Ventilator-associated pneumonia and oral care: A successful quality improvement project

Kathleen Hutchins, RN, MSN, George Karras, MD, Joan Erwin, RN, BSN, and Kevin L. Sullivan, RN, BSN, CIC
Springfield, Massachusetts

Background: Ventilator-associated pneumonia (VAP) is a nosocomial pneumonia that develops in patients on mechanical ventilation for ≥48 hours. VAP develops at an estimated rate of 1% to 3% per day of mechanical ventilation.
Methods: Quality improvement project. Mechanically ventilated patients received the following oral care every 4 hours: the teeth were brushed with cetylpyridinium chloride (changed to 0.12% chlorhexidine gluconate in 2007) using a suction toothbrush, the oral cavity was cleansed with suction swabs treated with hydrogen peroxide, a mouth moisturizer was applied, deep oropharyngeal suctioning was performed, and suction catheters were used to control secretions. The primary efficacy variable was a diagnosis of VAP in patients mechanically ventilated for ≥48 hours.
Results: The historical average rate of VAP in 2004 was 12.6 cases/1000 ventilator-days. After the inception of the quality improvement project, VAP rates decreased to 4.12 (VAP cases/days of ventilation × 1000) for May to December 2005, to 3.57 for 2006, and to 1.3 for 2007.
Conclusion: The use of an oral care protocol intervention and ventilator bundle led to an 89.7% reduction in the VAP rate in mechanically ventilated patients from 2004 to 2007.
Key Words: Ventilator-associated pneumonia; VAP; oral care; ventilator bundle.

(Am J Infect Control 2009;37:590-7.)

Ventilator-associated pneumonia (VAP) is the most common nosocomial infection in patients who are critically ill,[1] occurring at an estimated rate of 1% to 3% per day of mechanical ventilation.[2] VAP is defined as a nosocomial pneumonia that develops in a patient who has been on mechanical ventilatory support (intubated) for ≥48 hours.[3] The hospital mortality of patients with VAP is significantly higher than that of patients without VAP.[2] In addition to VAP being associated with increased morbidity and mortality, VAP is associated with higher medical care costs.

Bacterial infection of the lower respiratory tract typically occurs when the upper respiratory tract is colonized with pathogens, which is followed by aspiration of the oropharyngeal secretions.[4] Patients in the intensive care unit (ICU) are at particular risk of oropharyngeal colonization with pathogens because of exposure to pathogens endemic to the ICU environment, exposure to multiantibiotic regimens, impaired mucosal defenses (desiccation, decreased salivary secretion, and immunoglobulin A content), accumulation of secretions as a result of intubation, and the unique environment that the endotracheal tube creates for dispersing pathogenic bacteria.[4]

An organized approach to VAP prevention can reduce the rate of VAP. A ''ventilator bundle'' is a group of interventions for the intubated patient found to be effective in reducing the rate of VAP.[5-7] The interventions are recommended by the Institute for Healthcare Improvement (IHI) and include elevating the head of the bed, daily ''sedation vacations,'' daily assessment of readiness for extubation, and prophylaxis for peptic ulcer disease and deep venous thrombosis.[8] The ventilator bundle may be further enhanced by oral care, which may play a role in reducing the incidence of VAP.[4]

PROBLEM

At Mercy Medical Center in Springfield, MA, VAP rates have been calculated and recorded since January 1997 (8 years prior to the quality improvement intervention) and were not shown to meet the National Nosocomial Infections Surveillance System standard. The Center's annual average VAP rates (VAP cases/days of ventilation × 1000) ranged from a high of 19.19 in 1999 to a low of 10.01 in 2002. A performance improvement project was

From the Critical Care Unit, Mercy Medical Center, Springfield, MA.
Address correspondence to Kathleen Hutchins, RN, MSN, Mercy Medical Center, 299 Carew St., Springfield, MA 01102-9012. E-mail: kathleen.hutchins@sphs.com.
Conflicts of interest: None to report.
0196-6553/$36.00

doi:10.1016/j.ajic.2008.12.007

developed to address this negative clinical outcome and determine the effectiveness of combining an oral care protocol with a ventilator bundle to prevent VAP in intubated/mechanically ventilated patients in the ICU.

DESCRIPTION OF QUALITY IMPROVEMENT INTERVENTION

This quality improvement program was performed from May 2005 to December 2007 at Mercy Medical Center, a 182-bed, private, nonprofit, acute care hospital in Springfield, MA. This facility has a 12-bed ICU and a 9-bed coronary care unit. No such standardized protocol had been followed prior to institution of the VAP prevention protocol. The hospital ICU practice guidelines stated that patients were to receive ''oral care'' every 4 hours and as needed, but no further instructions were specified.

The project was not designed as a controlled study but rather as a quality improvement initiative; therefore, there was no control group or randomization. The hospital ICU practice guidelines were revised to incorporate instructions on the ventilator bundle and oral care. Education in the use of the ventilator bundle and oral care product and protocol was provided to nurses (registered nurses), respiratory therapists, and intensivists with an in-service given by an oral care product representative. Re-education was conducted a year later when an increase in VAP rates was noted, and additional training in appropriate utilization of the ventilator bundle was provided to nurses and physicians.

All mechanically ventilated patients admitted to the ICU between May 2005 and December 2007 were incorporated into the quality improvement program population unless they had a contraindication to the ventilator bundle or oral care intervention, such as massive oral trauma or prescriber orders that conflicted with implementation of the bundle and/or oral care every 4 hours.

Care consistent with the IHI-recommended ventilator bundle was provided to each patient.[8] This included daily breaks from sedation, daily assessment of readiness to extubate, prophylaxis for peptic ulcer disease and deep venous thrombosis, and elevation of the head of the bed. The head of the bed was kept elevated at $\geq$30 degrees (unless medically contraindicated), and the angle was monitored and verified with an angle marker on the bed. The compliance with the bundle elements was recorded.

In addition to the above ventilator bundle, patients received, at minimum, oral care every 4 hours and as needed. The instructions for oral care were as follows:

- Replace suction liner, tubing, and covered oral suction device every 24 hours.
- Brush teeth using suction toothbrush with cetylpyridinium chloride (CPC) (Antiplaque Solution; Sage Products, Cary, IL) twice a day on even hours and as needed (recommended at 08:00 and 20:00). Brush for approximately 1 to 2 minutes while applying suction at completion and as needed during the brushing. Gently brush the surface of the tongue. The initial oral care system with a product containing CPC was used every 12 hours; in January of 2007, CPC was substituted for a 0.12% chlorhexidine gluconate (CHG)-containing product (CHG Oral Rinse; Sage Products).
- Use suction swabs with a hydrogen peroxide (Perox-A-Mint; Sage Products) solution every 4 hours on even hours (12, 4, 8, . . ., with the exception of the twice-a-day brushing times) to clean the teeth and tongue.
- Use moisturizing swabs every 4 hours after completion of oral care. Apply mouth moisturizer to mucous membranes, buccal cavity, and lips.
- Perform deep oropharyngeal suctioning using a disposable oropharyngeal suction catheter every 12 hours to assist in removing oropharyngeal secretions that have pooled in the hypopharynx (with teeth brushing, recommended at 08:00 and 20:00).
- Use suction catheters to assist in controlling secretions prior to major position changes, extubation, cuff deflation, and repositioning of tube and as needed.

Family were also educated and informed about the ventilator bundle and oral care regimen and the goal of reducing ventilator-associated complications and VAP. If the patient self-extubated, the Critical Care Policy was followed. This policy states that, if ventilatory support is needed, noninvasive ventilation should be attempted before reintubation, and reintubation should be done only if it is necessary. All interventions, abnormal assessment findings, additional actions, patient and/or family teaching, and responses were documented by the staff. The time line for institution of the improvement initiatives is shown in Fig 1.

The hospital ICU protocol for ventilator setups underwent two changes unrelated to the quality improvement program during the course of the project. On October 1, 2005, the frequency of changes of ventilator in-line suction setups went from daily changes to changes as needed. In December 2006, a change was made to use heated wire circuits versus non-heated circuits.

KEY MEASURES FOR IMPROVEMENT

The primary outcome measure for improvement was the occurrence of VAP in patients who had been

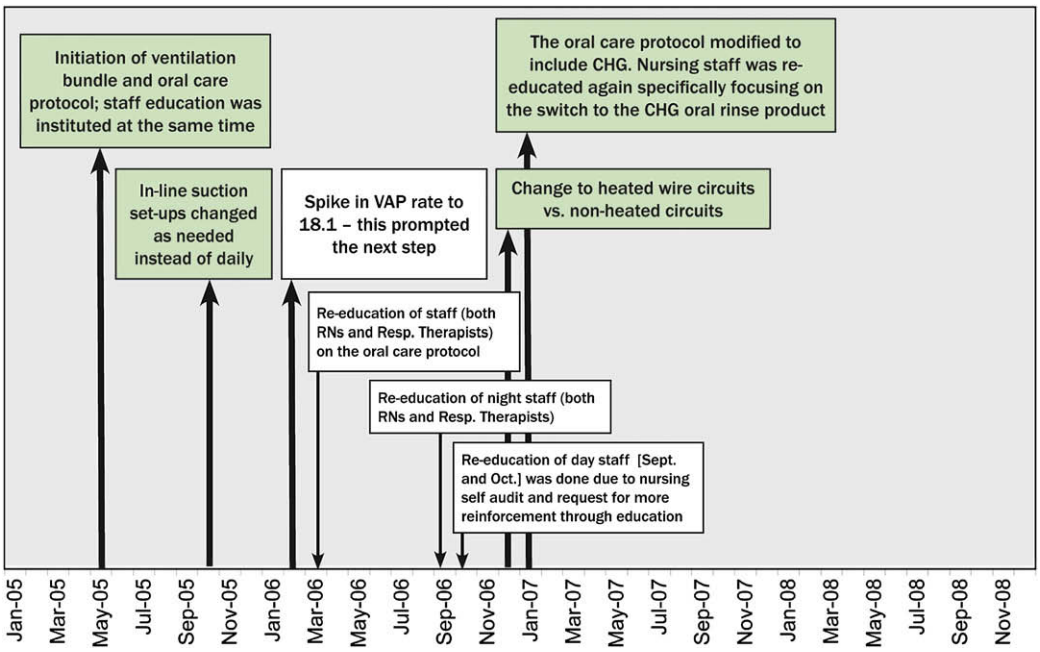

Fig 1. Project time line.

mechanically ventilated for ≥48 hours. The diagnosis of VAP was made on the basis of the clinical judgment of a medical doctor, microbiologic data (Gram's test and culture results), and radiographic evidence. The results of this quality improvement program are reported as simple means and percentages. VAP rates were calculated as the number of cases of VAP per 1000 ventilator-days, and additional information on the actual cases of VAP and actual number of ventilator days is provided.

ANALYSIS AND INTERPRETATION

Initial compliance with the IHI ventilator bundle was less consistent for the first year of implantation. Compliance ranged from 67% to 100% during 2005 and improved somewhat to 87% to 100% in 2006. However, as time went on and re-education persisted, compliance improved and ranged from 91% to 100% for both 2007 and 2008 (see Fig 2 for bundle compliance rates).

None of the patients were excluded during the quality improvement program period; therefore, 100% of the patients were included. The overall average daily census from 2004 through 2007 was 8.3 patients (average daily census was 9.2 in 2004, 9.0 in 2005, 7.9 in 2006, 7.2 in 2007; year-to-date for 2008 is 7.0) For 2004, the VAP rate at Mercy Medical Center was 12.6. From May (start of protocol) to December 2005, the VAP rate was 4.12 (5 cases of VAP/1211 ventilator-days). For 2006, the VAP rate was 3.57 (7 cases of VAP/1959 ventilator-days). For 2007, when the 0.12% CHG product replaced the CPC product in the oral care kits, the VAP rate was 1.3 (2 VAP cases/1533 ventilator-days) (Fig 3). The VAP rate decreased by 89.7% from 2004 to 2007. The decrease in VAP rate in 2005 was noted almost immediately after the inception of the quality improvement project (see Table 1 for monthly VAP rates in 2005). See Fig 4 for comparison of VAP rates.

DISCUSSION

Epidemiology

Nosocomial pneumonia accounts for 31% of nosocomial infections, and a large majority (83%) of patients who develop nosocomial pneumonia were mechanically ventilated.[9] VAP is associated with an increased mortality rate. Bercault and Boulain[10] found that VAP, as an independent risk factor, carries an odds ratio of 2.1 for death ($P = .008$). In a large retrospective cohort study, VAP was associated with a mortality rate of 29.3% ($P < .0001$).[11] VAP because of infection with antibiotic-resistant *Pseudomonas aeruginosa* is associated with an even higher mortality rate of 37.3% (odds ratio, 2.92; $P = .02$).[12]

Furthermore, patients with VAP have longer hospital and ICU stays than do patients without VAP.[13] The higher morbidity associated with VAP results in mean hospital charges per patient that are between

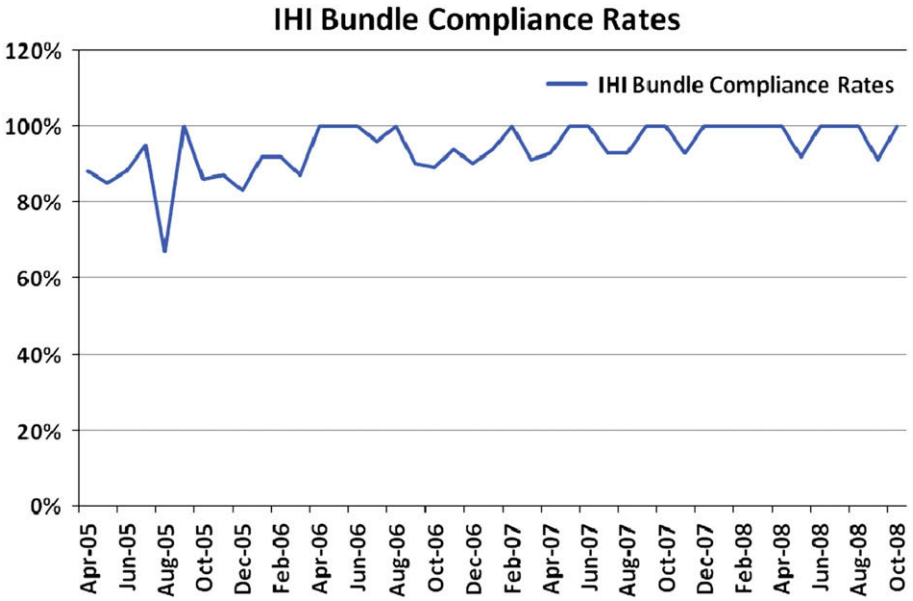

Fig 2. IHI bundle compliance rates from April 2005 through October 2008.

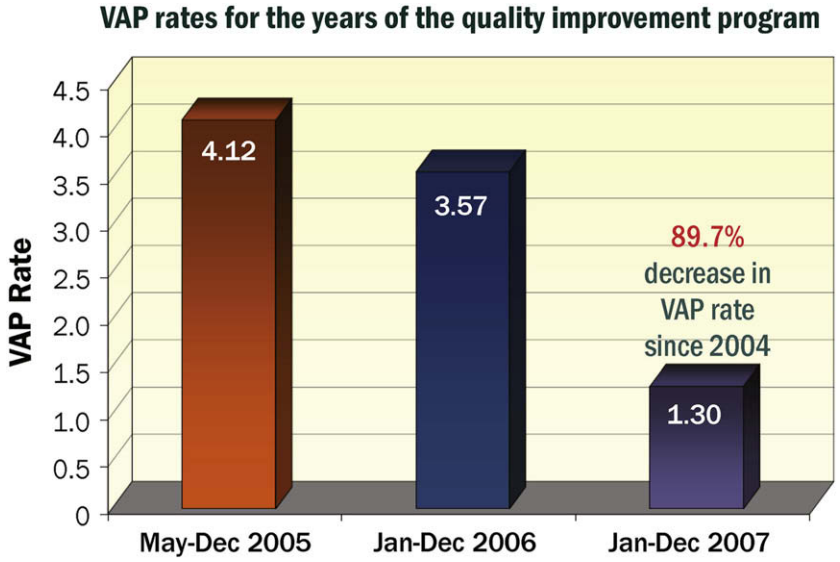

Fig 3. VAP rates for the years of the quality improvement program.

$11,897[13] and $40,000[14] higher than costs for case-control patients without VAP. Infection with methicillin-resistant *Staphylococcus aureus* (MRSA) increases hospital costs by an additional $7731 per patient.[14]

Ventilator bundle effectiveness

Introduction of a ventilator bundle has also been shown to decrease VAP rates. In a study of 35 ICUs, VAP rates had an average reduction of 44.5% after implementation of the VAP bundle.[7] Similar benefits were seen in a study of two 20-bed ICUs in which rates decreased from 6.1 to 2.7 per 1000 ventilator-days in one unit and from 2.66 to 0 per 1000 ventilator-days in the other unit.[5] Cocanour et al[6] found that institution of a ventilator bundle alone was not adequate to decrease VAP rates only as long as there was adequate feedback to maintain compliance. Education leading to improvement in compliance with evidence-based care has also been

Table 1. VAP rates in 2005

Month	VAP rate*	95% Confidence interval	Comparison with Benchmark (exact binomial test)
May	5.1 (1/197)	0.1-27.8	0.99
June	5.2 (1/192)	0.1-28.5	0.99
July	4.0 (1/247)	0.1-22.3	0.75
August	0.0 (0/124)	0.0-29.3	0.69
September	0.0 (0/67)	0.0-53.6	0.99
October	0.0 (0/115)	0.0-31.6	0.75

*Calculated as VAP cases/days of ventilation × 1000.

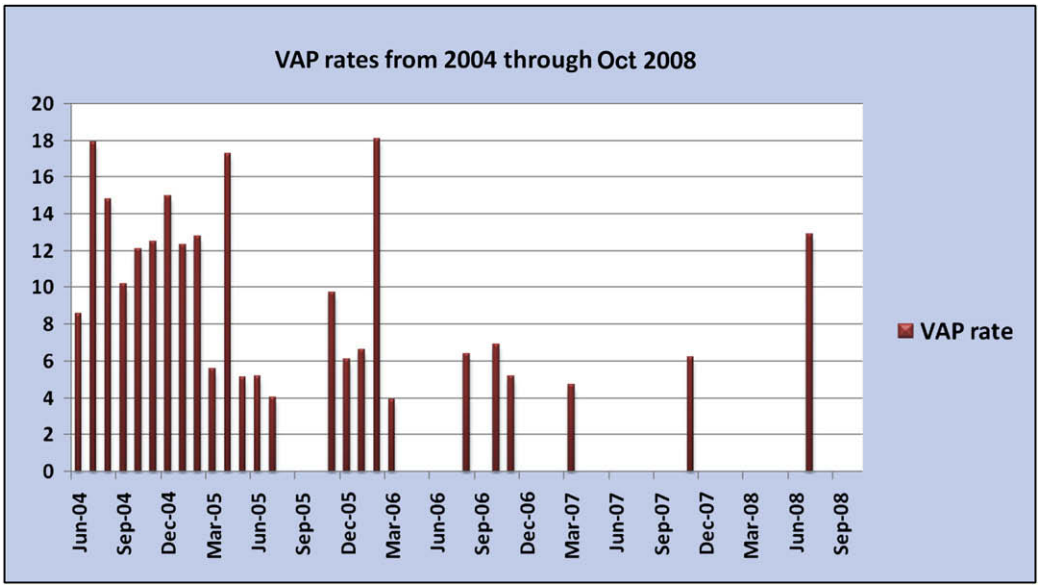

Fig 4. VAP rates from June 2004 through October 2008.

shown to improve VAP rates: Salahuddin et al[15] found that a multidisciplinary educational programme produced a 51% reduction in VAP rates.

Bacterial isolates and oral care

The most common pathogen associated with VAP is *S aureus*, which is found in 31% of isolates from VAP patients.[16] *P aeruginosa* was the identified pathogen in 25.3% of patients with health care-associated pneumonia.[11] Microbial antibiotic resistance is common among the pathogens responsible for nosocomial pneumonia. In patients with health care-associated pneumonia, 56.8% of *S aureus* isolates are MRSA.[11] In ICU patients treated with a fluoroquinolone for pneumonia, 40% of the pathogens isolated were MRSA, 24% were drug-resistant *P aeruginosa*, and 19% were resistant to extended-spectrum β-lactamases.[17] Needless to say, the development of antibiotic resistance complicates the medical care of VAP patients.

Previous studies in the 1990s confirmed the association between oral bacterial colonization and nosocomial pneumonia in mechanically ventilated patients.[18-20] Torres et al[18] isolated a greater number of coincident microbial species from gastric, pharyngeal, and endotracheal samples than from bronchoscopic-protected brush-sampling specimens in patients who were mechanically ventilated and had pneumonia. The same was true in ventilated patients who did not have pneumonia. The authors concluded that both the gastric and pharyngeal reservoirs played a role in the development of VAP and suggested that preventing colonization of these reservoirs might reduce the incidence of VAP.

Scannapieco et al[19] found that bacteria that commonly cause nosocomial pneumonia also

colonize the dental plaque and oral mucosa of patients in the ICU. In addition, patients in the ICU have higher mean plaque scores than do patients in a non-ICU control group. Pathogens isolated from the plaque of these ICU patients included MRSA, *P aeruginosa*, and other gram-negative bacteria. These findings suggest that dental plaque may also provide a reservoir for pathogenic bacteria that contribute to VAP.

In a study by Fourrier et al,[20] dental plaque colonization at the time of admission to the ICU or after 5 days in the ICU led to a relative risk of subsequent nosocomial infection of 9.6, including pneumonia ($P < .001$). By day 10 of admission to the ICU, 46% of patients had dental plaque cultures that were positive for aerobic pathogens. In addition, there was a high bacterial concordance between the dental plaque cultures and the tracheal aspirate cultures in these patients, supporting the idea that the oropharynx serves as a reservoir for pathogens that contribute to VAP.

The above studies from the 1990s were followed by protocols advocating oral care in the critical care setting[4]; however, the data on whether oral care management can influence outcomes in intubated patients remained equivocal. Studies demonstrating the effectiveness of oral care management and its potential influence on outcomes in intubated patients started emerging after 2000. In 2002, Schleder et al[21] conducted a 4-year retrospective study of adults in the ICU. The rates of VAP were documented prospectively after the inception of the protocol and were then compared with historical controls. Prior to the inception of the protocol, there were 5.6 VAP cases/1000 ventilator-days; after the protocol was initiated, there were 2.2 VAP cases/1000 ventilator-days.

Fourrier et al[22] studied the effect of dental plaque antiseptic decontamination on the occurrence of plaque colonization by aerobic nosocomial pathogens and the rates of subsequent nosocomial infection. In an initial study, it was found that oral decontamination with 0.2% CHG gel 3 times per day appeared to reduce nosocomial infection rates in ICU patients on mechanical ventilation. Subsequently, a prospective, multicenter, double-blind efficacy study was conducted in which 228 patients underwent oral decontamination with either 0.2% CHG gel or placebo gel 3 times per day. The incidence of nosocomial infections was 13.2/1000 ICU-days (17.5%) in the placebo group and 13.3/1000 ICU-days (18.4%) in the CHG-treated group, which represented a nonstatistically significant difference. However, by day 10, the number of dental plaque cultures that were positive for pathogens was significantly lower ($P < .05$) in the CHG-treated group (29%) than in the placebo group (66%).[23] Muscedere et al[24] undertook a comprehensive literature review to develop an evidence-based clinical practice guideline to reduce VAP rates and determined that oral antisepsis with CHG should be considered as part of protocols to reduce VAP.

EFFECTS OF CHANGE

The purpose of this quality improvement program was to determine the effectiveness of a quality improvement program instituting a ventilator bundle and consistent oral care in preventing VAP in mechanically ventilated patients. In 2004, the baseline VAP rate was 12.6 cases/1000 ventilator-days. The number of VAP cases decreased immediately after inception of the protocol, which included oral care and the ventilator bundle: 3.17 VAP rate over the first 6 months of the quality improvement program. The VAP rate (VAP cases/days of ventilation $\times$ 1000) for 2005 was 4.12 during the months of May through December. The improvement in VAP rates continued, with an annual VAP rate of 3.57 for 2006 and of 1.3 for 2007. The further decrease in VAP rates from 2006 to 2007 may have been attributed to the substitution of CPC with 0.12% CHG in the tooth brushing solution in January 2007.

The ventilator bundle seeks to address numerous risks that result from mechanical ventilation, including peptic ulcer disease and deep venous thrombosis. The reduction in VAP rates observed with implementation of the ventilator bundle may be due to the combination of raising the head of the bed, allowing sedation vacations, and frequently assessing readiness for extubation. Experts have speculated that the coordinated teamwork to improve patient care might be responsible for the improvement in VAP rates, rather than any specific intervention. It is likely that implementation of the VAP bundle also contributed to the observed improvement in our VAP rates, although compliance with the bundle was often less than 100%, particularly in the early years of implementation. Additional interventions that might be considered for future projects include rotation of beds and elevation of the head of the bed to 45°, both of which were identified by Muscedere et al[24] as evidence-based interventions that showed benefit in preventing VAP.

The likely reasons for the success of this quality improvement intervention are multifaceted. The products used in the oral care protocol, in addition to the ventilator bundle, may have reduced the rates of VAP by reducing the oral bacterial load, which may have occurred through the removal of colonized plaque, mucous, and bacteria from the buccal cavity and teeth because of the mechanical debriding action of the

hydrogen peroxide solution. Additionally, increased education likely improved the oral care methods of staff. Furthermore, routine suctioning of the oropharynx and hypopharynx may also have led to a reduction in bacterial counts. The application of a moisturizer may have decreased the number and severity of breaks in the oral mucosa because of desiccation and mechanical injury from pressure and rubbing by the endotracheal tube or other devices. The addition of 0.12% CHG-based products to the protocol in January 2007 improved the antimicrobial activity of the tooth brushing solution and likely reduced oral bacterial loads. Last, but most importantly, staff compliance with the protocol improved by 19.64% between the beginning and the end of the quality improvement program. This improvement may have occurred because the oral care products used are prescription products that required administration documentation and/or because of staff training and feedback. The increase in compliance coincided with the decrease in VAP rates; however, a contemporaneous occurrence does not prove causality. Clinical studies in this area, including studies designed as blinded randomized studies, are needed to determine the effect of compliance on VAP rates.

PRACTICE IMPLICATIONS

Strategies to effectively prevent VAP are urgently needed, and no single strategy has been proven to achieve prevention. This quality improvement program used the ventilator bundle and an oral care protocol intervention with CPC (changed to 0.12% CHG in January 2007) and hydrogen peroxide, which may have led to the 89.7% reduction in the rate of VAP in mechanically ventilated patients from 2004 to 2007. Our results suggest that oral care including the use of CPC (or 0.12% CHG) and a hydrogen peroxide-containing mouthwash combined with implementation of the ventilator bundle may assist in preventing VAP. Future clinical studies are warranted to determine to what extent each of these protocols (oral care and ventilator bundle) individually contributes to the reduction in VAP rates.

The authors thank Dr. Donna Coffman and Kersten Hammond with MedBio Publications for their medical writing and editorial assistance in the development of this manuscript.

References

1. Safdar N, Dezfulian C, Collard HR, Saint S. Clinical and economic consequences of ventilator-associated pneumonia: a systematic review. Crit Care Med 2005;33:2184-93.
2. Ibrahim EH, Tracy L, Hill C, Fraser VJ, Kollef MH. The occurrence of ventilator-associated pneumonia in a community hospital. Chest 2001; 120:555-61.
3. Institute for Healthcare Improvement. Ventilator-associated pneumonia (VAP) rate per 1000 ventilator days. Available from: http://www.ihi.org/IHI/Topics/CriticalCare/IntensiveCare/Measures/VentilatorAssociatedPneumoniaRateper1000VentilatorDays.htm. Accessed July 9, 2008.
4. Garcia R. A review of the possible role of oral and dental colonization on the occurrence of health care-associated pneumonia: underappreciated risk and a call for interventions. Am J Infect Control 2005;33: 527-41.
5. Youngquist P, Carroll M, Farber M, Macy D, Madrid P, Ronning J, et al. Implementing a ventilator bundle in a community hospital. Jt Comm J Qual Patient Saf 2007;33:219-25.
6. Cocanour CS, Peninger M, Domonoske BD, Li T, Wright B, Valdivia A, et al. Decreasing ventilator-associated pneumonia in a trauma ICU. J Trauma 2006;61:122-9.
7. Resar R, Pronovost P, Haraden C, Simmonds T, Rainey T, Nolan T. Using a bundle approach to improve ventilator care processes and reduce ventilator-associated pneumonia. Jt Comm J Qual Patient Saf 2005;31:243-8.
8. Institute for Healthcare Improvement. Implement the ventilator bundle. Available from :http://www.ihi.org/IHI/Topics/CriticalCare/IntensiveCare/Changes/ImplementtheVentilatorBundle.htm. Accessed April 25, 2007.
9. Richards MJ, Edwards JR, Culver DH, Gaynes RP. The National Nosocomial Infections Surveillance System. Nosocomial infections in combined medical-surgical intensive care units in the United States. Infect Control Hosp Epidemiol 2000;21:510-5.
10. Bercault N, Boulain T. Mortality rate attributable to ventilator-associated nosocomial pneumonia in an adult intensive care unit: a prospective case-control study. Crit Care Med 2001;29: 2303-9.
11. Kollef MH, Shorr A, Tabak YP, Gupta V, Liu LZ, Johannes RS. Epidemiology and outcomes of health-care-associated pneumonia: results from a large US database of culture-positive pneumonia. Chest 2005;128:3854-62.
12. Zavascki AP, Barth AL, Fernandes JF, Moro AL, Goncalves AL, Goldani LZ. Reappraisal of *Pseudomonas aeruginosa* hospital-acquired pneumonia mortality in the era of metallo-β-lactamase-mediated multidrug resistance: a prospective observational study. Crit Care 2006;10:R114.
13. Warren DK, Shukla SJ, Olsen MA, Kollef MH, Hollenbeak CS, Cox MJ, et al. Outcome and attributable cost of ventilator-associated pneumonia among intensive care unit patients in a suburban medical center. Crit Care Med 2003;31:1312-7.
14. Rello J, Ollendorf DA, Oster G, et al. Epidemiology and outcomes of ventilator-associated pneumonia in a large US database. Chest 2002; 122:2115-21.
15. Salahuddin N, Zafar A, Sukhyani L, Rahim S, Noor MF, Hussain K, et al. Reducing ventilator-associated pneumonia rates through a staff education programme. J Hosp Infect 2004;57:223-7.
16. Shorr AF, Tabak YP, Gupta V, Johannes RS, Liu LZ, Kollef MH. Morbidity and cost burden of methicillin-resistant *Staphylococcus aureus* in early onset ventilator-associated pneumonia. Crit Care 2006;10: R97.
17. Nseir S, Di Pompeo C, Soubrier S, Delour P, Lenci H, Roussel-Delvallez M, et al. First-generation fluoroquinolone use and subsequent emergence of multiple drug-resistant bacteria in the intensive care unit. Crit Care Med 2005;33:283-9.
18. Torres A, el-Ebiary M, Gonzalez J, Ferrer M, Puig de la Bellacasa J, Gene A, et al. Gastric and pharyngeal flora in nosocomial pneumonia acquired during mechanical ventilation. Am Rev Respir Dis 1993;148: 352-7.
19. Scannapieco FA, Stewart EM, Mylotte JM. Colonization of dental plaque by respiratory pathogens in medical intensive care patients. Crit Care Med 1992;20:740-5.

20. Fourrier F, Duvivier B, Boutigny H, Roussel-Delvallez M, Chopin C. Colonization of dental plaque: a source of nosocomial infections in intensive care unit patients. Crit Care Med 1998;26:301-8.
21. Schleder B, Scott K, Lloyd RC. The effect of a comprehensive oral care protocol on patients at risk for ventilator-associated pneumonia. J Adv Health Care 2002;4:27-30.
22. Fourrier F, Cau-Pottier E, Boutigny H, Roussel-Delvallez M, Jourdain M, Chopin C. Effects of dental plaque antiseptic decontamination on bacterial colonization and nosocomial infections in critically ill patients. Intensive Care Med 2000;26:1239-47.
23. Fourrier F, Dubois D, Pronnier P, Herbecq P, Leroy O, Desmettre T, et al, the PIRAD Study Group. Effect of gingival and dental plaque antiseptic decontamination on nosocomial infections acquired in the intensive care unit: a double-blind placebo-controlled multicenter study. Crit Care Med 2005;33:1728-35.
24. Muscedere J, Dodek P, Keenan S, Fowler R, Cook D, Heyland D, for the VAP Guidelines Committee and the Canadian Critical Care Trials Group. Comprehensive evidence-based clinical practice guidelines for ventilator-associated pneumonia: prevention. J Crit Care 2009;23:126-37.