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Weekly Ventilator Circuit Changes

A Strategy to Reduce Costs without Affecting Pneumonia Rates

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Background: **Mechanical ventilator circuits are commonly changed at 48-h intervals. This frequency may be unnecessary because ventilator-associated pneumonia often results from aspiration of pharyngeal secretions and not from the ventilator circuit. We compared the ventilator-associated pneumonia rates and costs associated with 48-h and 7-day circuit changes.**

Methods: **Ventilator circuits were changed at 48-h intervals during the control period (November 1992 to April 1993) and at 7-day intervals during the study period (June 1993 to November 1993). Nosocomial pneumonias were prospectively identified using the criteria of the Centers for Disease Control and Prevention. The annual cost difference of changing circuits at 48-h and 7-day intervals was calculated using the distribution of ventilator days for the control and study periods.**

Results: **There were 1,708 patients, 9,858 ventilator days, and a pneumonia rate of 9.64 per 1,000 ventilator days in the control group (48-h circuit changes). There were 1,715 patients, 9,160 ventilator days, and 8.62 pneumonias per 1,000 ventilator days when circuits were changed at 1-week intervals (study group). Using a logistic regression model, there were significantly greater odds of developing a ventilator-associated pneumonia in surgical patients (odds ratio 1.77, $P = 0.02$) and patients in critical care units (odds ratio 1.54, $P = 0.05$), but no significant risk of ventilator-associated pneumonia in patients in whom circuits were changed at 1-week intervals (odds ratio 0.82, $P = 0.22$). Changing circuits at 7-day intervals resulted in a 76.6% ($111,530) reduction in the annual cost for materials and salaries.**

Conclusions: **We found no difference in pneumonia rates with ventilator circuit changes at 48-h and 7-day intervals. Ventilator circuits can be safely changed at weekly intervals, resulting in large cost savings. (Key words: Complications: ventilator-associated pneumonia. Economics: health care costs. Lung(s): mechanical ventilation; respiratory therapy.)**

PNEUMONIA is a recognized complication of mechanical ventilation. From studies published in the 1960s,[1–3] it has become standard practice to change ventilator circuits at regular intervals. In the United States, ventilator circuits are commonly changed at 24 or 48-h intervals.[4] In 1983,[5] the Centers for Disease Control (CDC) recommended changing ventilator circuits at 24-h intervals. That recommendation has been recently altered to state that ventilator circuits should not be changed more frequently than every 48 h, with no recommendation for the maximum time between circuit changes.[6] Changing the ventilator circuit is not a benign procedure, and has the potential for disruption of the patient's ventilation. This practice also requires considerable resources in materials and personnel time.

It has become increasingly recognized that the ventilator circuit may be an uncommon source of nosocomial pneumonia.[7] Humidification is almost always accomplished using heated nonaerosol generating devices, and it has been shown that the temperature of these humidifiers often inhibits bacterial growth.[8] Craven *et al.*[9] showed that contamination of the ventilator circuit is similar at 24 and 48 h after a circuit change. Moreover, contamination of the circuit is often from the patient, rather than an exogenous source.[10] Thus, the patient may contaminate the ventilator circuit, rather than vice versa. Contamination of the lower

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respiratory tract in patients whose lungs are mechanically ventilated is often the result of aspiration of pharyngeal secretions, rather than aerosolization from the ventilator circuit.[7,11]

Using multivariate logistic regression analysis, Craven *et al.*[12] found that the odds ratio was 2.3 times greater for ventilator-associated pneumonia when circuits were changed at 24-h intervals (compared with 48-h intervals). Dreyfuss *et al.*[13] evaluated 68 patients who were randomized to 48-h circuit changes or no circuit changes, and found no difference in pneumonia rates between the two groups. However, the statistical power of that study was low because the sample was relatively small.

We conducted this study to compare ventilator-associated pneumonia rates with 48-h and 7-day circuit changes. Because of the large number of patients in our hospital whose lungs are mechanically ventilated, we were able to conduct this study with a high statistical power (low risk of β error). We also compared ventilator-associated pneumonia rates in medical *versus* surgical patients and in patients whose lungs are ventilated in the intensive care unit (ICU) *versus* those whose lungs are ventilated outside of the ICU.

Materials and Methods

Study Design and Patient Selection

Because logistical reasons did not allow a randomized design for a study of appropriate statistical power, we designed a prospective historical control study. The control group consisted of all adult patients receiving mechanical ventilation of their lungs at any time during the 6-month period from November 1992 to April 1993. During this time ventilator circuits were changed at 48-h intervals. On May 15, 1993, the ventilator circuit change frequency was converted to every 7 days. The study group then consisted of all adult patients receiving mechanical ventilation of their lungs in the 6-month period from June 1993 to November 1993.

Neonatal and pediatric patients were excluded because the nosocomial pneumonia rates in these patients are very low[14] and because previous work in our neonatal unit caused us to discontinue ventilator circuit changes in this patient population several years ago.‖# Some adult patients were noninvasively ventilated, and these were not included in the study. No other patients were excluded from the study.

Patients were subgrouped per medical and coronary ("medical") or surgical and medical–surgical ("surgical") units, as suggested by Jarvis *et al.*[14] Patients were also subgrouped per ICU or non-ICU. Non-ICU patients were those ventilated outside the ICU in the general care wards of the hospital. This produced four subgroups for analysis: medical ICU, medical non-ICU, surgical ICU, surgical non-ICU.

The study design was reviewed and approved by the Infection Control Committee of the Massachusetts General Hospital. Other than the frequency of ventilator circuit changes, the care of patients was not otherwise affected for purposes of this study.

Power Analysis

A power analysis was conducted to determine appropriate sample size. From a retrospective review of the nosocomial pneumonia rates in patients whose lungs were mechanically ventilated at the Massachusetts General Hospital, it was determined that the nosocomial pneumonia rates were usually in the range of 8–12 cases per 1,000 ventilator days. Using $\alpha = 0.05$, $\beta = 0.2$ (*i.e.*, power = 0.8), and a change in pneumonia rate from 8 per 1,000 to 12 per 1,000 as clinically important, the estimated sample size of 9,712 ventilator days was calculated. At a projected 1,500 ventilator days/month, it was decided to use a control period of 6 months, followed by a study period of 6 months.

Mechanical Ventilation Techniques

The study was conducted at the Massachusetts General Hospital. All respiratory therapists were registered (National Board for Respiratory Care). Respiratory therapy, physical therapy, nursing, and medical staff caring for patients whose lungs are mechanically ventilated are familiar with the infection control policies of the institution, as promulgated by the infection control unit. Universal precautions as defined by the CDC are practiced by all bedside clinicians. Selective decontamination of the digestive tract was not used, and medications to prevent gastric stress ulcers were used per the discretion of the physician teams managing the patients.

‖ English PA, Kacmarek RM, Vallende N, Hopkins CC: Contamination of heated neonatal ventilator circuits (abstract). Respiratory Care 35:1089, 1990.

Kacmarek RM, English P, Vallende N, Hopkins CC: Extended use of heated neonatal/pediatric ventilator circuits (HNVC) (abstract). Respiratory Care 36:1287, 1991.

The lungs of adult patients are mechanically ventilated at the Massachusetts General Hospital using Puritan-Bennett 7200 ventilators (Carlsbad, CA). Unheated disposable ventilator circuits are used. Water traps (Ballard, Ogden UT) are placed midway between the ventilator and the patient on both the inspiratory and expiratory limbs to collect tubing condensate. Condensate is evacuated aseptically on a regular basis without opening the circuit. When the ventilator circuit is purposefully removed from the patient, the patient connection is capped.

Humidification is provided by heated cascade (bubble) humidifiers (Puritan-Bennett). The humidifier temperature is set to provide a gas temperature of 30–33°C at the patient's proximal endotracheal tube. The humidifier reservoir is periodically refilled with sterile water using an aseptic technique. The ventilator circuit is positioned to prevent condensate from draining retrograde into the humidifier or forward into the patient. The humidifier is changed at the same frequency as the ventilator circuit. The humidifier is reusable, and it is sterilized between patients.

Reusable bag-valve resuscitators are used when mechanical ventilation is temporarily interrupted. These devices are changed and sterilized at 1-week intervals. When not in use, the patient connection is capped. The resuscitator is used primarily during suctioning of the trachea, and during patient transport. When the patient is transported (*e.g.,* diagnostic tests), the lungs are manually ventilated during the transport, and the endotracheal tube is reattached to the Puritan-Bennett 7200 ventilator at the transport site (*e.g.,* diagnostic imaging).

Suctioning is usually performed using an open-suction procedure, in which mechanical ventilation is interrupted. During the suction procedure, ventilation is provided by a bag-valve resuscitator. Closed suction devices are occasionally used per the discretion of the respiratory therapy and nursing staff. These are usually reserved for patients in whom a fraction of inspired oxygen greater than 0.6 and a positive end-expiratory pressure greater than 10 cmH_2O are required or patients with severe pulmonary infections. Inhaled therapeutic aerosols are administered to many patients using a metered dose inhaler. The metered dose inhaler adapter is part of the ventilator circuit and is not removed between treatments.

Identification Of Ventilator-associated Nosocomial Pneumonia

Infection control surveillance data related to nosocomial pneumonia was provided by infection control practitioners in the Infection Control Unit of the Massachusetts General Hospital, and supervised by a physician epidemiologist. Nosocomial pneumonias were prospectively identified per the criteria of the CDC.[15] Specifically, pneumonia was defined as radiographic evidence of a new or progressive infiltrate, consolidation, cavitation, or pleural effusion and any of the following: 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 (immunoglobulin M) or fourfold increase in paired serum samples (immunoglobulin G) for pathogen; histopathologic evidence of pneumonia. Chest radiographs were evaluated by radiologists. The general practice at the Massachusetts General Hospital is to obtain daily chest radiographs in critically ill patients whose lungs are mechanically ventilated, and whenever the respiratory status changes for patients whose lungs are ventilated outside the ICU.

The persons responsible for identification of nosocomial pneumonia were not involved in the study design, and were blinded to the study. The accuracy of identification of nosocomial pneumonia was monitored by the Infection Control Unit, and included comparison of their identification of nosocomial pneumonia with unit-based physicians. Clinical data were used to diagnose pneumonia, because the costs and risks of invasive procedures for purposes of infection surveillance could not be justified.

Data relevant to nosocomial pneumonia were collected on standardized forms, and recorded in the Infection Control Unit for infection surveillance purposes. This process was used to identify all nosocomial pneumonias (whether or not the patient's lungs were mechanically ventilated). The mechanical ventilation database in the Respiratory Care Department was then used to determine whether the pneumonia was ventilator-associated.

Data related to all patients whose lungs were ventilated was maintained in the computerized database of the respiratory care department. This included the date of initiation of mechanical ventilation and the number of ventilator days. This database also allowed identification of the type of unit in which the patient's lungs were ventilated (*e.g.,* ICU, non-ICU, medical, surgical). From this database, patient ventilator days and onset of nosocomial pneumonia rel-

ative to the initiation of mechanical ventilation were determined.

A nosocomial pneumonia was considered ventilator-associated if it occurred after 24 h from the initiation of mechanical ventilation and before extubation. This was determined by comparing information from the infection control database (onset of nosocomial pneumonia) with information from the respiratory care database (initiation and termination of mechanical ventilation). Because the ventilator-associated pneumonia rate for the period less than 48 h may not be affected by ventilator circuit changes at 7 days *versus* 48 h, we also evaluated our results after excluding all patients whose lungs were ventilated for less than 48 h (and all pneumonias that occurred in these individuals).

Cost Analysis

The cost of an adult mechanical ventilator circuit to the Respiratory Care Department at the Massachusetts General Hospital was $17.26. The distribution of the number of patients as a function of total ventilator days was determined for the period of the study. From this distribution, it was possible to calculate the number of circuit changes required for 48-h and 7-day change intervals. The time required for a respiratory therapist to change a ventilator circuit was estimated at 15 min, and the hourly salary of a respiratory therapist was estimated at $14.55.** †† Using the number of circuit changes required for 48-h and 7-day intervals, the annual cost of materials, personnel time, and personnel salaries was calculated.

Statistical Analysis

The proportion of patients with ventilator-associated pneumonias in each major group (48-h *vs.* 7-day circuit changes) was calculated as the number of cases per 1,000 ventilator days, and the 95% confidence interval for this proportion was calculated. Similar calculations were made for subgroups. Differences between groups was determined using the z test of proportions, the chi-squared test, and nonparametric tests as appropriate. A logistic regression model (SPSS, Chicago, IL) was developed using ventilator-associated pneumonia as the dependent variable, and the independent variables of ventilator circuit change frequency (48 h *vs.* 7 days), location (ICU *vs.* non-ICU), and type of unit (medical *vs.* surgical). The cumulative distribution was determined for the number of days after initiation of ventilation that ventilator-associated pneumonia occurred. The median of these distributions was evaluated for the 48-h and 7-day circuit change groups using the Mann–Whitney U test. $P < 0.05$ was be considered statistically significant.

Results

Nosocomial Pneumonia Rates

There were 1,708 patients, 9,858 ventilator days, and 95 pneumonias in the 6-month period in which circuits were changed at 48-h intervals, resulting in a pneumonia rate of 9.64 per 1,000 ventilator days (SE 0.98, 95% confidence interval 7.67–11.60). There were 1,715 patients, 9,160 ventilator days, and 79 pneumonias in the 6-month period in which circuits were changed at 1-week intervals, resulting in a pneumonia rate of 8.62 per 1,000 ventilator days (SE 0.97, 95% confidence interval 6.69–10.56). There was no significant difference in pneumonias per 1,000 ventilator days ($P = 0.51$) between these groups. The results of univariate analysis comparing the 48-h circuit change and 7-day circuit change frequencies are shown in table 1.

When patients whose lungs were ventilated for 48 h or less were excluded, the pneumonia rate was 9.86 per 1,000 ventilator days when circuits were changed at 48-h individuals (81 pneumonias, 8,215 ventilator days, SE 1.0, 95% confidence interval 7.86–11.86), and the pneumonia rate was 9.94 per 1,000 ventilator days when circuits were changed at 1-week intervals (75 pneumonias, 7,545 ventilator days, SE 1.0, 95% confidence interval 7.94–11.94). This difference in ventilator-associated pneumonia rate was not significant ($P = 0.976$).

The results of the logistic regression model are shown in table 2. In this model, pneumonia (present or absent) was used as the dependent variable, and location (non-ICU or ICU), patient type (medical or surgical), and circuit change frequency (48 h or 7 days) were used as independent variables. There were significantly greater odds of developing a ventilator-associated pneumonia in surgical patients and patients in the ICU.

** American Association for Respiratory Care: Respiratory Therapy Uniform Reporting Manual. 3rd edition. Dallas, TX, American Association for Respiratory Care, 1989.

†† Bunch D, Cathcart M: AARC completes 1992 human resource survey. AARC Times 16(5):56–63, 1992.

Table 1. Ventilator-associated Pneumonia for Subgroups and the Total Group, and for 48-hour *Versus* 7-day Circuit Changes

Group	48-h Circuit Changes					7-day Circuit Changes					*P* Value
	Days	VAP	VAP/1000	SE	95% CI	Days	VAP	VAP/1000	SE	95% CI	
Medical ICU	2,330	8	3.43	1.21	1.01–5.76	1,910	8	4.19	1.48	1.23–7.14	0.881
Medical non-ICU	739	4	5.41	2.70	0.01–10.81	905	6	6.63	2.70	1.23–12.03	0.998
Surgical ICU	5,143	76	14.78	1.68	11.41–18.14	5,169	63	12.19	1.53	9.14–15.24	0.291
Surgical non-ICU	1,646	7	4.25	1.60	1.04–7.46	1,176	2	1.7	1.20	0–4.10	0.397
All medical patients	3,069	12	3.91	1.13	1.66–6.16	2,815	14	4.97	1.33	2.32–7.63	0.678
All surgical patients	6,789	83	12.23	1.33	9.56–14.89	6,345	65	10.24	1.26	7.72–12.77	0.319
All ICU patients	7,473	84	11.24	1.22	8.80–13.68	7,079	71	10.03	1.18	7.66–12.40	0.529
All non-ICU patients	2,385	11	4.61	1.39	1.84–7.39	2,081	8	3.84	1.36	1.13–6.56	0.870
All patients	9,858	95	9.64	0.98	7.97–11.60	9,160	79	8.62	0.97	6.69–10.56	0.508

VAP = ventilator-associated pneumonia; VAP/1000 = ventilator-associated pneumonia rate per 1,000 ventilator days; SE = standard error; CI = confidence interval.

However, there was no significant risk of ventilator-associated pneumonia in patients in whom circuits were changed at 7-day intervals.

The onset of pneumonia after initiation of mechanical ventilation is shown in figure 1. Ventilator-associated pneumonias occurred at a median of 5 days after initiation of mechanical ventilation in the 48-h circuit change group, and at a median of 7 days after initiation of mechanical ventilation in the 7-day circuit change group ($P = 0.26$ by Mann–Whitney U test).

Cost Comparisons

During the 6-month control period in which ventilator circuits were changed every 48 h, there were 3,602 circuit changes. The cost of these circuits was $62,171 ($17.26 each). These circuit changes required 900.5 h of therapist time, producing a salary cost of $13,102 ($14.55/h). If circuits would have been changed at 7-day intervals during this period, there would have been 847 circuit changes at a cost of $14,619 and requiring 211.75 h of therapist time (salary cost of $3,081).

During the 6-month study period in which ventilator circuits were changed every 7 days, there were 787 circuit changes. The cost of these circuits was $13,584, and required 196.75 h of therapist time ($2,863 in salaries). If circuits would have been changed at 48-h intervals during this period, there would have been 3,369 circuit changes at a cost of $58,149 and requiring 842.25 h of therapist time ($12,255 in salaries).

The total annual costs in materials and salaries was $145,676.48 for 48-h circuit changes and $34,146.51 for 7-day circuit changes. This was a 76.6% reduction in annual costs with circuit changes at 7-day intervals.

Table 2. Results of Logistic Regression Model

Variable	Coefficient	SE	Significance	Relative Odds
Surgical patient	0.57	0.25	0.02	1.77
ICU patient	0.43	0.22	0.05	1.54
One-week circuit change frequency	−0.20	0.16	0.22	0.82

Discussion

In this large study of more than 3,000 patients and nearly 20,000 ventilator days, we found no significant difference in ventilator associated pneumonia rates with ventilator circuit changes at 48-h intervals and 7-day intervals. By logistic regression analysis, the odds of ventilator-associated pneumonia were actually slightly lower with 7-day circuit changes. This suggests that circuits can be safely changed at weekly intervals, and we have adopted this practice at the Massachusetts General Hospital. Moreover, we found no difference in ventilator-associated pneumonia rates without modifications in our ventilator circuits (*e.g.,* use of wick humidifiers, heated circuits, or artificial noses), which is important because of the costs associated with practices such as the use of heated circuits. We continue to monitor ventilator-associated pneumonia rates as part of our quality assurance program, and there has been no increasing trend in pneumonia rates for the 18 months after we adopted the practice of weekly ventilator circuit changes.

There are impressive cost savings with changing ventilator circuits at weekly intervals rather than 48-h in-

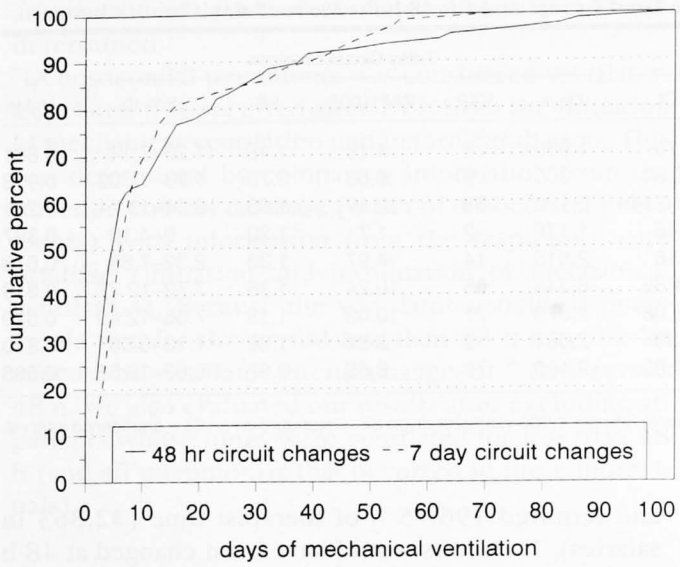

Fig. 1. Cumulative percentage of pneumonias as a function of ventilator days. Ventilator-associated pneumonias occurred at a median of 5 days after initiation of ventilation in the 48-h circuit change group and 7 days in the weekly circuit change group ($P = 0.26$).

tervals. For the 12-month period of this study, the cost savings in materials and salaries for circuit changes at 7-day rather than 48-h intervals was $111,530. The cost savings for any hospital will depend upon the number of patients whose lungs are mechanically ventilated, the distribution of ventilator days per patient, the actual cost of ventilator circuits at the institution, and the salary of the respiratory therapists. Our data suggest a 76.6% reduction in the costs of materials and salaries with 7-day circuit changes. In this study, the annual time savings for 7-day circuit changes was 1,334.5 h. If a full-time equivalent (FTE) position is 2,080 h/yr, this time savings is 0.64 FTE.

According to a 1992 estimate, 571,510 patients undergo mechanical ventilation in the United States each year.‡‡ Extrapolating our cost savings to all patients undergoing ventilation in the United States results in a $18,621,235 cost savings and a personnel time savings of 222,808 h (107 FTE).

Our results extend the work of Craven *et al.*,[9] who suggested more than 10 yr ago that circuits could be changed at 48-h intervals rather than 24-h intervals. Of interest, however, is that Craven *et al.*[9] evaluated only the extent of circuit contamination because their patient sample size was too small to evaluate pneumonia rates. Our results are consistent with the results of Dreyfuss *et al.*,[13] who found no difference in ventilator associated pneumonia rates with circuit changes at 48-h intervals *versus* no circuit changes. The major strength of the Dreyfuss *et al.*[13] study was their strict diagnosis of pneumonia (including invasive procedures and quantitative cultures), but this study had a small sample size.

Although cascade humidifiers like those used throughout this study may potentially deliver microaerosols,[16] this has little consequence because the humidifier reservoir does not become grossly contaminated. Goularte *et al.*[8] found low rates of contamination at 24 and 48 h after initiating the use of a heated cascade humidifier. Heated humidifier reservoirs are an unlikely source of high-level colonization, and nosocomial pathogens inadvertently added during filling often do not survive at the high temperature in the humidifier.[8] An artificial nose can be used to passively humidify the inspired gas of patients whose lungs are mechanically ventilated, and the ventilator circuit remains dry when these devices are used. However, this may not necessarily affect the nosocomial pneumonia rate.[17] Heated wire circuits may also be used to prevent circuit condensation, but the effect of these on the development of nosocomial pneumonia has not been reported. Although they maintain a dry circuit, artificial noses[18] and heated circuits[19] may provide inadequate humidification of the inspired gases if they are not used correctly.

We reported ventilator-associated pneumonia rates with 1,000 ventilator days as the denominator. As suggested by the CDC,[14] the use of ventilator days as a denominator may be the most appropriate way to report ventilator-associated pneumonia rates because it controls for the duration of mechanical ventilation. Most previous studies have reported ventilator-associated pneumonia rates using 100 patients as the denominator. This makes duration of ventilation a confounder, and also makes it difficult to compare those results with ours. Using 100 patients as the denominator, our ventilator-associated pneumonia rate was 5.1 per 100 patients in the 12-month period of this study, which is less than that reported in most other studies.[20] The difference between our ventilated-associated pneumonia rate and that reported in previous studies may be the result of changes in prophylaxis that occurred from the time that previous

‡‡ Sanborn W: Personal communication. Carlsbad, CA, Puritan-Bennett. 1994.

studies were published and the data in our study were collected.

The ventilator-associated pneumonia rate that we found was less than that reported by the National Nosocomial Infections Surveillance System of the CDC.[14] Similar to the findings of the National Nosocomial Infections Surveillance System, we found greater ventilator-associated pneumonia rates in surgical patients as compared with medical patients. We are unaware of any previous study of pneumonia rates in patients outside the critical care unit and whose lungs were mechanically ventilated. We also found lower pneumonia rates in patients ventilated outside the critical care unit. The reasons for these differences are unknown, and our study was not designed to determine the causes of these differences.

The relatively low ventilator-associated pneumonia rates found in this study may be attributed to several factors. Universal precautions and appropriate infection control practices are followed by all persons caring for patients whose lungs are mechanically ventilated at the Massachusetts General Hospital. The ventilator circuit remains closed as much as possible. Water traps are placed in the inspiratory and expiratory limbs of the circuit, and condensate is evacuated without opening the system. Aerosolized medications are delivered by metered dose inhaler, rather than by nebulizer. The ventilator circuit is capped when it is removed from the patient. An aggressive infection control quality assurance program related to ventilator-associated pneumonia is followed. Unit-specific ventilator-associated pneumonia rates are reported to each unit on a monthly basis, and appropriate infection-control actions are taken as necessary. Equipment (*e.g.,* oxygen analyzers and spirometers) is not taken from patient to patient, but rather remains with the same patient for the entire course of mechanical ventilation. Our mechanical ventilation and infection control practices may not be unique, and others have reported low pneumonia rates with similar practices.[21] Kelleghan *et al.*[21] and Britt *et al.*[22] found that pneumonia rates were lower when an awareness program related to nosocomial pneumonia was used.

There were several potential limitations of this study that we acknowledge, but we do not believe that these are sufficient to affect our findings. The diagnosis of pneumonia was determined using clinical criteria. However, invasive techniques are impractical for a large study such as this, and may be of limited use in patients already treated with antibiotics. Furthermore, the use of invasive diagnostic testing for ventilator-associated pneumonia is controversial, and it has recently been suggested that this testing is unnecessary for high-quality patient care.[23] Another potential limitation of this study design was that the care of patients may have been different between the two study periods. However, there were no changes in the mechanical ventilation strategies, infection control policies for patients whose lungs were mechanically ventilated, or surveillance methods for nosocomial pneumonia during this time period. Because there may be some seasonal variation in the incidence of nosocomial pneumonia,[12] it might have been better to choose the same time periods on consecutive years, but this would have increased the likelihood of important changes in practice between the control period and the study period. A randomized design would have been ideal, but the logistics of such for a large study like this are overwhelming and difficult to conduct.

It is now well appreciated that ventilator-associated pneumonia is often the result of colonization of the lower respiratory tract with organisms aspirated from the upper airway.[11] The importance of gut and upper airway colonization in the genesis of ventilator-associated pneumonia has led to treatment strategies such as selective decontamination of the digestive tract[24–26] and medications to prevent stress ulcers that maintain gastric acidity.[27–29] Although the effectiveness of these treatments is controversial, it emphasizes the relative unimportance of the ventilator circuit in the development of ventilator-associated pneumonia.

Most of the cost savings related to ventilator circuit change frequency is realized with 1-week circuit changes. In the acute care setting, most patients can be separated from mechanical ventilation by the 7th day. At the Massachusetts General Hospital, mechanical ventilation can be discontinued by the 7th day in 82% of patients. Our study was conducted in an acute care setting. Further work is needed to determine whether ventilator circuits can be safely changed at weekly or greater intervals in patients requiring long-term ventilation in an extended care facility or at home.

There are increasing pressures in the United States to control health care costs. It is important that all practices are examined for their cost effectiveness. The practice of changing mechanical ventilator circuits at 48-h intervals may superficially seem reasonable and the cost of this practice was not considered

when health care dollars were plentiful. Extending the ventilator circuit change frequency to every 7 days puts patients in our hospital at no greater risk for nosocomial pneumonia and results in a large cost savings. As the result of weekly ventilator circuit changes, we were able to add a new service (assistance with bronchoscopy procedures) without increasing our budget for additional personnel or materials. In the current era of cost containment, it will be important to identify other costly traditional practices that may not be necessary.

In conclusion, we found no difference in ventilator-associated pneumonia rates with circuit changes at 48-h intervals *versus* weekly intervals, and there are substantial cost savings when circuits are changed at weekly intervals rather than every 48 h. We believe that many cases of ventilator-associated pneumonia may not be caused by the ventilator. Of interest, Reinarz *et al.* stated 20 yr ago that "respirators without mainstream reservoir nebulizers impose no greater risk to a patient than that imposed by breathing room air." [30]

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