patients admitted		
	Passive implementation period 1 Sept 2005–27 Feb 2007	Active implementation period 27 Feb 2007–31 Dec 2007
Total	675	393
Male	388 (57%)	216 (55%)
Ventilated (%)	(510/675) 75%	(306/393) 78%
Mean LOS	5.5	5.2
Patients ventilated for >48 h		
Total	374	215
Male	208 (56%)	132 (61%)
Mean APACHE II*	19.1	20.4
Median LOS	4.5	5.0
Pneumonia as admitting diagnosis**	16%	14%
Septic shock as admitting diagnosis†	15.5%	10%
'Medical'patients††	46.5%	52%
Admitted from theatre‡	31%	27%
Admitted from emergency department‡‡	28%	34%

LOS length of stay, *APACHE* acute physiological and chronic health evaluation

*$P = 0.66$ (Mann–Whitney U test)

**$P = 0.48$, †$P = 0.072$, ††$P = 0.187$, ‡$P = 0.38$, ‡‡$P = 0.3$ (all chi squared)

Table 2 Percentage compliance with protocol elements

Care element	Level of compliance achieved (%)			Chi-squared *P* value (Nov 2006 vs. Oct 2007)
	'Passive' implementation period	'Active' implementation period		
	Nov 2006	May 2007	Oct 2007	
Patient at 30°–45° angle	54	80	94	<0.001
Subglottic ETDT	72	92	92	<0.001
Oral antiseptic wash	8	94	100	<0.001
Tubing management	98	98	100	0.31
Daily weaning plan	52	72	72	0.039
Daily sedation holiday	72	86	82	0.23
All elements performed	0	48	54	<0.0001

ETDT endotracheal drainage tube

Table 3 VAP incidence, mortality and LOS

Patients ventilated for >48 h		
	Passive implementation period 1 Sept 2005–27 Feb 2007	Active implementation period 27 Feb 2007–31 Dec 2007
Total	374	215
Ventilator days	2,556	1,327
Episodes of VAP	49	10
VAP/1,000 ventilator days	19.17	7.5
Median LOS	4.5	5.0
Mortality	(112/374) 30%	(49/215) 23%

Patient outcomes: VAP incidence and unit mortality

In the passive implementation period there were 49 episodes of VAP and 2,556 ventilator days (19.2/1,000 ventilator days) compared with 10 episodes of VAP and 1,327 ventilator day's (7.5/1,000 ventilator days) during the active implementation period (see Table 3). The rate difference (99% confidence interval, CI) was 11.6 (2.3–21.0)/1,000 ventilator days. The rate ratio (99% CI) was 0.39 (0.16, 0.96). Both measures demonstrate high statistical significance. There was a trend towards a lower unit mortality in the active implementation period ($P = 0.06$).

Statistical process control

Figure 1 shows the 'g-chart' plot. There is a consistent pattern of VAP acquisition in the earlier part of the plot (during 'passive implementation period'). Towards the end of the plot (during the 'active implementation period') there is an increase in the number of ventilator days between VAP acquisitions. The UCL = upper control limit, CL = center line (mean) and UWL = upper warning limit lines define the central tendency and the range of natural variation of the plotted values. Values that fall outside the upper control limits (three SDs) exceed the range within which almost all of the values are expected to lie if the process remains unchanged. Crossing the UCL once denotes statistical evidence of a clinical change. With two points above the upper control limit (UCL), this change is consistent with an 'external cause variation'.

Discussion

Passive implementation was associated with poor compliance with elements of the VAP prevention bundle. This is consistent with previously recognised patterns of provider behaviour [20]. However, the 'passive' bundle implementation was consistent with usual operational policy and management practice in our ICU.

Multimodal 'active' implementation was associated with a significant improvement in VAP bundle compliance ('process'), which in turn was associated with a significant improvement in outcome (reduced VAP rate). VAP incidence fell from 19.2 to 7.5/1,000 ventilation days between passive and active periods and continued falling into the final quarter of the time period described (to 5.5/1000 ventilation days). The SPC chart demonstrates a change in the pattern of VAP acquisition in the active period of study.

These observations need to be interpreted in the light of some important limitations. The method was not of a randomised controlled trial, but of a quasi-experimental quality improvement study using before and after interventional cohorts. There is the possibility for bias in our results as data collection and educational intervention were performed by the same individuals. It is possible that the reduction in VAP rates was due to an unrecognised secular trend or seasonal variation in rate, or caused by 'regression to the mean' [38]. It might be that changes in staff behaviour might be attributed to a Hawthorne effect [39], although this is by definition only temporary.

Establishing causality between process and outcome independent of other potential variables is not possible,

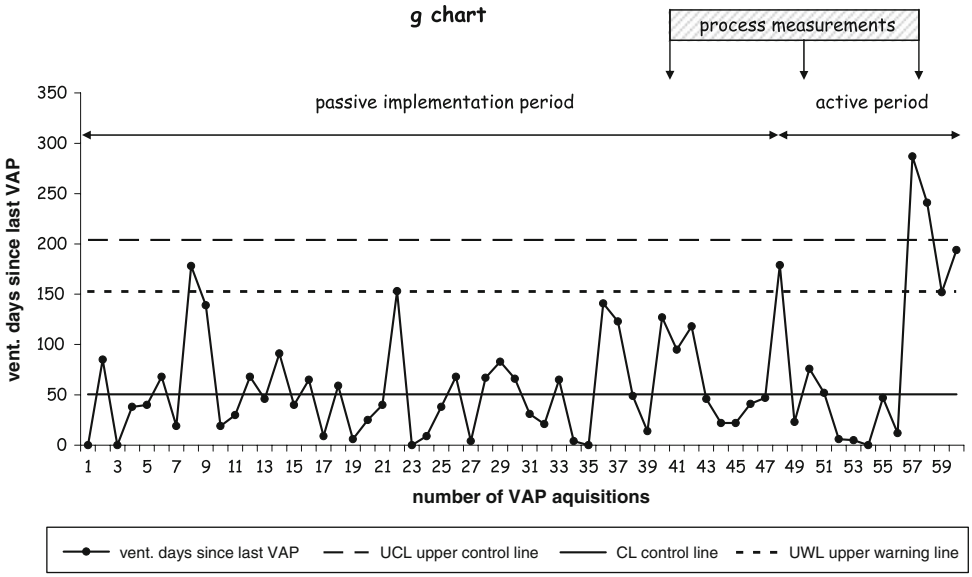

Fig. 1 'g-chart' plot of at risk ventilation days between acquisitions of VAP

but the association is strengthened by the following points: VAP acquisition was continuously recorded using standardised and validated definitions. The time period of the study (28 months) included a prolonged pre-active intervention baseline period (18 months) supporting the view that infection rates were not unusually high prior to the start of active intervention and a relatively long post intervention period (10 months). Staff behaviour and process were measured as bundle compliance over extended time periods on three separate occasions (one before and two after the intervention), which is supportive of a sustained change in staff behaviour.

Although we described the educational intervention, we did not attempt to objectively quantify staff knowledge before or after. We have not performed sub-group or regression analysis, but numbers are small, and the groups appear balanced. We made no formal assessment of potential adverse effects of the intervention, though none were brought to our attention. There was a trend towards a reduction in mortality between the passive and active periods. This is worthy of noting only. Many factors can influence unit mortality. However, the groups appeared well matched. No other outcomes were assessed, and we did not perform a health economic assessment. Other studies have demonstrated significant potential cost savings from preventing infection [21–23].

We have described a challenging journey of effective bundle implementation. VAP rates were significantly reduced in association with an active multimodal quality improvement intervention with four main components including staff education, process measurement, infection surveillance and organisational change. We are not able to comment on the relative importance of the individual components. Sub-optimal performance was only recognised after the first set of process measurements. Educational interventions are known to reduce VAP incidence [21–26]. Surveillance of infection been long recognised as a means of reducing infections. Dissemination of outcome results to those who might use them to prevent and control has been recognised as an important element of surveillance.

Knowledge about the best way to implement bundles and guidelines continues to evolve, but we have described a package that has been successful in changing staff behaviours and benefiting our patients by reducing the incidence of VAP. There remains opportunity for further improvement. Bundle compliance could be improved, particularly with daily sedation breaks and weaning from the ventilator, giving the potential for further reduction in the VAP acquisition rate. We firmly advocate ongoing education, process measurement and infection surveillance in our ICU and believe that it is worthy of consideration elsewhere.

This pragmatic study performed within Europe contributes to recent requests for wider implementation and further investigation of quality improvement interventions to prevent VAP [38]. Further study in the form of a cluster randomised controlled trial has been suggested [40], but in the meantime this work adds to our knowledge surrounding effective guideline and bundle implementation and contributes to the evolving evidence base supporting strategies encompassing continuous surveillance, process measurement and staff education as modalities to prevent ventilator acquired pneumonia.

Conclusion

Passive implementation of the VAP prevention bundle was associated with low levels of compliance. Compliance

improved during an active multimodal implementation period that included process and outcome measurement, a staff educational programme and operational changes in the unit. This was associated with a significant reduction in the occurrence of VAP.

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