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**An Educational Intervention to Reduce Ventilator-Associated Pneumonia in an Integrated Health System: A Comparison of Effects**

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# An Educational Intervention to Reduce Ventilator-Associated Pneumonia in an Integrated Health System*

## A Comparison of Effects

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***Study objectives:*** **To determine whether an educational initiative could decrease rates of ventilator-associated pneumonia in a regional health-care system.**

***Setting:*** **Two teaching hospitals (one adult, one pediatric) and two community hospitals in an integrated health system.**

***Design:*** **Preintervention and postintervention observational study.**

***Patients:*** **Patients admitted to the four participating hospitals between January 1, 1999, and June 30, 2002, who acquired ventilator-associated pneumonia.**

***Intervention:*** **An educational program for respiratory care practitioners and ICU nurses emphasizing correct practices for the prevention of ventilator-associated pneumonia. The program included a self-study module on risk factors for, and strategies to prevent, ventilator-associated pneumonia and education-based in-services. Fact sheets and posters reinforcing the information were posted throughout the ICU and respiratory care departments.**

***Measurements and results:*** **Completion rates for the module were calculated by job title at each hospital. Rates of ventilator-associated pneumonia per 1,000 ventilator days were calculated for all hospitals combined and for each hospital separately. Overall 635 of 792 ICU nurses (80.1%) and 215 of 239 respiratory therapists (89.9%) completed the study module. There were 874 episodes of ventilator-associated pneumonia at the four hospitals during the 3.5-year study period out of 129,527 ventilator days. Ventilator-associated pneumonia rates for all four hospitals combined dropped by 46%, from 8.75/1,000 ventilator days in the year prior to the intervention to 4.74/1,000 ventilator days in the 18 months following the intervention ($p < 0.001$). Statistically significant decreased rates were observed at the pediatric hospital and at two of the three adult hospitals. No change in rates was seen at the community hospital with the lowest rate of study module completion among respiratory therapists (56%).**

***Conclusions:*** **Educational interventions can be associated with decreased rates of ventilator-associated pneumonia in the ICU setting. The involvement of respiratory therapy staff in addition to ICU nurses is important for the success of educational programs aimed at the prevention of ventilator-associated pneumonia.** ***(CHEST 2004; 125:2224–2231)***

**Key words:** education; infection; mechanical ventilation; pneumonia; prevention respiratory therapy

Ventilator-associated pneumonia is the most common hospital-acquired infection among patients requiring mechanical ventilation, resulting in excess mortality, prolonged lengths of hospitalization, and increased medical care costs.[1–6] Colonization of the aerodigestive tract with pathogenic bacteria and subsequent aspiration of contaminated secretions into the lower airways appear to be the most important mechanisms for the development of ventilator-associated pneumonia.[7] Therefore, clinical strategies aimed at preventing bacterial colonization of the host and subsequent aspiration have been most extensively investigated for the prevention of this nosocomial infection.[8]

Although the optimal approach to reducing ventilator-associated pneumonia is unclear, studies[9–13] indicate that educating health-care workers who care for patients receiving mechanical ventilation can decrease the rate of ventilator-associated pneumonia. In times of limited resources, focusing health-care workers' efforts on the prevention of ventilator-associated pneumonia is important, especially given the association between inadequate staffing in the

ICU setting and the occurrence of nosocomial infections.[14–17] Despite the importance of preventing nosocomial infections, available information suggests that such infections are on the rise, resulting in warnings from professional and national agencies to refocus efforts on their prevention.[1,18,19] Additionally, there are limited data documenting the influence of infection control education-based interventions targeting regional health-care systems.[20] Therefore, we investigated the impact of a targeted educational intervention to prevent ventilator-associated pneumonia at four different hospitals in one large health system. The intervention was previously effective at decreasing rates of ventilator-associated pneumonia at one of these institutions, the adult teaching hospital, as reported by Zack et al.[13] In this study, we compared the effect of the intervention in the adult teaching hospital and three other hospitals within the same integrated health system.

## Materials and Methods

### *Intervention*

A multidisciplinary task force consisting of two physicians (M.H.K. and V.J.F.) and members of the Barnes-Jewish Hospital Infection Control Team was formed in February 1999 to develop a policy for the prevention of ventilator-associated pneumonia. This policy was derived in large part from two literature reviews authored by one of the task force members.[7,8] The task force also compared the new policy to the Centers for Disease Control and Prevention recommendations for the prevention of ventilator-associated pneumonia.[18] Based on this information, the task force designed an educational module to improve practices related to the prevention of ventilator-associated pneumonia.

The centerpiece of the educational initiative was a 10-page self-study module. The module included information on the following topics related to ventilator-associated pneumonia: (1) epidemiology and scope of the problem, (2) risk factors, (3) etiology, (4) definitions, (5) methods to decrease risk, (6) procedures for collecting suctioned sputum specimens, and (7) clinical and economic outcomes influenced by ventilator-associated pneumonia. Risk factors for ventilator-associated pneumonia that were specifically addressed included those promoting aspiration (supine positioning and gastric overdistention) and those associated with bacterial colonization of the upper airway and stomach (prior antibiotic exposure and the use of stress ulcer prophylaxis). A section from the self-study module outlining specific risk reduction strategies addressed in the infection control policy is shown in Table 1. The points made in the module were summarized with the acronym WHAP VAP, in

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**Table 1—*Section From the Self-Study Module for the Prevention of Ventilator-Associated Pneumonia****

| |
|---|
| How do I reduce the risk of VAP in my patients? |
| The primary intervention to prevent any nosocomial infection is handwashing. Careful infection control practices related to respiratory care are also essential to preventing VAP. Health-care workers should use the following recommendations for all patients receiving mechanical ventilation. |
| To prevent bacterial colonization of the aerodigestive tract: |
| Meticulous hand hygiene with the use of soap and water or a waterless hand antiseptic agent is essential before and after ventilator contact or patient suctioning. |
| Do not change ventilator circuits and/or in-line suction catheters unless visibly soiled or malfunctioning. |
| Do not use heat moisture exchangers for patients with excessive secretions or hemoptysis (be sure to provide alternative form of humidification). |
| Change heat moisture exchangers every 24 h, or when visibly soiled with secretions. |
| Drain condensate from ventilator circuits per policy using appropriate technique to avoid contamination of the circuit. |
| To prevent aspiration of contaminated secretions: |
| Maintain adequate ventilation and cuff pressure. |
| Place ventilated patients in semi-recumbent position with head of bed elevated to at least 30°, as tolerated, even during transport. |
| Drain ventilator circuit condensate before repositioning patient. |
| To avoid gastric distention monitor gastric residual volumes before initiating gastric feedings via nasogastric, orogastric, or percutaneous gastrostomy tubes. |
| Remove nasogastric tubes as soon as possible. |
| To reduce risk of VAP when suctioning a ventilated patient: |
| Use clean gloves for in-line suctioning and sterile gloves for single use catheter suctioning. |
| Do not store catheter where it can become contaminated, or contaminate clean supplies. |
| Oral suction catheters (*eg*, Yankauer) should be stored in a nonsealed paper or plastic bag when not in use. |
| Do not lay suction catheters on ventilator. |
| Suction when necessary. Frequent unnecessary suctioning may introduce organisms into the lower respiratory tract. |
| Other key points to reduce the risk of VAP include: |
| Avoid nasal intubation. |
| Adequately secure endotracheal tube and take necessary measures to prevent accidental extubation. |
| Avoid overuse of multiple antibiotics. |
| Limit stress ulcer treatment if possible. |
| Use daily chlorhexidine oral rinse (only for patients undergoing cardiothoracic surgery). |
| Provide immunizations (*eg*, influenza, pneumococcus, haemophilus B). |

*VAP = ventilator-associated pneumonia.

which W stood for “Wean the Patient” as soon as possible, H for “Hand Hygiene,” A for “Aspiration Precautions,” and P for “Prevent Contamination.” This acronym was also used on posters and fact sheets posted in the ICUs and respiratory therapy departments of all four hospitals.

Prior to receiving the self-study module, participants were required to undergo a 20-question examination, testing their baseline knowledge about how to prevent ventilator-associated pneumonia. An identical examination was administered after completion of the module. Individuals who scored < 80% on the postintervention test were required to repeat the self-study module. In addition to the self-study module, the intervention included posters and fact sheets and in-services for nursing and respiratory therapy staffs. The in-services were provided by infection control specialists specifically trained on the policy aimed at preventing ventilator-associated pneumonia. In-services were provided at monthly intervals for the first 3 months of the intervention during scheduled training times and staff meetings in order to gain access to the majority of nursing and respiratory therapy staff. At the adult teaching hospital, respiratory care practitioners also received two 1-h lectures on the pathogenesis and prevention of ventilator-associated pneumonia (provided by M.H.K.).

The self-study module was encouraged for all respiratory care practitioners and nursing staff working in the ICU setting. At the pediatric hospital, adult teaching hospital, and Community Hospital 1, it was incorporated into mandatory competency training for the nurses. For staff not participating in the formal self-study module, attendance at the scheduled in-services, review of educational posters describing the “WHAP VAP” intervention (provided in all participating ICUs), and interaction with the local ICU infection control specialist were encouraged to promote acceptance of the guidelines aimed at preventing ventilator-associated pneumonia. Examinations were only administered to staff completing the self-study module.

### *Study Location and Patient Population*

The intervention was performed at four hospitals in a single health system in the Midwestern United States: one adult teaching hospital, one pediatric teaching hospital, and two community hospitals. The adult teaching hospital is a 1,400-bed primary and tertiary care facility affiliated with a university medical school. An average of 6,400 patients are admitted annually to its five ICUs (medical, 19 beds; surgical/trauma/burns, 18 beds; medical/surgical, 12 beds; surgical cardiothoracic, 17 beds; and neurology/neurosurgical, 20 beds). The pediatric teaching hospital is a 235-bed primary and tertiary care facility associated with the same university medical school. This hospital has two ICUs: a neonatal ICU and a pediatric ICU. The neonatal ICU is a level-three, 52-bed unit with 700 to 750 admissions per year. The pediatric ICU is a combined medical and surgical unit with 26 beds that admits approximately 1,400 patients per year. Community hospital 1 is a 500-bed, private, suburban facility with three ICUs: two 10-bed medical-surgical ICUs and a 10-bed cardiothoracic surgery ICU, which admit approximately 1700 patients, combined, per year. Community hospital 2 is a 700-bed private suburban hospital with two combined medical-surgical ICUs with 25 beds each, with approximately 2,100 admissions to their ICUs.

During this investigation, no other protocols were introduced into these ICUs aimed at influencing the rate of ventilator-associated pneumonia. The ICUs participating in this program are all closed units with multidisciplinary teams providing patient care under the direction of attending physicians who are board certified in adult or pediatric critical care medicine. The leadership of the ICUs, including unit medical directors and clinical nurse specialists, remained constant during this study, and the staffing ratio of one nurse to two patients was also uniform throughout this time period. Overall, there was limited turnover in the respiratory therapy and nursing staffs of the ICUs (approximately ≤ 15% during the study period). Each ICU also had an established protocol or policy for the weaning of mechanical ventilation employed by the nursing staff and respiratory therapists.[21]

### *Study Design*

At each of the hospitals, ventilator-associated pneumonia is tracked by the infection control specialists of that facility through prospective surveillance. All episodes of ventilator-associated pneumonia are reported to a common database at the Infection Control and Hospital Epidemiology Consortium of the health system. The definitions of ventilator-associated pneumonia used for surveillance are based on the Centers for Disease Control and Prevention National Nosocomial Infection Surveillance definitions,[22] and are shown in Table 2 (adults) and Table 3 (children). Rates of ventilator-associated pneumonia per 1,000 ventilator days were followed from January 1, 1999, to June 30, 2002. For the pediatric and adult teaching hospitals and for community hospital 1, data regarding the microbiologic etiologies and timing of pneumonia were also available.

The educational program was initiated in January 2000. All patients admitted to the participating ICUs were followed up in a similar fashion throughout the study period. The preintervention period was defined as January through December 1999, the year before the intervention was introduced. The postintervention period was defined as January 2001 through June 2002, the

**Table 2—*Definition of Ventilator-Associated Pneumonia for Adults (Pneumonia Must Meet Only One of the Following Three Criteria Groups But May Meet More)****

| |
|---|
| Group 1: Patient has rales or dullness to percussion on physical examination of the chest and at least one of the following: |
| New onset of purulent sputum or change in character of sputum. |
| Organism isolated from blood culture. |
| Isolation of pathogen from a specimen obtained by BAL, transtracheal aspirate, bronchial brushing, or biopsy. |
| Group 2: Patient has a chest radiographic examination that shows new or progressive infiltrate, consolidation, cavitation, or pleural effusion that persists for > 48 h and at least one of the following: |
| New onset of purulent sputum or change in character of sputum. |
| Organism isolated from blood culture. |
| Isolation of pathogen from a specimen obtained by BAL, transtracheal aspirate, bronchial brushing, or biopsy. |
| Isolation of virus or detection of viral antigen in respiratory secretions. |
| Diagnostic single antibody titer (IgM) or fourfold increase in paired sera (IgG) for pathogen. |
| Histopathologic evidence of pneumonia. |
| Group 3: Patient has a chest radiographic examination that shows new or progressive infiltrate, consolidation, cavitation, or pleural effusion that persists for > 48 h and the following two criteria: |
| Temperature > 38°C. |
| WBC count > 10,000/μL. |

*From Garner et al.[22]

**Table 3—*Definition of Ventilator Associated Pneumonia for Children****

| |
|---|
| Patient < 12 mo of age has two of the following: apnea, tachypnea, bradycardia, wheezing, rhonchi, or cough and any of the following: |
| Increased production of respiratory secretions. |
| New onset of purulent sputum or change in character of sputum. |
| Organism isolated from blood culture. |
| Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy. |
| Isolation of virus or detection of viral antigen in respiratory secretions. |
| Diagnostic single antibody titer (IgM) or fourfold increase in paired serum samples (IgG) for pathogen. |
| Histopathologic evidence of pneumonia. |
| Patient > 12 mo of age has chest radiologic examination that shows new or progressive infiltrate, cavitation, consolidation, or pleural effusion and any of the following: |
| Increased production of respiratory secretions. |
| New onset of purulent sputum or change in character of sputum. |
| Organism isolated from blood culture. |
| Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy. |
| Isolation of virus or detection of viral antigen in respiratory secretions. |
| Diagnostic single antibody titer (IgM) or fourfold increase in paired serum samples (IgG) for pathogen. |
| Histopathologic evidence of pneumonia. |

*From Garner et al.[22]

18 months after the intervention was completed at all facilities. An 18-month postintervention period was selected to minimize the influence of early changes associated with the introduction of the education program that eroded with time.

Data were analyzed using a statistical software program (SPSS 10.0 for Windows; SPSS; Chicago, IL). Rates of ventilator-associated pneumonia were compared using $\chi^2$ analysis. All tests were two tailed; $p < 0.05$ was considered statistically significant. For the three hospitals with available data, common microbiologic findings and the ratio of early onset (occurring < 96 h after intubation) to late-onset ventilator-associated pneumonia before and after the intervention were analyzed with $\chi^2$ analysis. The study was approved by the Washington University School of Medicine Human Studies Committee.

## Results

### *Compliance Results*

The intervention was introduced in the spring of 2000 at community hospital 1, summer 2000 at community hospital 2, fall 2000 at the adult teaching hospital, and winter 2000 at the pediatric hospital. All hospitals had completed the intervention by the fall of 2000, except the pediatric hospital, which completed the intervention by the end of 2000. The infection control nurse assigned to the individual ICU determined when completion of the intervention had occurred in terms of staff exposure to the available education resources.

Overall, for all four hospitals, 635 of 792 ICU nurses (80.1%) and 215 of 239 respiratory therapists (89.9%) completed the module. The staff completion rates at the individual hospitals for the self-study module are shown in Table 4. The highest rates of module completion among nurses were at the pediatric hospital (335 of 335 nurses) and at community hospital 1 (93 of 94 nurses). At both of these hospitals, the self-study module was included in mandatory competency training for the nurses. The completion rates among nurses at the adult teaching hospital (146 of 225 nurses) and at community hospital 2 (61 of 138 nurses) were statistically lower than at the other two hospitals ($p < 0.001$). The highest rates of module completion among respiratory therapists were at the adult teaching hospital (114 of 114 therapists) and community hospital 2 (54 of 54 therapists), and lowest at community hospital 1 (18 of 32 therapists) [$p < 0.001$ for comparison to both adult hospitals].

### *Ventilator-Associated Pneumonia Rates*

During 1999, the year before the intervention, the overall ventilator-associated pneumonia rate for all four hospitals combined was 8.75/1,000 ventilator days. The intervention was introduced and completely implemented during 2000, and the combined annual rate during that year did not change significantly (7.81/1,000 ventilator days, $p = 0.161$). In the 18 months after the intervention was completed (January 1, 2001, through June 30, 2002), the overall rate dropped to 4.74/1,000 ventilator days ($p < 0.001$). There were no statistically significant differences in the ventilator-associated pneumonia rates during the first 6 months or 12 months after the intervention was completed compared to the last 12 months or 6 months after the intervention was completed.

**Table 4—*Staffing Completion Rates for the Self-Study Module***

| Hospital | Nursing Completion Rate, % | Respiratory Therapy Completion Rate, % | Ventilator-Associated Pneumonia Reduction, % |
|---|---|---|---|
| Adult teaching | 64.9 | 100.0 | 53.3 |
| Pediatric teaching | 100.0 | 74.3 | 38.0 |
| Community hospital 1 | 98.9 | 56.3 | 2.5* |
| Community hospital 2 | 44.2 | 100.0 | 60.7 |
| All four hospitals | 80.1 | 89.9 | 45.8 |

*Indicates an increase in the rate of ventilator-associated pneumonia during the study period.

Three of the four hospitals had a statistically significant drop in their ventilator-associated pneumonia rates from the preintervention year to the postintervention period (Fig 1). The largest decrease was seen at community hospital 2, where the rate dropped by 61% (5.17 episodes vs 2.03 episodes of ventilator-associated pneumonia per 1,000 ventilator days, $p = 0.003$). The adult academic center had a decrease of 53% (10.5 episodes vs 4.9 episodes per 1,000 ventilator days, $p < 0.001$). Rates at the pediatric teaching hospital dropped by 38% (7.9 episodes vs 4.9 episodes per 1,000 ventilator days, $p < 0.001$). Community hospital 1 did not have a significant change in their rates of ventilator-associated pneumonia (7.9 episodes vs 8.1 episodes per 1,000 ventilator days, p = not significant). While this hospital did have a high module completion rate among nurses (98.9%), the module completion rate among respiratory therapists was the lowest of the four hospitals (56.3% vs 95.2% at the other three hospitals combined, $p < 0.001$). The changes in ventilator-associated pneumonia rates by quarter are shown in Figure 2.

Microbiologic data from the patients with ventilator-associated pneumonia were available for the two teaching hospitals and for community hospital 1. For these three hospitals, in both the preintervention and postintervention periods, *Pseudomonas aeruginosa* was the most commonly identified organism associated with ventilator-associated pneumonia (22.3% preintervention vs 23% postintervention). *Staphylococcus aureus* was the second most commonly identified organism (21.3% preintervention vs 22.5% postintervention). No differences in the proportions of major causative organisms associated with pneumonia were seen when results were reviewed by individual hospital. In these three hospitals, late-onset ventilator-associated pneumonia (after > 96 h intubated) was more common than early onset pneumonia in both the preintervention and postintervention periods (86.6% and 86.9%, respectively). Data were not available for community hospital 2.

## Discussion

This study demonstrated that an educational initiative directed at respiratory care practitioners and ICU nurses was associated with decreases in the incidence of ventilator-associated pneumonia at three of four participating hospitals. Decreases in ventilator-associated pneumonia rates ranged from 38 to 61%. Our results suggest that participation by respiratory therapy staff and incorporation of the self-study module into mandatory competency training for staff are important for reducing ventilator-associated pneumonia rates using education-based interventions.

Previous studies have been primarily carried out at single institutions, usually large, urban teaching facilities. Our current study found that educational interventions can also be effective in pediatric settings, where little data exist about the prevention of ventilator-associated pneumonia, and in community hospitals. For the three hospitals with available data, we did not find any change in the time to onset of pneumonia nor any change in the microbiology of the infections. These findings suggest that the inter-

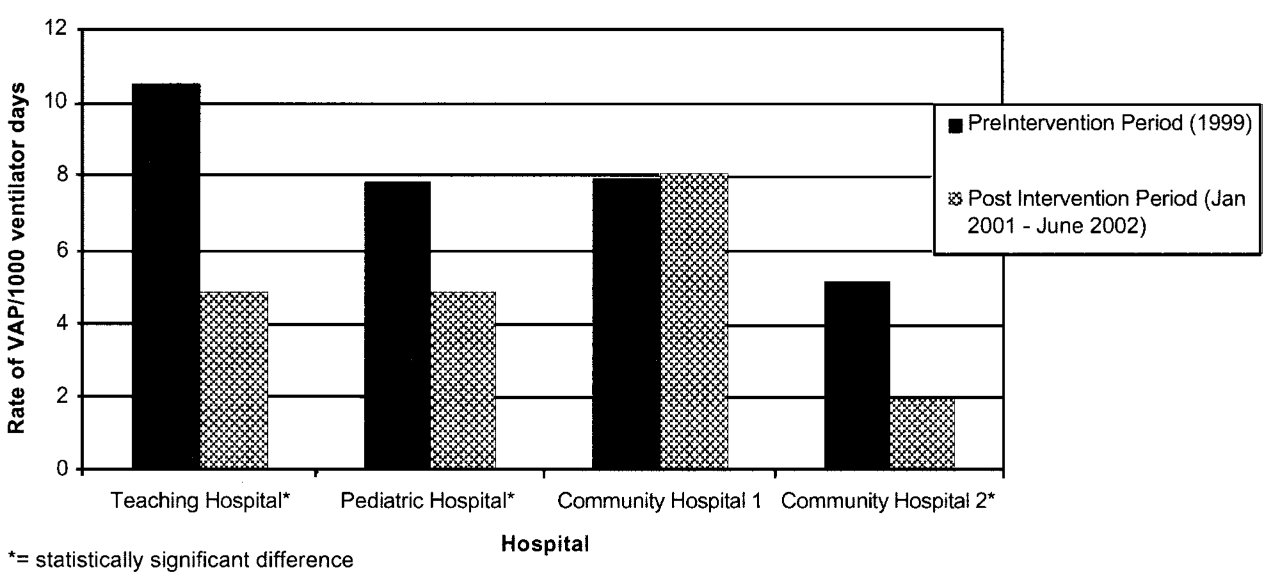


FIGURE 1. Ventilator-associated pneumonia rates preintervention and postintervention by hospital.

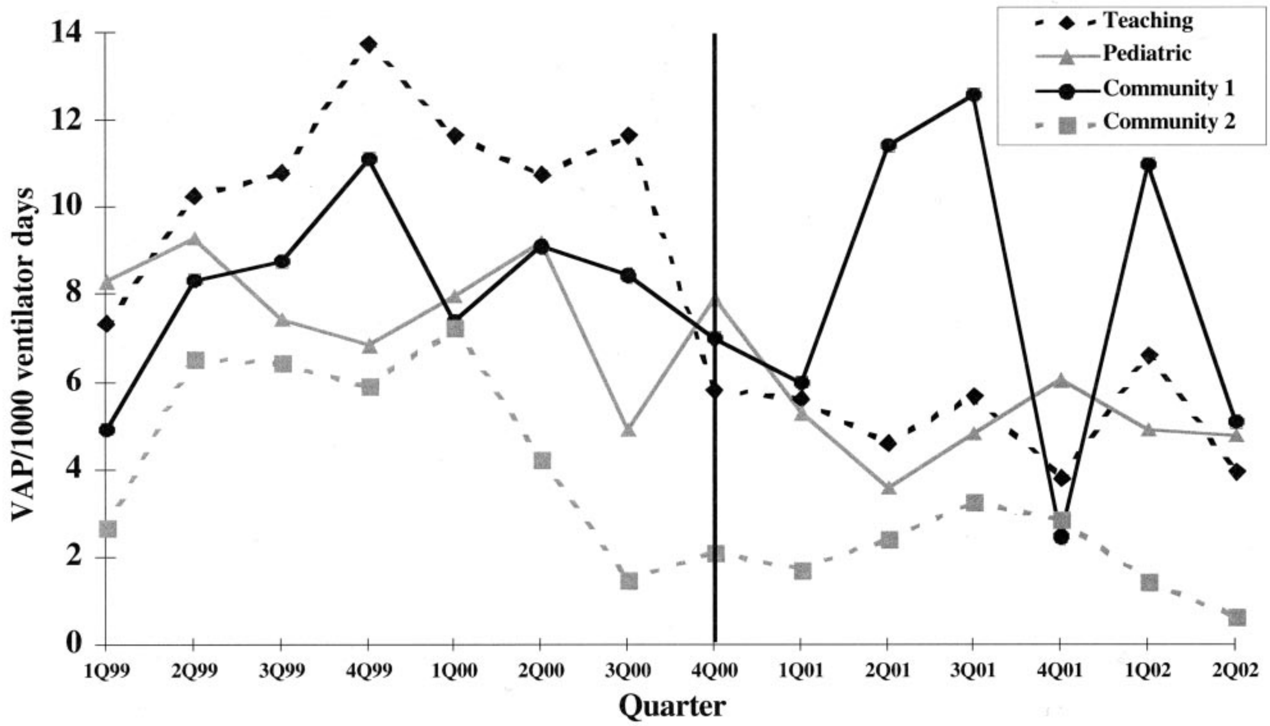


FIGURE 2. Ventilator-associated rates by quarter (Q). Solid line indicates when all hospitals had completed their interventions.

vention improved ventilator management and care, rather than eliminating a particular nosocomial reservoir of infection. Our results also suggest respiratory therapists may be important targets for educational interventions about ventilator-associated pneumonia. The one hospital without any appreciable effect from the intervention had the lowest rate of participation by respiratory therapy staff. High rates of participation from nursing at this hospital did not appear to offset the deficit in participation by respiratory therapists.

Nosocomial infections are common causes of excess morbidity and hospital costs among patients requiring intensive care. A prevalence of 20.6% was reported by Vincent et al[23] in the European Prevalence of Infection in Intensive Care study, which included 10,038 patients from 1,417 European ICUs in 1992. Pneumonia was the most common nosocomial infection (46.9%) in that study. In a large study[1] of US medical ICUs involving 181,993 patients, urinary tract infections were most frequent (31%), followed by pneumonia (27%). Ventilator-associated pneumonia has been associated with excess attributable mortality in several well-controlled studies,[24–26] as well as significant attributable cost.[27] These studies, as well as several risk factor intervention studies,[28,29] suggest that prevention of this nosocomial infection could improve patient outcomes.

Prevention of hospital-acquired infections, including ventilator-associated pneumonia, is advocated as an important management objective for all hospitals.[30] Several reviews[7,8,18] have outlined the available strategies to prevent ventilator-associated pneumonia that have been effective. However, other studies suggest that these interventions are not being widely implemented. Cook et al[31] compared Canadian and French ICUs regarding the use of seven strategies to control secretions and care for ventilator circuits to prevent ventilator-associated pneumonia and reduce overall health-care costs. Adherence to specific prevention guidelines for ventilator-associated pneumonia was more common among French ICUs (64% vs 30%, $p = 0.002$), but rates were low in both countries. These investigators also found that published recommendations did not appear to substantially affect whether prevention interventions were used within individual ICUs. Similarly, a European survey found that 37.0% of ICUs practitioners were not following published recommendations for the prevention of ventilator-associated pneumonia.[32] The most common reasons for nonadherence were disagreement with the interpretation of clinical trials (35.0%), lack of resources (31.3%), and costs associated with the implementation of specific interventions (16.9%).

Educational initiatives provide another strategy for preventing nosocomial infections. Joiner et al[9] assembled a multidisciplinary team to develop strategies to reduce ventilator-associated lower respiratory tract infections in the ICUs of a 540-bed acute care teaching medical center. The group included medical, nursing, and respiratory therapy staff that developed the intervention and educated the ICU staff on its implementation. This intervention prevented 18 lower respiratory tract infections in 1993, at an estimated cost savings of $126,000. Similarly, Kelleghan et al[10] used continuous quality improvement concepts to create a Nosocomial Pneumonia Prevention Team including representatives from nursing, respiratory therapy, pulmonary medicine, internal medicine, anesthesiology, education and training, and infection control. During the intervention year, they observed a 57% reduction in the rate of ventilator-associated pneumonia compared to the baseline years, resulting in a cost savings of $105,000. Similarly, we previously reported the effect of this educational intervention at a large teaching hospital, where it resulted in an estimated cost savings of at least $425,606.[13] These experiences suggest that the implementation of educational initiatives to prevent nosocomial infections can result in cost savings, which can justify the initial investment required for the development and implementation of such interventions.

There are a number of limitations to our current study. First, in a preintervention and postintervention observational, nonrandomized study, other possible factors might have occurred coincident with the intervention that resulted in lower pneumonia rates. Similarly, we did not collect baseline data such as demographics or severity of illness that may have influenced the occurrence of ventilator-associated pneumonia. The inclusion of multiple hospitals and of multiple ICUs within each hospital makes this less likely. The use of the module and educational materials may also have resulted in other changes in behavior, in addition to or instead of those directly encouraged by the initiative, among respiratory care practitioners, nurses, or other health-care providers, which could have accounted for these results. Although this is possible, the end result of a reduction in the rate of ventilator-associated pneumonia appears to be temporally associated with implementation of this initiative. Therefore, the goal of decreasing infections was accomplished despite our inability to identify the specific intervention(s) accounting for it. We also did not account for the distribution in staff taking the self-study module vs the in-services and how this may have influenced the overall success of the intervention.

Another important limitation of our study is that we did not evaluate outcomes other than ventilator-associated pneumonia. As a result, we cannot determine whether this intervention influenced antibiotic utilization, length of hospital stay, mortality, or antibiotic resistance patterns. Additionally, staffing in the ICUs setting has been shown to be an important determinant of compliance with infection control policies.[14–17] Although we did not collect information on daily staffing, all four participating hospitals had nursing policies on staffing that resulted in unit diversion for new admissions when staffing resources were exceeded. Microbiologic data were not available for one of the community hospitals. Nevertheless, our current and prior experience suggests that the bacteria associated with ventilator-associated pneumonia are similar among the adult community and teaching hospitals in St. Louis, where *P aeruginosa* and *S aureus* are the two most common pathogens.[27,33]

A final limitation of our study is that there appeared to be variability in local participation with the education program among the participating hospitals despite encouraging nurses and respiratory therapists to complete the study module and attend the in-services. Our findings demonstrate that even though this education program was incorporated into mandatory competency training for nurses at three of the participating hospitals, completion rates varied from a low of 56% for respiratory therapists at one of the community hospitals to 100% for nurses at the pediatric hospital and respiratory therapists at the adult teaching hospital and one of the community hospitals (Table 4). The high rates of completion for respiratory therapists in the adult teaching hospital and one of the community hospitals may be due, in part, to the physician medical directors of those departments having participated in the initial development and/or review of the education module. Nevertheless, incorporation of the self-study module into formal competency training for staff was associated with the highest completion rates, especially for nurses. Additionally, it appears that support for the education program from the medical directors of respiratory therapy may improve participation in the education program.

Despite these limitations, our results have broad clinical implications. While much emphasis has been placed on guidelines to prevent ventilator-associated pneumonia, a large discrepancy still exists at many institutions between published guidelines and actual practice. This may be accounted for by the lack of motivation for hospitals to invest resources into successful implementation of such guidelines. By instituting a simple, risk-free educational module, infection rates decreased in three hospitals by 38 to 61%. This effect was achieved not only in an adult academic medical center but also in a pediatric teaching hospital and in a large community hospital. The achievement of a similar effect in multiple settings suggests that the intervention may be generalizable to other facilities. Hospital organizations interested in providing similar educational programs to their staffs should consider incorporating them into mandatory competency training. This is currently being planned for the participating hospitals in this study when this educational program is relaunched in 2004.

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