Mechanical Ventilation with or without Daily Changes of In-Line Suction Catheters

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The purpose of this study was to determine the safety and cost-effectiveness of not routinely changing in-line suction catheters for patients requiring mechanical ventilation. Patients were randomly assigned to receive either no routine in-line suction catheter changes (n = 258) or in-line suction catheter changes every 24 h (n = 263). The main outcome measure was the incidence of ventilator-associated pneumonia. Other outcomes evaluated included hospital mortality, acquired organ system derangements, duration of mechanical ventilation, lengths of intensive care and hospital stay, and the cost for in-line suction catheters. Ventilator-associated pneumonia was seen in 38 patients (14.7%) receiving no routine in-line suction catheter changes and in 39 patients (14.8%) receiving in-line suction catheter changes every 24 h (relative risk, 0.99; 95% CI, 0.66 to 1.50). No statistically significant differences for hospital mortality, lengths of stay, the number of acquired organ system derangements, death in patients with ventilator-associated pneumonia, or mortality directly attributed to ventilator-associated pneumonia were found between the two treatment groups. Patients receiving in-line suction catheter changes every 24 h had 1,224 catheter changes costing a total of $11,016; patients receiving no routine in-line suction catheter changes had a total of 93 catheter changes costing $837. Our findings suggest that the elimination of routine in-line suction catheter changes is safe and can reduce the costs associated with providing mechanical ventilation. Kollef MH, Prentice D, Shapiro SD, Fraser VJ, Silver P, Trovillion E, Weilitz P, Von Harz B, St. John R. Mechanical ventilation with or without daily changes of in-line suction catheters.

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Endotracheal suctioning is an essential and common supportive treatment for patients requiring mechanical ventilation. Currently, there are two types of suction-catheter systems used in U.S. hospitals, the open single-use catheter system and the closed multiuse catheter system. Studies comparing these two types of suction catheters have been limited because of the small numbers of patients examined. However, the results of these studies suggest that the risk of nosocomial pneumonia is similar in both suction-catheter systems (1–5). The main advantages attributed to the closed multiuse catheters are lower costs and decreased environmental cross-contamination (6, 7). However, the definitive advantages of one system over the other await the performance of larger studies with appropriate clinical outcome measures (8, 9).

Currently, the largest manufacturer of in-line suction catheter systems (Trach Care; Ballard Medical Products, Draper, UT) recommends routinely changing the catheter every 24 h. This recommendation is based, in part, on the ability of bacteria to aggregate on the surface of suction catheters and endotracheal tubes to form a glycocalyx (biofilm) that protects the bacteria from the action of antimicrobial agents or host defenses (10, 11). Dislodgement of these bacterial aggregates into the lung has been proposed as a possible mechanism for the development of ventilator-associated pneumonia (12, 13). Therefore, changing in-line suction catheters daily may reduce both the aspiration of bacterial aggregates and the incidence of nosocomial pneumonia. However, other investigators have suggested that increased manipulation of the ventilator circuit (and its attachments) can predispose to the development of ventilator-associated pneumonia (14–17). This is thought to occur by increasing the occurrence of aspiration of contaminated secretions or tubing condensate (14). Therefore, avoiding any unnecessary manipulation of the ventilator circuit may be beneficial in reducing the incidence of nosocomial pneumonia among patients requiring mechanical ventilation.

To better determine the optimal use of in-line suction catheters, we performed a randomized trial comparing the safety and cost-efficacy of mechanical ventilation with and without daily in-line suction catheter changes. In large part, we performed this study to provide data upon which to develop respiratory therapy practice guidelines using an evidence-based approach (18, 19). At present, no rigorously obtained scientific evidence exists to guide such practices as evidenced by the most recent guidelines for the prevention of nosocomial

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pneumonia published by the Centers for Disease Control and Prevention (20). These guidelines are generally ambiguous because of the lack of clinical outcomes data in this area. Our main goals in performing this study were to determine (*1*) the incidence of ventilator-associated pneumonia in patients receiving scheduled in-line suction catheter changes and (*2*) to determine whether this incidence was increased in patients not receiving routine suction catheter changes.

METHODS

Study Location and Patients

The study was conducted at a university-affiliated teaching hospital: Barnes-Jewish Hospital (900 beds). During a 5-mo period (March 1996 to July 1996), all patients receiving mechanical ventilation for more than 12 h in the intensive care units of this hospital (surgical, burn-trauma, medical, neurosurgical, cardiac) were potentially eligible for this investigation. Patients were entered into the investigation if they were older than 18 yr of age and required mechanical ventilation while in the intensive care unit setting. Patients were excluded if they had transferred from other hospitals and had already received mechanical ventilation, if they had heart or lung transplantation, or if they had massive hemoptysis. The study was approved by the Washington University School of Medicine Human Studies Committee. The requirement for informed consent was waived because this study was a quality assessment of two low-risk practices already in clinical use.

Study Design

Patients were randomly assigned to receive no routine in-line suction catheter changes or in-line suction catheter changes every 24 h throughout the duration of mechanical ventilation. Randomization was done using opaque, sealed envelopes, which were opened at the time each patient was enrolled in the study.

As part of the study protocol, in-line suction catheters could also be changed at any time secondary to mechanical failure of the device (e.g., malfunction of the valve resulting in the leakage of air into the protected covering sheath of the catheter) or visible soil (such as that resulting from blood or aspirated emesis). Scheduled in-line suction catheter changes were done during the evening or night shifts to minimize the identification of individual patient group assignments to both care givers and the blinded investigators. All nonscheduled in-line suction catheter changes were done when an appropriate indication for the change (that is, mechanical defeat or soil) was identified. Patients transferred to the operating room for a surgical procedure (such as tracheostomy) or to diagnostic radiology received the same mechanical ventilator and circuit (including the same in-line suction catheter) when they returned to the intensive care unit. Routine nursing and respiratory therapy suctioning practices were carried out during the study period for both treatment groups.

For purposes of this investigation, ventilator circuits were defined to include the gas delivery tubing, humidifier water reservoirs or hygroscopic condenser humidifiers, water traps, and medication delivery devices (such as metered-dose inhaler chambers or adapters). Starting at the patient's endotracheal tube, in-line suction catheters were attached followed by a medication delivery device (if used), a hygroscopic condenser humidifier, and the gas delivery tubing. Hygroscopic condenser humidifiers were used for the first 96 h of mechanical ventilation in all patients unless specifically contraindicated (because of the presence of hemoptysis or excessive airway secretions as in bronchiectasis). Patients with contraindications to the use of hygroscopic condenser humidifiers or patients receiving mechanical ventilation for more than 96 h were placed on a heated wire humidification system. On the basis of published experience (17, 21–23), the same ventilator circuit tubing was used throughout each patient's course of mechanical ventilation unless the circuit became visibly soiled or experienced a mechanical failure. Respiratory therapists rounded on all ventilators at least every 2 h. During these rounds the ventilator circuit was checked for condensate accumulation or air leaks, the in-line suction catheter was inspected, and the overall function of the ventilator was reviewed.

We employed a commercially available in-line suction catheter for this investigation (Trach Care). The ventilators used for this study included Siemens Servo 900C (Siemens-Elema Ventilator Systems, Schaumberg, IL), Puritan-Bennett 700 Series (Puritan-Bennett Corporation, Carlsbad, CA), and Bird 8400 Series ventilators (Bird Products Corp., Palm Springs, CA). All ventilator circuits were equipped with hygroscopic condenser humidifiers (Ballard 1000; Ballard Medical Products) and standard gas deliver tubing (Hudson RCI Ventilator Set; Hudson RCI, Temecula, CA) or a heated water humidifier (MR730 Respiratory Humidifier; Fisher & Paykel Healthcare, New Zealand) and heated wire gas delivery tubing (Isothermal™ Breathing Circuit; Baxter Healthcare Corp., Deerfield, IL) according to the schedule noted above. Aerosolized medications were delivered to patients using metered-dose inhalers and an attached chamber device (Aerovent; Monaghan Medical Corp., Plattsburg, NY). Water traps (Marquest Medical Products, Englewood, CO) were used in ventilator circuits when significant condensate formation was noted.

Data Collection

For all study patients, the following characteristics were prospectively recorded by one of the investigators: age, sex, diagnosis at hospital admission, indication for mechanical ventilation, Premorbid Lifestyle Score (24), the ratio of arterial blood oxygen tension to the concentration of inspired oxygen (Pa_{O_2}/FI_{O_2}), severity of illness based on APACHE II (Acute Physiology and Chronic Health Evaluation scores) (25), and the occurrence of a witnessed aspiration event. Specific processes of medical care examined to assess risk factors for ventilator-associated pneumonia were the administration of antacids or histamine-2-receptor antagonists, supine positioning of the head of the bed, pharmacologic aerosol treatments during mechanical ventilation (such as bronchodilators, antibiotics, mucolytics), administration of antibiotics during the same hospitalization but prior to intubation and the start of mechanical ventilation, fiberoptic bronchoscopy, reintubation, surgical tracheostomy, the use of a hygroscopic condenser humidifier, and the number of in-line catheter changes. Additionally, the indications for in-line suction catheter changes (scheduled according to the study protocol, soil, or mechanical defect) were also prospectively recorded.

One of the investigators made daily rounds on all study patients in the intensive care units to identify eligible patients. Patients entered into the study were prospectively followed for the occurrence of ventilator-associated pneumonia until they were successfully weaned from mechanical ventilation, were discharged from the hospital, or died. All patients suspected of having ventilator-associated pneumonia were prospectively and independently reviewed by another investigator (an infection control nurse) who was blinded to patients' treatment group assignments. The diagnosis of ventilator-associated pneumonia was strictly based on the predetermined criteria described below.

In addition to the occurrence of ventilator-associated pneumonia, we assessed secondary outcomes, including the lengths of hospitalization and intensive care, the duration of mechanical ventilation, the number of acquired organ system derangements using the Organ System Failure Index (26), hospital mortality, and mortality directly attributed to ventilator-associated pneumonia.

Definitions

All definitions were selected prospectively as part of the original study design. The Premorbid Lifestyle score was used as previously defined (24): Zero indicated that the patient was employed without restriction; 1 indicated that the patient was independent, fully ambulatory, not employed, or employed with restriction; 2 indicated that the patient had restricted activities, could live alone and get out of the house to do basic necessities, or had severely limited exercise ability; 3 indicated that the patient was housebound, could not get out of the house unassisted, could not live alone, or could not do heavy chores; 4 indicated that the patient was bed- or chair-bound. We calculated APACHE II scores on the basis of clinical data available from the first 24-h period of intensive care.

The Organ System Failure Index was modified from that used by Rubin and coworkers (26). One point was given for acquired dysfunction of each organ system. Renal dysfunction was defined as a twofold increase in baseline creatinine level or an absolute increase in baseline

creatinine level of 176.8 μmol/L (2.0 mg/dl); hepatic dysfunction was defined as an increase in total bilirubin level to more than 34.2 μmol/L (2.0 mg/dl); pulmonary dysfunction was defined as (*1*) a requirement for mechanical ventilation for a diagnosis of pneumonia, chronic obstructive pulmonary disease, asthma, or pulmonary edema (cardiogenic or noncardiogenic); (*2*) a Pa_{O_2} of less than 60 mm Hg while receiving a fraction of inspired oxygen of 0.50 or more; (*3*) the use of at least 10 cm H_2O of positive end-expiratory pressure; hematologic dysfunction was defined as the presence of disseminated intravascular coagulation, a leukocyte count of less than 1,000 cells/mm^3 (1.0×10^9/L), or a platelet count of less than $75 \times 10^3/mm^3$ (75×10^9/L); neurologic dysfunction was defined as a new focal deficit (such as hemiparesis after cerebral infarction) or a new generalized process (for example, seizures or coma); gastrointestinal dysfunction was defined as gastrointestinal hemorrhage requiring transfusion, new ileus, or diarrhea lasting more than 24 h and unrelated to previous bowel surgery; cardiac dysfunction was defined as acute myocardial infarction, cardiac arrest, or the new onset of congestive heart failure.

The diagnostic criteria for ventilator-associated pneumonia were modified from criteria established by the American College of Chest Physicians (27). Ventilator-associated pneumonia was considered to be present when a new or progressive roentgenographic infiltrate developed in conjunction with one of the following: radiographic evidence of pulmonary abscess formation (i.e., cavitation within preexisting pulmonary infiltrates); histologic evidence of pneumonia in lung tissue; a positive blood or pleural fluid culture; or two of the following: fever, leukocytosis, and purulent tracheal aspirate. Blood and pleural fluid cultures could not be related to another source, and both had to be obtained within 48 h before or after the clinical suspicion of ventilator-associated pneumonia. Microorganisms recovered from blood or pleural fluid cultures also had to be identical to the organisms recovered from cultures of respiratory secretions. A new infiltrate was prospectively determined to be present if it occurred more than 48 h after the start of mechanical ventilation or within 48 h of extubation. Persistence of the infiltrate was established if it was roentgenographically visible for at least 72 h. Fever was defined as an increase in the core temperature of 1° C or more and a core temperature of more than 38.3° C. Leukocytosis was defined as a 25% increase in circulating leukocytes from baseline and a leukocyte count of more than $10 \times 10^3/mm^3$ (10×10^9/L). Tracheal aspirates were considered purulent if Gram's stain showed more than 25 neutrophils per high power field.

Hospital mortality was defined as those patient deaths occurring in the initial hospital admission during which the patients were studied. Mortality directly related to ventilator-associated pneumonia was predetermined to be present when a patient died during an episode of nosocomial pneumonia and the death could not be directly attributed to any other cause. Costs for in-line suction catheter changes were based on 1996 costs of $9 per change, which only included materials and not the time of the respiratory therapists.

Statistical Analysis

We estimated sample size to provide 80% power to detect a 15% difference in the rate of occurrence of ventilator-associated pneumonia between the two study groups. We used an α-error of 0.05 (two-tailed). On the basis of these assumptions, 250 patients were needed in each of the two study groups.

All comparisons were unpaired and all tests of significance were two-tailed. Continuous variables were compared using Student's *t* test for normally distributed variables and Wilcoxon's rank-sum test for non-normally distributed variables. Chi-square or Fisher's exact test was used to compare categorical variables. The primary data analysis compared the incidence of ventilator-associated pneumonia between patients assigned to receive no routine in-line suction catheter changes and patients assigned to receive daily in-line suction catheter changes. We confirmed the results of these tests while controlling for specific patient characteristics (Table 1), using multiple logistic regression analysis and a commercial statistical package (28).

A stepwise approach was used to enter new terms into the logistic regression model; 0.05 was set as the limit for the acceptance or removal of these terms. All potential confounding variables associated with ventilator-associated pneumonia were forced to enter the model regardless of statistical significance. Results of the logistic regression analysis are reported as adjusted odds ratios with 95% CIs. Relative

TABLE 1

CHARACTERISTICS OF STUDY PATIENTS AT THE TIME OF RANDOMIZATION AND RISK FACTORS FOR VENTILATOR-ASSOCIATED PNEUMONIA DURING THE STUDY PERIOD

Characteristic	Patients Receiving Daily In-Line Suction Catheter Changes (*n = 263*)	Patients Receiving No Routine In-Line Suction Catheter Changes (*n = 258*)	p Value
At randomization			
Age, yr*	56.9 ± 19.7	58.2 ± 19.8	0.43
Male/Female, n	139/124	140/118	0.75
Race, n (%)			
White	179 (68.1)	165 (63.9)	0.53
Black	80 (30.4)	90 (34.9)	
Other	4 (1.5)	3 (1.2)	
Premorbid Lifestyle Score*	1.1 ± 1.0	1.1 ± 1.0	0.94
APACHE II Score*	17.9 ± 7.0	17.9 ± 7.2	0.96
Pa_{O_2}/Fi_{O_2}	276 ± 118	263 ± 113	0.21
Previous intubation, n (%)	40 (15.2)	33 (12.8)	0.43
Surgical diagnostic category, n (%)	154 (58.6)	136 (52.7)	0.18
Risk factors for ventilator-associated pneumonia during the study period, n (%)			
Received antacids or H-2 blocker	117 (44.5)	118 (45.7)	0.77
Received sucralfate	110 (41.8)	97 (37.6)	0.32
Received aerosol therapy	74 (28.1)	71 (27.5)	0.88
Received prior antibiotic therapy	62 (23.6)	50 (19.4)	0.24
Elevation of head of bed	44 (16.7)	43 (16.7)	0.99
Witnessed aspiration event	14 (5.3)	16 (6.2)	0.67
Tracheostomy	29 (11.0)	22 (8.5)	0.34
Fiberoptic bronchoscopy	14 (5.3)	16 (6.2)	0.67
Initial use of hygroscopic condenser humidifier	263 (100.0)	258 (100.0)	> 0.99

Definition of abbreviations: APACHE = acute physiology and chronic health evaluation; ICU = intensive care unit; H-2 = histamine-2 receptor.

* Values are means ± SD.

risks and their 95% CIs were calculated using standard methods. Values are expressed as the mean ± SD (continuous variables) or as a percentage of the group from which they were derived (categorical variables). All p values were two-tailed, and p values of 0.05 or less were considered to indicate statistical significance.

RESULTS

Patients

Five hundred thirty consecutive patients requiring mechanical ventilation for at least 12 h in the intensive care setting were enrolled into the study. Four patients were transferred from outside hospitals while receiving mechanical ventilation, and five patients were randomized on two different occasions (their second study admissions were excluded). Therefore, 521 patients were analyzed, of whom 258 (49.5%) received no routine in-line suction catheter changes and 263 (50.5%) received changes every 24 h. At the time of randomization, no statistically significant differences were found between the two treatment groups for age, sex, ethnicity, Premorbid Lifestyle scores, APACHE II scores, the ratio of arterial blood oxygen tension to the concentration of inspired oxygen, history of previous intubation (in the operating room or in intensive care for less than 12 h), and diagnostic category (surgical versus nonsurgical) (Table 1). The distribution of risk factors for the development of ventilator-associated pneumonia during the study period (Table 1) and the diagnostic categories (Table 2) were also similar in both treatment groups.

Ventilator-associated Pneumonia

Seventy-seven of the 521 study patients (14.8%) developed ventilator-associated pneumonia, yielding a rate of 26.9 episodes of ventilator-associated pneumonia per 1,000 ventilator days. Patients with ventilator-associated pneumonia were statistically more likely to be male, to have lower Premorbid Lifestyle scores, greater APACHE II scores, and lower ratios of arterial blood oxygen tension to the concentration of inspired oxygen. Patients developing ventilator-associated pneumonia were also significantly more likely to have received prior intubation during the same hospitalization, sucralfate, aerosol therapy, or previous antibiotics, and to have had a tracheostomy compared with patients without ventilator-associated pneumonia (Table 3). Patients receiving sucralfate (n = 207) had APACHE II scores that were significantly greater than the APACHE II scores of patients not receiving sucralfate (n = 314) (19.6 ± 6.5 versus 16.9 ± 7.2; $p < 0.001$).

In the group randomly assigned to receive no routine in-line suction catheter changes, 38 patients (14.7%) developed ventilator-associated pneumonia; 39 (14.8%) patients randomly assigned to receive daily in-line suction catheter changes also developed ventilator-associated pneumonia (relative risk, 0.99; 95% CI, 0.66 to 1.50). Similar results were found when the analysis was stratified according to diagnostic category (surgical diagnoses: relative risk, 0.72; 95% CI, 0.40 to 1.30; medical diagnoses: relative risk, 1.40; 95% CI, 0.76 to 2.61). The average duration of mechanical ventilation prior to the onset of ventilator-associated pneumonia was similar among these two study populations (9.2 ± 4.1 d versus 9.7 ± 3.8 d; p = 0.596). When we used multiple logistic regression analysis to control for all relevant confounders, the adjusted odds ratio assessing the relationships between ventilator-associated pneumonia and treatment group assignment (receiving no in-line suction catheter changes compared with receiving daily in-line suction catheter changes) was 0.75 (95%, 0.48 to 1.15).

Sixty-five (84.4%) patients with ventilator-associated pneumonia had at least one pathogenic microorganism isolated from either their tracheal aspirates (n = 30) or bronchoalveolar lavage (BAL) fluid (n = 35). In the remaining 12 (15.6%) patients classified as having ventilator-associated pneumonia (seven from the group receiving daily in-line suction catheter changes and five from the group receiving no routine suction catheter changes), all of whom were receiving broad-spectrum antibiotics at the time respiratory specimens were obtained, a pathogenic microorganism was not isolated. The diagnosis of ventilator-associated pneumonia was established on the basis of BAL fluid cultures in 42.1% of the patients with pneumonia receiving no routine suction catheter changes and 48.7% of the patients with pneumonia receiving daily in-line suction catheter changes (p = 0.560).

Bacterial isolates from the tracheal aspirates and bronchoalveolar lavage specimens obtained in patients with ventilator-associated pneumonia were similar in the two treatment groups ($p > 0.20$). The predominant organisms included *Pseudomonas aeruginosa* (20.3%), oxacillin-sensitive *Staphylococcus au-*

TABLE 2

DIAGNOSTIC CATEGORIES OF STUDY PATIENTS

Category	Patients Receiving Daily In-Line Suction Catheter Changes (*n = 263*)	Patients Receiving No Routine In-Line Suction Catheter Changes (*n = 258*)	p Value
Surgical, n (%)			
Orthopedic	11 (4.2)	6 (2.3)	0.23
Neurologic	22 (8.4)	25 (9.7)	0.60
Abdominal	102 (38.8)	88 (34.1)	0.27
Thoracic	2 (0.8)	5 (1.9)	0.28
Other*	17 (6.5)	12 (4.7)	0.37
Medical, n (%)			
Pneumonia	24 (9.1)	27 (10.5)	0.61
Obstructive lung disease	16 (6.0)	16 (6.2)	0.96
Drug overdose	8 (3.0)	4 (1.6)	0.38
Noncardiogenic pulmonary edema	7 (2.7)	6 (2.3)	0.81
Nonsurgical trauma	6 (2.3)	10 (3.9)	0.29
Other†	27 (10.3)	30 (11.6)	0.62
Pulmonary edema/congestive heart failure	21 (7.9)	29 (11.2)	0.21

* Includes gynecologic, otolaryngologic, and plastic surgery.

† Multifactorial, neurologic, upper airway protection, postendoscopic procedure, or unclear etiology for respiratory failure requiring mechanical ventilation.

TABLE 3

CHARACTERISTICS OF STUDY PATIENTS ACCORDING TO THE PRESENCE OR ABSENCE OF VENTILATOR-ASSOCIATED PNEUMONIA

Characteristic	Patients with Ventilator-Associated Pneumonia (*n = 77*)	Patients without Ventilator-Associated Pneumonia (*n = 444*)	p Value
At randomization			
Age, yr*	55.7 ± 18.9	57.7 ± 20.0	0.40
Male/Female, n	51/26	228/216	0.016
Race, n (%)			
White	44 (57.1)	300 (67.6)	0.017
Black	32 (41.6)	138 (31.1)	
Other	1 (1.3)	6 (1.3)	
Premorbid Lifestyle Score*	0.9 ± 1.0	1.1 ± 1.0	0.024
APACHE II Score*	19.5 ± 5.7	17.7 ± 7.3	0.012
Pa_{O_2}/Fi_{O_2}*	239 ± 109	275 ± 116	0.009
Previous intubation, n (%)	30 (39.0)	43 (9.7)	< 0.001
Surgical diagnostic category, n (%)	41 (53.3)	249 (56.1)	0.64
Risk factors for pneumonia, n (%)			
Received antacids or H-2 blocker	34 (44.2)	201 (45.3)	0.86
Received sucralfate	42 (54.6)	165 (37.2)	0.004
Received aerosol therapy	38 (49.4)	107 (24.1)	< 0.001
Received prior antibiotic therapy	24 (31.2)	88 (19.8)	0.025
Elevation of head of bed	12 (15.6)	75 (16.9)	0.78
Witnessed aspiration event	5 (6.5)	25 (5.6)	0.76
Tracheostomy	24 (31.2)	27 (6.1)	< 0.001
Fiberoptic bronchoscopy	6 (7.8)	24 (5.4)	0.41
Initial use of hygroscopic condenser humidifier	77 (100.0)	444 (100.0)	> 0.99

For definitions of abbreviations, *see* Table 1.
* Values are means ± SD.

reus (17.6%), oxacillin-resistant *Staphylococcus aureus* (16.2%), *Klebsiella* species (10.8%), *Enterobacter* species (9.5%), *Serratia marcescens* (9.5%), *Hemophilus influenza* (6.8%), *Escherichia coli* (4.0%), *Acinetobacter baumannii* (2.7%), *Stenotrophomonas maltophilia* (1.3%), and *Citrobacter freundii* (1.3%).

Secondary Outcomes

The average duration of mechanical ventilation for the entire study group was 5.7 ± 8.9 d (median, 2 d; range, 1 to 67 d). There were 296 (56.8%) patients who required mechanical ventilation for more than 1 d. The duration of mechanical ventilation, the length of intensive care, and the total length of hospital stay did not significantly differ between the two treatment groups (Table 4). Patients assigned to receive in-line suction catheter changes every 24 h had a total of 1,224 changes; patients assigned to receive no routine in-line suction catheter changes had a total of 93 changes. Among patients assigned to receive in-line suction catheter changes every 24 h, 1,222 (99.8%) of the changes were routine changes done according to the study protocol and 2 (0.2%) were done because of mechanical leaks. For patients assigned to receive no routine in-line suction catheter changes, 32 (34.4%) were changed because of mechanical leakage, seven (7.5%) were changed because of soil, and 54 (58.1%) were changed as a result of human error. Total costs for in-line suction catheter changes was $11,016 in the group receiving changes every 24 h and $837 in the group receiving no routine changes.

Six (2.3%) patients in the treatment group assigned to re-

TABLE 4

OUTCOME MEASURES*

Outcome	Patients Receiving Daily In-Line Suction Catheter Changes (*n = 263*)	Patients Receiving No Routine In-Line Suction Catheter Changes (*n = 258*)	p Value
Ventilator-associated pneumonia, n (%)	39 (14.8)	38 (14.7)	0.97
Episodes of ventilator-associated pneumonia (per 1,000 ventilator days)	27.5	25.8	0.79
Ventilator-associated pneumonia among patients requiring mechanical ventilation for > 7 d, n (%)	31 (63.3) [n = 49]‡	29 (50.0) [n = 58]‡	0.168
Duration of mechanical ventilation, d	5.4 ± 8.4	5.7 ± 8.3	0.69
Length of intensive care, d	7.0 ± 9.8	6.9 ± 7.9	0.90
Length of hospital stay, d	14.7 ± 12.4	14.4 ± 12.2	0.80
In-line suction catheter changes, n†	4.7 ± 8.3	0.4 ± 0.9	< 0.001
Acquired organ system derangements	1.1 ± 1.3	1.2 ± 1.2	0.28
Hospital mortality	64 (24.3)	67 (26.0)	0.67

* Values are means ± SD.
† Number of suction catheter changes per patient.
‡ Numbers in brackets represent patients requiring mechanical ventilation for more than 7 d.

ceive no routine in-line suction catheter changes required mechanical ventilation for 30 d or longer (40.7 ± 13.6 d). This subgroup of patients received 20 in-line suction catheter changes (3.3 ± 2.3 catheter changes per patient). The indications for these catheter changes included 13 (65.0%) for mechanical leakage, 3 (15.0%) because of soil, and 4 (20.0%) as a result of human error.

Acquired Organ System Derangements and Mortality

The average number of organ system derangements for the entire study population was 1.2 ± 1.2 organ systems. The number of acquired organ system derangements did not differ between the two treatment groups (Table 4). Patients with ventilator-associated pneumonia (n = 77) acquired significantly more organ system derangements than did patients without ventilator-associated pneumonia (n = 444) (2.0 ± 1.2 versus 1.0 ± 1.2 organ systems; $p < 0.001$). One hundred thirty-one patients died during their study hospitalization, yielding an overall hospital mortality rate of 25.1%. Hospital nonsurvivors had significantly more acquired organ system derangements than did hospital survivors (2.0 ± 1.2 versus 0.9 ± 1.1 organ systems; $p < 0.001$).

The hospital mortality rate was similar between the two study groups (Table 4). The hospital mortality rate for patients with ventilator-associated pneumonia (37.7%) was statistically greater than the hospital mortality rate for patients without ventilator-associated pneumonia (23.0%) (relative risk, 1.64; 95% CI, 1.17 to 2.29). The hospital mortality rate for patients developing ventilator-associated pneumonia was not statistically different for those patients receiving no routine in-line suction catheter changes (42.1%) compared with patients receiving catheter changes every 24 h (33.3%) (relative risk, 1.25; 95% CI, 0.71 to 2.26). Similarly, the deaths directly attributed to ventilator-associated pneumonia were similar between these two study groups (1.9 versus 1.5%; relative risk, 1.27; 95% CI, 0.35 to 4.69).

DISCUSSION

We demonstrated that a practice of not routinely changing in-line suction catheters during mechanical ventilation was safe and cost-effective compared with a practice of daily in-line suction catheter changes. The overall rates of ventilator-associated pneumonia and the episodes of ventilator-associated pneumonia per 1,000 ventilator days were similar between our two study groups ($p \geq 0.79$) (Table 4). Additionally, hospital mortality, the number of acquired organ system derangements, duration of mechanical ventilation, lengths of stay in intensive care and the hospital, deaths in patients with ventilator-associated pneumonia, and deaths directly attributed to ventilator-associated pneumonia were not statistically different between patients receiving no routine in-line suction catheter changes and patients receiving in-line suction catheter changes every 24 h.

The findings of this investigation are consistent with recent studies showing the safety of not routinely changing ventilator circuits (17, 21–23). These earlier studies found that the incidence of ventilator-associated pneumonia was not increased (and even decreased in specific subgroups of patients) by the prolonged use of ventilator circuits. Prior to the performance of these investigations, ventilator circuits were usually changed every 48 h in most hospitals treating patients with respiratory failure. This practice was based on the recommendation of manufacturers and clinical studies suggesting that more frequent circuit changes (i.e., circuit changes every 24 h or less) were associated with increased rates of ventilator-associated pneumonia (14, 29, 30). It is expected, based on the quality of the available medical evidence (17, 21–23), that more definitive recommendations for the prolonged use of ventilator circuits will be made by national medical organizations (20). Similarly, institutional practice guidelines regarding the use of in-line suction catheters have relied on the recommendations of manufacturers because of the lack of rigorously performed clinical investigations. Therefore, more objective guidelines for the utilization of in-line suction catheters could not be previously made, awaiting the performance of appropriate outcome studies (20).

Compared with a policy of changing in-line suction catheters every 24 h, we estimate that not routinely changing in-line suction catheters will result in a cost savings of $48,859 per year at our hospital. Additionally, the time spent by our respiratory therapists performing routine in-line suction catheter changes (approximately 5,429 routine catheter changes per year) can now be used to perform other tasks that may have a higher likelihood of improving patient outcomes. It is important to note that the incidence of ventilator-associated pneumonia and lengths of stay in intensive care and the hospital were not increased by the practice of not routinely changing in-line suction catheters. Therefore, the cost savings accrued by adopting a policy of no routine in-line suction catheter changes will unlikely be eroded by other unforeseen costs because of prolonged lengths of stay and excessive cases of ventilator-associated pneumonia (31, 32).

Our study had several limitations. First, we used a clinical diagnosis of ventilator-associated pneumonia that did not rely on quantitative cultures of lower respiratory secretions obtained bronchoscopically (27). This clinical method of establishing the diagnosis of ventilator-associated pneumonia is controversial because of its lack of specificity (33). However, recent investigations suggest that the use of clinical criteria are acceptable because of their greater diagnostic sensitivity, compared with bronchoscopically obtained cultures, and their good correlation with patient outcomes (34, 35). Additionally, we examined other discrete clinical outcomes (e.g., hospital mortality, lengths of stay) that were similar between the two treatment groups. The lack of any significant differences in these secondary outcomes also supports the safety and clinical efficacy of changing medical practices in favor of no routine in-line suction catheter changes.

A second limitation of our study was that we used hygroscopic condenser humidifiers for the first 96 h followed by heated water humidification with heated wire circuits. It is possible that our results would have differed had we employed other methods of humidification, especially those associated with significant condensate formation. The latter could predispose to aspiration and the occurrence of ventilator-associated pneumonia, particularly among patients receiving more frequent ventilator circuit manipulation (15). Third, we examined a small number of patients requiring prolonged mechanical ventilation (i.e., 30 d or more). Future studies are planned to determine the optimal use of in-line suction catheters for this specific subgroup of patients. Fourth, we did not perform routine cultures of the suction catheters. Therefore, we could not determine if the same organisms and the same level of bacterial contamination of in-line suction catheters were present in both study groups. Lastly, we did not include a study arm examining the use of open-suction catheters. Thus, our results are only relevant to institutions using closed-suction catheter systems.

In summary, we have demonstrated that eliminating routine in-line suction catheter changes is both safe and cost-effective compared with the currently accepted practice of daily in-

line suction catheter changes. Adopting a policy of not routinely changing in-line suction catheters should result in substantial medical cost savings across the United States. Additionally, such a policy should decrease the risks of patient cross-contamination and health care provider exposure to respiratory secretions. However, institutions adopting a practice of not routinely changing in-line suction catheters should also require regular inspection of these suction catheters in order to detect mechanical failure and soilage. Our study also provides an example of how an evidence-based approach can be used to identify the best medical practice in the absence of previous scientific information. Similar approaches should be used to rigorously evaluate other currently accepted but unproved medical strategies (20). In this way we can hope to avoid continuing the use of established practices or adopting new medical practices that may not be associated with optimal patient outcomes.

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