Review

Influence of Airway Management on Ventilator-Associated Pneumonia

Evidence From Randomized Trials

Deborah Cook, MD; Bernard De Jonghe, MD; Laurent Brochard, MD; Christian Brun-Buisson, MD

Objective.—Ventilator-associated pneumonia (VAP) is a serious complication of critical illness, conferring increased morbidity and mortality. Many interventions have been studied to reduce the risk of VAP. We systematically reviewed the influence of airway management on VAP in critically ill patients.

Data Sources.—Studies were identified through searching MEDLINE and EMBASE from 1980 through July 1997 and by searching SCISEARCH, the Cochrane Library, bibliographies of primary and review articles, personal files, and contact with authors of the randomized trials.

Study Selection.—We selected randomized trials evaluating ventilator circuit and secretion management strategies on the rate of VAP.

Data Extraction.—Two investigators independently abstracted key data on design features, the population, intervention, and outcome of the studies.

Data Synthesis.—The frequency of ventilator circuit changes and the type of endotracheal suction system do not appear to influence VAP rates (3 trials, none with significant difference; range of relative risks [RRs], 0.84-0.91). However, lower VAP rates may be associated with avoidance of heated humidifiers and use of heat and moisture exchangers (5 trials, only 1 showing a significant difference; range of RRs, 0.34-0.86), use of oral vs nasal intubation (1 trial; RR, 0.52; 95% confidence interval, 0.24-1.13), subglottic secretion drainage vs standard endotracheal tubes (2 trials, 1 showing a significant difference; range of RRs, 0.46-0.57), and kinetic vs conventional beds (5 trials, only 1 showing a significant difference; range of RRs, 0.35-0.78).

Conclusions.—Some ventilator circuit and secretion management strategies may influence VAP rates in critically ill patients. Whether these strategies are adopted in practice depends on several factors such as the magnitude and precision of estimates of benefit and harm, as well as access, availability, and costs.

JAMA. 1998;279:781-787

IN CRITICALLY ILL patients, the development of nosocomial pneumonia may confer an increased morbidity and mortality.[1] The largest intensive care unit (ICU) prevalence study conducted to date revealed that ventilator-associated pneumonia (VAP) accounted for almost half of ICU infections in Europe.[2] In the last decade, there has been a profusion of informative studies on the epidemiology, risk factors, diagnosis, treatment, cost, and clinical sequelae of this serious condition. Several prophylactic interventions hold the promise of decreasing the burden of illness caused by nosocomial pneumonia.

These strategies can be classified as mechanical, focusing on the ventilator circuit (eg, frequency of tubing changes and gas humidification strategies), the endotracheal tube (eg, intubation orifice, suctioning, and secretion drainage), and patient placement (eg, body position and kinetic bed therapy); or interventions directed at the gastrointestinal tract (eg, enteral feeding strategies); or pharmacologic approaches (eg, selective digestive decontamination, endotracheal antibiotics, and stress ulcer prophylaxis); or the influences of the ICU environment.

Randomized trials have evaluated the influence of some of these interventions on surrogates of VAP. Craven et al[3] allocated patients to receive ventilator tubing changes every 24 or 48 hours and found no difference in inspiratory-phase gas cultures or tubing colonization. In another study, a trend toward decreased tracheal colonization was observed in patients ventilated with heat and moisture exchangers vs heated humidifiers.[4] Rouby and colleagues[5] randomized patients to nasal or oral intubation and found that radiologic evidence of maxillary sinusitis was markedly higher in the nasal group. The relationship between body position and tracheobronchial aspiration has been highlighted by 3 randomized trials showing that scintigraphic evidence of aspiration occurs less often in patients placed in the semirecumbent than in the supine position.[6-8] The foregoing studies represent prominent contributions to the experimental evidence regarding VAP prevention strategies, though a direct, confirmed causal relationship between these surrogate end points and VAP would strengthen the inferences we draw from them.

The goal of this systematic review is to evaluate the influence of ventilator circuit and secretion management strategies on nosocomial pneumonia as studied in randomized clinical trials.

From the Department of Medicine, St Joseph's Hospital and McMaster University, Hamilton, Ontario (Dr Cook); Service de Reanimation Medicale, Hôpital de Poissy, Poissy, France (Dr De Jonghe); and Service de Reanimation Medicale, Hôpital Henri Mondor, Universite Paris-Val de Marne, Creteil, France (Drs Brochard and Brun-Buisson).

Reprints: Deborah Cook, MD, Department of Medicine, St Joseph's Hospital, 50 Charlton Ave E, Hamilton, Ontario, Canada L8N 4A6 (e-mail: debcook@fhs.csu.mcmaster.ca).

Table 1.—Ventilator Circuit and Secretion Management Trials: Design Characteristics*

Source, y	Intervention	Population	Allocation	Cointervention
Dreyfuss et al,[30] 1991	Ventilator circuit changes every 48 h vs no change	Medical ICU patients needing ventilation >48 h	Odd/even years of birth	Unspecified proportion received stress ulcer prophylaxis with antacids, H_2RAs, or sucralfate
Kollef et al,[31] 1995	Ventilator circuit changes every 7 d vs no change	Mixed ICU patients (surgical, trauma, medical, cardiac, and neurosurgical) needing ventilation >5 d	"Randomly assigned"	Unspecified proportion received antacids, H_2RAs
Long et al,[32] 1996	Ventilator circuit changes every 7 d vs 3 times per wk	Medical ICU and neurosurgery patients	Odd/even medical record numbers	All patients had HH
Martin et al,[33] 1990	Daily change of HME vs HH	ICU patients needing ventilation >24 h	"Randomly assigned"	Suctioning at nurse discretion (HME, 52±10 times vs HH, 75±9 times); physiotherapy twice a day; circuit changes 3 times per wk
Roustan et al,[34] 1992	Daily change of HME vs HH with daily decontamination	General ICU patients	"Randomly assigned"	No circuit changes
Dreyfuss et al,[35] 1995	Daily change of HME with no circuit changes vs HH with no circuit changes	Medical ICU patients needing ventilation >48 h	"Randomly assigned"	No circuit changes; minority received SUP but groups not specified; tracheal aspirations similar (HME, 7.1±1.7; HH, 7.5±1.4)
Hurni et al,[36] 1997	Daily change of HME with weekly circuit changes vs HH with circuit changes every 48 h	Medical ICU patients needing ventilation	"Were randomized"	Respiratory therapy every 4 h to both groups
Kirton et al,[37] 1997	Daily change of HME vs HH	Trauma ICU patients	Random-number generation	Weekly circuit changes; closed system suction catheters changed every 3 d; all received same nutrition protocol and SUP
Holzapfel et al,[38] 1993	Oral vs nasal endotracheal intubation	General ICU patients	"Randomly allocated"	None received SDD; none received SUP; all received oral antiseptic and antibiotics similarly
Mahul et al,[39] 1992	SSD vs standard suctioning as needed	ICU patients needing ventilation >72 h	Stratified randomization of SDD and SUP with antacids or sucralfate	Stratification based on antacid or sucralfate
Valles et al,[40] 1995	SSD vs standard suctioning as needed	Medical and surgical ICU patients expected to need ventilation >72 h	"Randomly assigned"	All received sucralfate; none received SSD
Deppe et al,[41] 1990	Closed suction system with daily catheter changes vs disposable open suction system	Medical and surgical ICU patients needing ventilation >48 h	Random-number table; stratified according to >72 or <72 h in hospital	Antibiotics, NGT, antacids, and H_2RAs used but groups not specified; suctioning frequency in both groups at nurse discretion; open system suctioned 12.4 times per d; closed system suctioned 16.6 times per d
Johnson et al,[42] 1994	Closed suction system vs disposable open suction system	Trauma or general surgery ICU patients needing ventilation	4 Rooms assigned to closed suctioning, 4 to open suctioning; patients allocated based on bed availability	Suctioning frequency in both groups at nurse discretion; number of passes to clear airway 2.5 in open system, 2.4 in closed system
Gentilello et al,[43] 1988	KTT (total arc 120°) vs standard bed (position change every 2 h)	Trauma ICU patients	"Drawing a randomization card"	Antibiotic given to 87% standard bed and 74% KTT patients
Summer et al,[44] 1989	KTT (total arc 62°) vs standard bed	Medical ICU patients	"Random sequences of 40 letters using standard tables of random numbers stratified by diagnosis"	NR
Fink et al,[45] 1990	KTT (total arc 80°) vs standard bed (position change every 2 h)	Trauma ICU patients	"Random number tables with sequentially numbered opaque envelopes"	NR
de Boisblanc et al,[46] 1993	Air-supported OSC (total arc 90°) vs standard bed (position change every 2 h)	Medical ICU	"Randomized by shuffled sealed envelopes stratified by disease related groups"	NR
Whiteman et al,[47] 1995	CLRT (total arc 120°) vs standard bed (position change every 2 h)	Liver transplant ICU	"Computer-generated randomized treatment assignment"	NR

*ICU indicates intensive care unit; H_2RA, histamine$_2$ receptor antagonist; HIV, human immunodeficiency virus; CFU, colony-forming unit; VAP, ventilator-associated pneumonia; ETA, endotracheal aspirate; CXR, chest x-ray; T, temperature; WBC, white blood cell count; HPF, high-power field; HH, heated humidifier; HME, heat and moisture exchanger; NR, not reported; PSB, protected specimen brush; SSD, subglottic secretion drainage; SUP, stress ulcer prophylaxis; BAL, bronchoalveolar lavage; NGT, nasogastric tube; KTT, kinetic treatment table; ICP, intracranial pressure; IV, intravenous; PVC, premature ventricular contraction; OSC, continuous postural oscillation; and CLRT, continuous lateral rotation therapy. This table summarizes the interventions evaluated in this systematic review by presenting individual trial results according to (1) the population, (2) the method of treatment allocation, (3) whether cointerventions were reported, (4) whether there were exclusions after randomization, (5) whether the pneumonia outcome was assessed blinded to knowledge of the intervention received, and (6) the pneumonia definition used.

Exclusions After Randomization	Blinding of Outcome Assessor	Pneumonia Definition
2 Patients with bleeding disorder, 1 with aortic aneurysm, 1 with HIV, 10 ventilated <96 h	Intensivists unaware of surveillance cultures; radiologist blind	Patients with new and persistent infiltrate and purulent secretions had PSB (positive if $>10^3$ CFU/mL) *or* patients dying with suspected VAP had biopsy (positive if $>10^4$ CFU/g)
None	Patients with suspected VAP were independently reviewed by investigator blinded to intervention	New and persistent infiltrate with either positive blood or pleural cultures with the same ETA organism *or* cavitation on CXR film *or* histopathologic evidence *or* 2 of T >38°C and increase in 1° *or* WBC $>10 \times 10^9$/L with 25% increase *or* purulent secretions with >25 WBC/HPF
None	Not blinded	New and persistent infiltrate, cavitation or effusion *and* 1 of purulent sputum *or* change in sputum *or* positive blood culture *or* positive bronchial brush or wash or biopsy *or* isolation of virus or antigen *or* diagnostic antibody *or* histopathology
NR	NR	Suggestive CXR film and purulent sputum and ETA potential pathogen
NR	NR	New or progressive infiltrate and fever and leukocytosis and purulent tracheobronchial secretions
17 Patients in HME group and 16 in HH group due to ventilation <72 h; all pneumonias developing within 48 h excluded	Radiologist blind	Patients with new and persistent infiltrate and purulent secretions had PSB (positive if $>10^3$ CFU/mL; protected tracheal catheter sample if bleeding diathesis) *or* positive blood culture with same organism as found in ETA with no other infection
Patients ventilated <48 h excluded; also, 6 crossed from HME to HH (4, hypothermia; 2, to decrease dead space) but were analyzed by intention to treat	Microbiologist blind	New infiltrates and T >38°C *or* <36°C and WBC $>12\times10^9$/L and positive ETA culture
6 Patients in HME group were withdrawn (3, jet ventilation; 1, hemoptysis; 1, pulmonary edema; 1, copious secretions)	Microbiologist blind	New or progressive infiltrate and 1 of change in sputum purulence *or* positive ETA culture >72 h after intubation
NR	NR	New and persistent infiltrate and fever, WBC and/or purulent secretions, and PSB $>10^3$ CFU/mL
NR	NR	Patients with new and persistent infiltrate had BAL (positive if $>10^3$ CFU/mL)
19 Excluded in SSD group (8 extubated within 72 h, 9 died, 2 had VAP within 72 h); 18 excluded in control group (11 extubated within 72 h, 7 died)	Radiologist blind	New and persistent infiltrate and fever, WBC, purulent secretions had PSB (positive if $>10^3$ CFU/mL) or BAL (positive if $>10^3$ CFU/mL) or satisfactory antibiotic response
NR	Radiologist blind; patients independently reviewed by investigator blinded to intervention	New *or* progressive infiltrate and purulent sputum and T >38°C *or* <35°C and WBC $>12\times10^9$/L *or* $<3\times10^9$/L and hospitalized ≥48 h
1 Patient in open-suction group desaturated and crossed to closed suction group for analysis; 2 patients in closed suction group were removed because of tracheal bleeding and mucous plugs	NR	New infiltrate and 2 of purulent sputum, T >38°C without extrapulmonary source, WBC $>12 \times 10^9$/L
1 Patient removed from KTT group because of high ICP	NR	For 48 h, new infiltrate and all of T >38°C and WBC $>15\times10^9$/L *or* 0.15 segmented neutrophils and many WBC and organisms on ETA Gram stain and moderate growth on culture
2 Patients removed from KTT group (1, difficulty maintaining IV access; 1, PVCs)	2 Independent blind observers interpreted CXR film; only 1 physician aware of study design	Diagnosis according to infection control practitioners requiring new and persistent infiltrate and T >38°C and purulent sputum with >3 WBC/HPF and positive ETA culture
13 Patients in KTT group never put on bed or were withdrawn but were analyzed in intention to treat; 7 randomized patients were excluded because of stay <24 h	No blinding	Persistent infiltrate and T >38°C and purulent sputum with >3 WBC/HPF and positive ETA culture
3 Patients removed from OSC group due to discomfort but were analyzed by intention to treat	Blind CXR film interpretation by respirologist	New and persistent infiltrate and T >38°C and purulent sputum and positive ETA culture all within 5 d
5 Patients excluded from CLRT (4, discomfort; 1, limiting care)	Blind CXR film interpretation by respirologist	Persistent infiltrate and T >38°C and WBC $>12\times10^9$/L and purulent sputum and positive ETA culture

Table 2.—Ventilation Circuit and Secretion Management Trials: Results

Intervention (Source)	Pneumonia Rates	RR (95% CI)	Other Outcomes
Ventilator circuit changes every 48 h vs no change (Dreyfuss et al[30])	Every 48 h: 11/35 (31%) No change: 8/28 (29%)	0.91 (0.42-1.95)	No difference in pharyngeal, tracheal, or condensate colonization, length of intubation, or ICU mortality
Ventilator ciucuit changes every 7 d vs no change (Kollef et al[31])	Every 7 d: 44/153 (29%) No change: 36/147 (24%)	0.85 (0.58-1.24)	No difference in length of intubation or ICU stay, ICU or hospital mortality
Ventilator circuit changes every 7 d vs 3 times per wk (Long et al[32])	3 Times per wk: 27/213 (13%) Every 7 d: 25/234 (11%)	0.84 (0.51-1.41)	Not reported
HME vs HH (Martin et al[33])	HH: 8/42 (19%) HME: 2/31 (6%)	0.34 (0.08-1.49)	More days of tenacious secretions† and ET occlusions† in HME group; no difference in mortality‡
HME vs HH (Roustan et al[34])	HH: 9/61 (15%) HME: 5/51 (10%)	0.66 (0.24-1.86)	More ET occlusions causing asphyxia† in HME group; no difference in atelectasis, length of intubation or ICU stay, or mortality
HME vs HH (Dreyfuss et al[35])	HH: 8/70 (11%) HME: 6/61 (10%)	0.86 (0.32-2.34)	Less colonization of circuit† and expiratory tubing trap† in HME group; 4 HME patients with tenacious secretions required emergency filter change; no difference in ET occlusion, atelectasis, pharyngeal or tracheal colonization, or mortality
HME vs HH (Hurni et al[36])	HH: 7/56 (13%) HME: 5/59 (8%)	0.68 (0.23-2.01)	No difference in respiratory epithelium, hypothermia, ET occlusion, atelectasis, length of ventilation or ICU stay, or mortality
HME vs HH (Kirton et al[37])	HH: 22/140 (16%) HME: 9/140 (6%)	0.41 (0.20-0.86)†	Fewer ICU days in HME group†; no difference in ET occlusion, work of breathing
Oral IT vs nasal endotracheal IT (Holzapfel et al[38])	Nasal IT: 17/149 (11%) Oral IT: 9/151 (6%)	0.52 (0.24-1.13)	No difference in atelectasis, laryngeal edema, sinusitis, bacteremia, length of ventilation or ICU stay, or mortality
SSD vs standard suctioning as needed (Mahul et al[39])	No SSD: 21/75 (28%) SSD: 9/70 (13%)	0.46 (0.23-0.93)†	No difference in gastric or tracheal colonization or ICU mortality
SSD vs standard suctioning as needed (Valles et al[40])	No SSD: 25/77 (32%) SSD: 14/76 (18%)	0.57 (0.32-1.01)	No difference in length of ventilation or ICU stay or mortality
Open vs closed endotracheal suction system (Deppe et al[41])	Open: 11/38 (29%) Closed: 12/46 (26%)	0.90 (0.45-1.81)	More tracheal colonization in closed suction system†; no difference in mortality
Open vs closed endotracheal suction system (Johnson et al[42])	Open: 10/19 (53%) Closed: 8/16 (50%)	0.95 (0.50-1.82)	Fewer arrhythmias† and less desaturation† in closed suction system
KTT vs standard bed (Gentilello et al[43])	Standard: 8/38 (21%) KTT: 4/27 (15%)	0.70 (0.24-2.10)	No difference in atelectasis, ARDS, decubitus ulcers, length of ventilation or ICU stay, ICU or hospital mortality
KTT vs standard bed (Summer et al[44])	Standard: 7/43 (16%) KTT: 4/43 (9%)	0.57 (0.18-1.81)	No difference in atelectasis, Pao_2/FIo_2 ratio, decubitus ulcers, length of ICU stay, or mortality
KTT vs standard bed (Fink et al[45])	Standard: 19/48 (40%) KTT: 7/51 (14%)	0.35 (0.16-0.75)†	No difference in length of ventilation, ICU stay, or mortality
Continuous postural oscillation vs standard bed (de Boisblanc et al[46])	Standard: 11/51 (22%) OSC: 6/69 (9%)	0.40 (0.16-1.02)	No difference in length of ventilation or ICU or hospital stay, or mortality
CLRT vs standard bed (Whiteman et al[47])	Standard: 14/36 (39%) CLRT: 10/33 (30%)	0.78 (0.40-1.51)	No difference in atelectasis, length of ventilation or ICU stay

*RR indicates relative risk; CI, confidence interval; ICU, intensive care unit; HME, heat and moisture exchanger; HH, heated humidifier; ET, endotracheal; IT, intubation; SSD, subglottic secretion drainage; KTT, kinetic treatment table; ARDS, adult respiratory distress syndrome; FIo_2, fraction of inspired oxygen; OSC, continuous postural oscillation; and CLRT, continuous lateral rotation therapy. This table presents the pneumonia rates in the 2 groups of each randomized trial, and the associated RRs and 95% CIs. Additional possible benefits and harms as reported in the trials are also recorded.

†$P<.05$ for difference between the 2 interventions.

‡Study discontinued after death secondary to ET to be obstruction in HME group.

METHODS

Data Sources

We searched computerized databases from 1980 to July 1997 using the following text words and key words for MEDLINE: *critical care, intensive care units, pneumomia, respiratory tract infection, cross infection, respiration, artificial ventilators, mechanical ventilation, randomized controlled trials,* and *prospective studies;* and the following terms for EMBASE: *pneumonia, prevention,* and *control.* Frequently cited articles were identified and SCISEARCH (Science Citation Index online) was used to locate any additional relevant randomized trials. We also used the Cochrane Library, searching the Clinical Trials Registry for randomized trials. We examined the Cochrane Database of Systematic Reviews as well as the Database of Abstracts of Reviews (DARE) for systematic reviews. We had no language restrictions. The titles (and the abstracts, when available) in the MEDLINE and EMBASE printouts and the reference lists of all primary articles and review articles were reviewed independently in duplicate. Any additional relevant articles were identified and retrieved. We also developed a comprehensive list of relevant trials and wrote to the first author of each to identify any other relevant unpublished trials in this field.

Study Selection

The following selection criteria were applied to the full articles by 2 of us independently (D.C. and B.A.J.): population: critically ill adults including trauma patients; interventions: ventilator circuit and secretion management strategies; outcomes: VAP; and design: published human clinical studies with random or alternate treatment allocation.

A priori, we excluded populations of seriously but not necessarily critically ill patients, neutropenic patients, those with human immunodeficiency virus infection, and children. We omitted studies with a before-after study design.[9,10] We excluded pharmacologic approaches to VAP prevention, whether mediated through the endotracheal tube such as intratracheal antibiotics[11,12] or the gastrointestinal tract such as selective digestive decontamination,[13-17] stress ulcer prophylaxis,[18] and enteral nutrition.[19-28] We also excluded strategies that evaluated surrogate VAP end points.[3-8]

Data Extraction

In duplicate, we abstracted data from the trials to describe the population, the method of treatment allocation, the proportion of patients who were excluded after randomization, whether cointerventions were described, whether the outcome of VAP was made by investigators blinded to the intervention, and the definition of pneumonia used. Disagreements between reviewers on design characteristics and raw data abstraction were resolved by discussion and consensus.

Analysis

We measured agreement between reviewers on the selection of articles for inclusion in the review. We standardized presentation of the VAP rates using relative risk reduction and calculated 95% confidence intervals using a natural log transformation. When the relative risk reduction was significant at the $P<.05$ level, we calculated the number of patients we would need to treat to prevent 1 case of VAP.[29] Since study designs and the definitions of pneumonia differed, we did not statistically pool results of these trials, or subgroups of them, in a meta-analysis. Other clinical outcomes reported in the individual trials were recorded qualitatively. Significant differences ($P<.05$) were noted. Readers are referred to the original publications for details.

Data Synthesis

Study Identification and Selection.— These multiple search strategies yielded 3 trials on ventilator circuit changes,[30-32] 5 comparing heated humidifiers vs heat and moisture exchangers,[33-37] 1 trial of oral vs nasal endotracheal intubation,[38] 2 trials of subglottic secretion drainage,[39,40] 2 trials of closed vs open system suctioning,[41,42] and 5 trials of kinetic bed therapy.[43-47] Agreement was 100% for selection of these studies.

Study Characteristics.— Study characteristics are reported in Table 1. All were randomized trials except 3 that used alternate treatment allocation according to year of birth,[30] medical record number,[32] or room assignment.[42] The mechanical nature of these interventions precluded blinding of the patients and caregivers. Therefore, care delivered by bedside nurses, respiratory therapists, and intensivists could have differed among groups and influenced the development of VAP; accordingly, potential cointerventions are important to consider (Table 1). The chest radiograph was assessed blinded to group assignment in 9 studies.[30,31,35,37,40,41,44,46,47] Six studies included invasive bronchoscopic tests as criteria for the diagnosis of VAP.[30,32,35,38-40] Two studies adjudicated VAP events by investigators blinded to group assignment.[31,41] Most trials described whether there were any withdrawals after randomization.

Outcomes

The results of these studies are presented in Table 2. Of 2677 patients in these 18 randomized trials, a total of 458 had a diagnosis of VAP. The relative risk reduction in VAP associated with these 6 interventions ranged from 0.34 (favoring heat and moisture exchangers over heated humidifiers) to 0.95 (suggesting no difference between closed vs open suction systems).

Considering VAP risk, there is no apparent advantage to changing ventilator circuits frequently. This holds true whether circuits are changed every 2 days[30] or every 7 days[31] compared with no change at all and whether they are changed weekly as opposed to 3 times per week.[32] Other measures of potential benefit and harm recorded in these trials appear similar using different circuit management strategies.

Antibacterial humidification strategies that minimize tubing condensate show clinically important trends in 4 studies[33-36] and a significant difference in a fifth study[37] suggesting that heat and moisture exchangers are at least comparable to heated humidifiers and may be associated with lower rates of VAP than heated humidifiers. Kirton et al[37] found that 10 patients would need to be managed using heat and moisture exchangers instead of heated humidifiers to prevent 1 case of VAP. However, 2 of these 5 trials show significantly more endotracheal occlusions[33] causing asphyxiation,[34] and more tenacious secretions[33] in the heat and moisture exchanger groups.

The site of endotracheal intubation may influence the risk of VAP, and sinusitis is a particular concern in nasally intubated patients. Holzapfel and colleagues[38] found that the incidence of lung infection in patients who were orally intubated was approximately half that found in those who were nasally intubated, though this difference was not significant. Other physiologic and clinical outcomes were similar between the 2 groups.

Aspiration of contaminated oropharyngeal and upper respiratory tract secretions pooled above inflated endotracheal cuffs may be an important factor predisposing to VAP. Endotracheal tubes furnished with a separate lumen open to the subglottic area above the endotracheal cuff allow continuous aspiration of subglottic secretions and have been studied in 2 randomized trials, both suggesting a 50% decrease in VAP rates.[39,40] In 1 of these trials, this difference was significant, suggesting that 7 patients would need to be managed using subglottic secretion drainage instead of a standard endotracheal tube to prevent 1 case of VAP.[39] Additional outcomes appear comparable between these 2 groups.

To avoid hypoxia, hypotension, and contamination of suction catheters entering the endotracheal tube, investigators have examined closed suctioning systems. The 2 published trials suggest a similar VAP rate in patients managed with either a closed or open suction system.[41,42] However, increased tracheal colonization in the closed system group was noted in 1 study.[41]

Sequelae of prolonged immobility such as impaired mucociliary clearance, decreased tracheal secretion removal, and suboptimal gas exchange prompted evaluation of rotational bed therapy. Four studies show a trend toward lower VAP rates in patients receiving kinetic bed treatment.[43,44,46,47] In the remaining trial,[48] the VAP rate was significantly reduced, implying that 4 patients would need to be nursed on a kinetic bed rather than a standard bed to prevent 1 episode of VAP. While physiologic and clinical outcomes appear otherwise comparable between these bed management strategies (Table 2), several patients were withdrawn from these studies because of discomfort[46,47] or possible adverse physiologic effects[43-45] (Table 1).

COMMENT

Practitioners are faced with multiple potential pneumonia prevention strategies that have been evaluated in randomized controlled trials over the last decade. We have critically appraised and summarized the interventions related to ventilator circuit and secretion management that may influence the risk of acquired lung infection in critically ill patients. Three of the 6 interventions among these 18 studies demonstrated significantly lower rates of VAP, including avoidance of heated humidifiers,[37] use of subglottic secretion drainage,[41] and kinetic bed therapy.[45] Whether and how to encode trial results into practice requires consideration of patient risk, the availability and cost of the intervention, adaptation to local circumstances, and integration of the results of observational research. Interpreting data from systematic reviews in this light is central to evidence-based practice and highlights the distinction between evidence and recommendations.[48] Given the modest number of trials evaluating each strategy, their modest sample sizes, variable cointerventions, and the different pneumonia definitions used, cautious interpretation of their results is warranted.

In terms of ventilator management, infrequent circuit changes are associated with a similar, or modestly lower, rate of VAP than frequent changes and no apprent serious adverse outcomes. Though the optimal exchange schedule is uncertain, a policy of no circuit changes or infrequent circuit changes is simple to implement, and the costs are likely lower than those generated by regular, frequent circuit changes. Avoidance of heated humidifiers by using heat and

moisture exchangers may also be worthwhile. Heat and moisture exchangers are associated with either similar or lower VAP rates than heated humidifiers. The mechanism for their apparent benefit is unclear and could be related to minimal circuit condensate compared with heated humidifiers, could be related to the bacterial filtration properties of the filters themselves, or could be due to other mechanisms. Preliminary results of a randomized trial comparing heated humidification using a heated wire circuit aimed at minimizing tubing condensate vs an extended use hygroscopic condenser humidifier showed similar VAP rates.[49] Nevertheless, despite the administrative ease of heat and moisture exchangers, which require no change in the ventilator tubing or circuit, observational studies have documented an increased resistive load associated with exchangers.[50-52] A randomized crossover trial of spontaneous breathing using heat and moisture exchangers vs heated humidifiers in patients able to tolerate a weaning trial identified a larger dead space, higher $PaCO_2$, and increased minute ventilation in the former group,[53] which could hinder weaning from mechanical ventilation. Another 3-arm randomized trial of hot water humidification vs heat and moisture exchanger with either a hydrophobic or hygroscopic filter[54] suggested that hygroscopic but not hydrophobic heat and moisture exchangers minimize endotracheal tube obstruction and offer a satisfactory alternative to the more cumbersome hot water humidifiers.

Secretion management represents another approach to VAP prevention. Oral intubation appears more beneficial than nasal intubation and may confer the added advantage of a decreased risk of sinusitis; costs are similar and there are few impediments to implementation. Subglottic secretion drainage seems to be a promising method of VAP prevention without serious adverse effects. Barriers to the use of these endotracheal tubes include their lack of availability at most institutions and the need to secure them wherever patients may be intubated (eg, the emergency department, operating suite, on the wards). Adoption of closed rather than open suction systems may provide some safety in terms of fewer arrhythmias and desaturation episodes at the expense of increased tracheal colonization; however, these studies are inconclusive. Kinetic bed therapy, while potentially effective at VAP prevention, may interfere with nursing care and cause patient discomfort that is difficult to measure in the critically ill population. While many decisions to acquire new ICU technology or exchange existing equipment for new equipment are made without the need for or benefit of a formal economic evaluation,[55] initial capital equipment costs for kinetic beds and some of the other interventions included in this review need to be considered in cost-effectiveness studies comparing the clinical and fiscal consequences of competing preventive approaches.

The 1994 Centers for Disease Control and Prevention (CDC) guidelines[56] on pneumonia prevention strongly recommend infrequent ventilator circuit changes for all hospitals, but consider the other interventions included in this review as unresolved, for which no recommendations are made.[37] The 1995 American Thoracic Society (ATS) statement[57] classifies the interventions in this review as probably effective and used widely in some clinical settings.[38] Other strategies cataloged in these documents have been summarized elsewhere in systematic reviews[13-18,58] and are beyond the scope of this article. Reasons for different recommendations found in the CDC and ATS position papers may be attributable to different approaches to searching, selecting, and interpreting the literature and synthesizing it with expert opinion. Although systematic reviews and evidence-based guidelines can help to assimilate and appraise research, they represent only aids to decision making, which warrant updating as new evidence emerges. Ideally, these aids are critically appraised and integrated with clinical expertise, which evolves as experience grows.

Subsequent randomized trials might usefully stratify patients according to risk profile.[59] The diverse mechanical, gastrointestinal, and pharmacologic interventions that may influence VAP rates suggest that explicit protocols for cointerventions, or at least faithful reporting of ancillary management such as antimicrobial therapy, would be helpful.[60,61] Transparent, reproducible VAP definitions, whether based on clinical criteria[62] or invasive bronchoscopic techniques,[63] would aid practitioners in interpreting results. Relevant end points include measures of both benefit and safety, mortality, and economic outcomes such as length of ICU stay and direct and indirect costs.

Strategies to prevent VAP continue to undergo evaluation; for example, several trials of subglottic secretion drainage are ongoing. Preliminary results of trials of composite interventions are also being conducted; Girou and colleagues[64] randomized patients to subglottic secretion drainage and semirecumbency or to intubation with a standard endotracheal tube and the supine position. A recent multimodality trial[65] evaluated selective aerodigestive tract decontamination, sucralfate administration, and kinetic therapy compared with no decontamination, ranitidine administration, and repositioning every 2 hours and found a trend toward a lower rate of pneumonia in the former group. Complementary lines of future investigation might include factorial designs examining the unique effect as well as the interaction of 2 or more interventions. If strategies to prevent VAP were evaluated through multicenter collaboration, more precise and generalizable estimates of their impact may become available.

This work was partly funded by the Ontario Ministry of Health (Dr Cook).

We are grateful to Francois Feihl, MD, Orlando Kirton, MD, and Brian DeHaven, MD, for help interpreting their studies. We thank Jill Randall for her comments on early drafts, and we appreciate the help of Barbara Hill with manuscript preparation.

References

1. Fagon JY, Chastre J, Vuagnat A, Trouillet JL, Novara A, Gibert C. Nosocomial pneumonia and mortality among patients in intensive care units. *JAMA.* 1996;275:866-869.
2. Vincent JL, Bihari DJ, Suter PM, et al. The prevalence of nosocomial infection in intensive care units in Europe (EPIC). *JAMA.* 1995;274:639-644.
3. Craven DE, Connolly MG, Lichtenberg DA, Primeau PJ, McCabe WR. Contamination of mechanical ventilators with tubing changes every 24 or 48 hours. *N Engl J Med.* 1982;306:1505-1509.
4. Misset B, Escudier B, Rivara D, Leclercq B, Nitenberg G. Heat and moisture exchanger versus heated humidifier during long-term mechanical ventilation: a prospective randomized study. *Chest.* 1991;100:160-163.
5. Rouby JJ, Laurent P, Gosnach M, et al. Risk factors and clinical relevance of noscomial maxillary sinusitis in the critically ill. *Am Rev Respir Crit Care Med.* 1994;150:776-783.
6. Torres A, Serra-Batlles J, Ros E, et al. Pulmonary aspiration of gastric contents in patients receiving mechanical ventilation: the effect of body position. *Ann Intern Med.* 1992;116:540-543.
7. Ibanez J, Penafiel A, Raurich JM, Marse P, Jorda R, Mata F. Gastroesophageal reflux in intubated patients receiving enteral nutrition: effect of supine and semirecumbent positions. *JPEN J Parenter Enteral Nutr.* 1992;16:419-422.
8. Orozco-Levi M, Torres A, Ferrer M, et al. Semirecumbant position protects from pulmonary aspiration but not completely from gastroesophageal reflux in mechanically ventilated patients. *Am J Respir Crit Care Med.* 1995;152:1387-1390.
9. Hess D, Burns E, Romangnoli D, Kacmarek RM. Weekly ventilator circuit changes: a strategy to reduce costs without affecting pneumonia rates. *Anesthesiology.* 1995;82:903-911.
10. Kollef MH, Vlasnik J, Sharpless L, Pasque C, Murphy D, Fraser V. Scheduled change of antibiotic classes. *Am J Respir Crit Care Med.* 1997;156:1040-1048.
11. Rouby JJ, Poete P, Martin de Lassale E, et al. Prevention of gram negative nosocomial bronchopneumonia by intratracheal colistin in critically ill patients. *Intensive Care Med.* 1994;20:187-192.
12. Lode H, Hoffken G, Kemmerich B, Schaberg T. Systemic and endotracheal antibiotic prophylaxis of nosocomial pneumonia in ICU. *Intensive Care Med.* 1992;18:S24-S27.
13. Vandenbrouke CM, Vandenbrouke JP. Effect of selective decontamination of the digestive tract on respiratory tract infections and mortality in the intensive care unit. *Lancet.* 1991;338:859-862.
14. Selective Decontamination of the Digestive Tract Trialists' Collaborative Group. Meta-analysis

of randomized controlled trials of selective decontamination of the digestive tract. *BMJ.* 1993;307:525-532.
15. Kollef MH. The role of selective digestive tract decontamination on mortality and respiratory infections: a meta-analysis. *Chest.* 1994;105:1101-1108.
16. Heyland DK, Cook DJ, Jaeschke RZ, Griffith LE, Lee HN, Guyatt GH. Selective decontamination of the digestive tract: an overview. *Chest.* 1994;105:1221-1229.
17. Hurley JC. Prophylaxis with enteral antibiotics in ventilated patients: selective decontamination or selective cross-infection? *Antimicrob Agents Chemother.* 1995;39:941-947.
18. Cook DJ, Reeve BK, Guyatt GH, et al. Stress ulcer prophylaxis in critically ill patients: resolving discordant meta-analyses. *JAMA.* 1996;275:308-314.
19. Young B, Ott L, Twyman D, et al. The effect of nutritional support on outcome from severe head injury. *J Neurosurg.* 1987;67:668-676.
20. Moore FA, Moore EE, Jones TN, McCroskey BL, Peterson VM. TEN versus TPN following major abdominal trauma: reduced septic morbidity. *J Trauma.* 1989;29:916-923.
21. Kudsk KA, Croce MA, Fabian TC, et al. Enteral versus parenteral feeding: effects on septic morbidity after blunt and penetrating abdominal trauma. *Ann Surg.* 1992;215:503-511.
22. Borzotta AP, Pennings J, Papasadero B, et al. Enteral versus parenteral nutrition after severe closed head injury. *J Trauma.* 1994;373:459-468.
23. Eyer SD, Micon LT, Konstantinides FN, et al. Early enteral feeding does not attenuate metabolic response after blunt trauma. *J Trauma.* 1993;34:639-644.
24. Bonten MJM, Gaillard CA, van der Hulst R, et al. Intermittent enteral feeding: the influence on respiratory and digestive tract colonization in mechanically ventilated intensive-care-unit patients. *Am J Respir Crit Care Med.* 1996;154:394-399.
25. Montecalvo MA, Steger KA, Farber HW, et al. Nutritional outcome and pneumonia in critical care patients randomized to gastric versus jejunal tube feedings. *Crit Care Med.* 1992;20:1377-1387.
26. Gottschlich MM, Jenkins M, Warden GD, et al. Differential effects of three enteral dietary regimens on selected outcome variables in burn patients. *JPEN J Parenter Enteral Nutr.* 1990;14:225-236.
27. Moore FA, Moore EE, Kudsk KA, et al. Clinical benefits of an immune-enhancing diet for early postinjury enteral feeding. *J Trauma.* 1994;37:607-614.
28. Kudsk KA, Minard G, Croce MA, et al. A randomized trial of isonitrogenous enteral diets after severe trauma: an immune-enhancing diet reduces septic complications. *Ann Surg.* 1996;224:531-543.
29. Laupacis A, Sackett DL, Roberts RS. An assessment of clinically useful measures of the consequences of treatment. *N Engl J Med.* 1988;318:1728-1733.
30. Dreyfuss D, Djedaini K, Weber P, et al. Prospective study of nosocomial pneumonia of patient and circuit colonization during mechanical ventilation with circuit changes every 48 hours versus no change. *Am Rev Respir Dis.* 1991;143:738-743.
31. Kollef MH, Shapiro SD, Fraser VJ, et al. Mechanical ventilation with or without 7-day circuit changes: a randomized controlled trial. *Ann Intern Med.* 1995;123:168-174.
32. Long MN, Wickstrom G, Grimes A, Benton CF, Belcher B, Stamm AM. Prospective, randomized study of ventilator-associated pneumonia in patients with one versus three ventilator circuit changes per week. *Infect Control Hosp Epidemiol.* 1996;17:14-19.
33. Martin C, Perrin G, Gevaudan MJ, Saux P, Gouin F. Heat and moisture exchangers and vaporizing humifiers in the intensive care unit. *Chest.* 1990;97:144-149.
34. Roustan JP, Kienlen J, Aubas P, Aubas S, du Cailar J. Comparison of hydrophobic heat and moisture exchangers with heated humidifiers during prolonged mechanical ventilation. *Intensive Care Med.* 1992;18:97-100.
35. Dreyfuss D, Djedaini K, Gros I, et al. Mechanical ventilation with heated humidifiers or heat and moisture exchangers: effects on patient colonization and incidence of nosocomial pneumonia. *Am J Respir Crit Care Med.* 1995;151:986-992.
36. Hurni JM, Feihl F, Lazor R, Leuenberger P, Perret C. Safety of combined heat and moisture exchanger filters in long-term mechanical ventilation. *Chest.* 1997;111:686-691.
37. Kirton OC, DeHaven B, Morgan J, Morejon O, Civetta J. A prospective, randomized comparison of an in-line heat moisture exchange filter and heated wire humidifiers: rates of ventilator-associated early-onset (community-acquired) or late-onset (hospital-acquired) pneumonia and incidence of endotracheal tube occlusion. *Chest.* 1997;112:1055-1059.
38. Holzapfel L, Chevret S, Madinier G, et al. Influence of long-term oro- or nasotracheal intubation on nosocomial maxillary sinusitis and pneumonia: results of a prospective randomized clinical trial. *Crit Care Med.* 1993;21:1132-1138.
39. Mahul P, Auboyer C, Jospe R, et al. Prevention of nosocomial pneumonia in intubated patients: respective role of mechanical subglottic secretions drainage and stress ulcer prophylaxis. *Intensive Care Med.* 1992;18:20-25.
40. Valles J, Artigas A, Rello J, et al. Continuous aspiration of subglottic secretions in preventing ventilator-associated pneumonia. *Ann Intern Med.* 1995;122:179-186.
41. Deppe SA, Kelley JW, Thoi LL, et al. Incidence of colonization, nosocomial pneumonia, and mortality in critically ill patients using TrachCare closed-suction system versus an open-suction system: prospective, randomized study. *Crit Care Med.* 1990;18:1389-1393.
42. Johnson KL, Kearney PA, Johnson SB, Niblett JB, MacMillan NL, McClain RE. Closed versus open endotracheal suctioning: costs and physiologic consequences. *Crit Care Med.* 1994;22:658-666.
43. Gentilello L, Thompson DA, Tonnesen AS, et al. Effect of rotating bed on the incidence of pulmonary complications in critically ill patients. *Crit Care Med.* 1988;16:783-786.
44. Summer WR, Curry P, Haponik EF, Nelson S, Elston R. Continuous mechanical turning of intensive care unit patients shortens length of stay in some diagnostic-related groups. *J Crit Care.* 1989;4:45-53.
45. Fink MP, Helsmoortel CM, Stein KL, Lee PC, Cohn SM. The efficacy of an oscillating bed in the prevention of lower respiratory tract infection in critically ill victims of blunt trauma: a prospective study. *Chest.* 1990;97:132-137.
46. de Boisblanc BP, Castro M, Everret B, Grender J, Walker CD, Summer WR. Effect of air-supported, continuous postural oscillation on the risk of early ICU pneumonia in nontraumatic critical illness. *Chest.* 1993;103:1543-1547.
47. Whiteman K, Nachtmann L, Kramer D, Sereika S, Bierman M. Effects of continuous lateral rotation therapy on pulmonary complications in liver transplant patients. *Am J Crit Care.* 1995;4:133-139.
48. Cook DJ, Mulrow CD, Haynes RB. Systematic reviews: synthesis of best evidence for clinical decisions. *Ann Intern Med.* 1997;126:376-380.
49. Kollef MH, Shapiro SD, Boyd V, Silver P, von Harz BC, Trovillion E. A randomized controlled trial comparing an extended-use hygroscopic condenser humidifier to heated humidification in mechanically ventilated patients. *Chest.* 1997;112:86S.
50. Conti G, de Blasi RA, Rocco M, et al. Effects of the heat-moisture exchangers on dynamic hyperinflation of mechanically ventilated COPD patients. *Intensive Care Med.* 1990;16:441-443.
51. Chiaranda M, Verona L, Pinamonti O, et al. Use of heat and moisture exchanging (HME) filters in mechanically ventilated ICU patients: influence on airway flow-resistance. *Intensive Care Med.* 1993;19:462-466.
52. Ploysongsang Y, Branson R, Rashking MC, et al. Pressure flow characteristics of commonly used heat-moisture exchangers. *Am Rev Respir Dis.* 1988;138:675-678.
53. Le Bourdelles G, Mier L, Fiquet B, et al. Comparison of the effects of heat and moisture exchangers and heated humidifiers on ventilation and gas exchange during weaning trials from mechanical ventilation. *Chest.* 1996;110:1294-1298.
54. Villafane MC, Cinnella G, Lofaso F, et al. Gradual reduction of endotracheal tube diameter during mechanical ventilation via different humidification devices. *Anesthesiology.* 1996;85:1341-1349.
55. Heyland DK, Gafni A, Kernerman P, Cook DJ. Economic evaluation of the critical care literature: do they help us improve the efficiency of our unit? *Crit Care Med.* 1996;24:1591-1598.
56. Tablan OC, Anderson LJ, Arden N, et al, and the Hospital Infection Control Practices Advisory Committee. Guideline for prevention of nosocomial pneumonia, I: issues on prevention of nosocomial pneumonia. *Am J Infect Control.* 1994;22:247-292.
57. American Thoracic Society Ad Hoc Committee of the Scientific Assembly on Microbiology, Tuberculosis and Pulmonary Infections. Hospital-acquired pneumonia in adults: diagnosis, assessment of severity, initial antimicrobial therapy and preventive strategies: a consensus statement. *Am J Respir Crit Care Med.* 1995;153:1711-1725.
58. Cook DJ, De Jonghe B, Heyland DK. The relation between nutrition and nosocomial pneumonia: randomized trials in critically ill patients. *Crit Care.* 1997;1:3-9.
59. Kollef MH. Ventilator-associated pneumonia: a multivariate analysis. *JAMA.* 1993;270:1965-1970.
60. Dotson RG, Pingleton SK. The effect of antibiotic therapy on recovery of intracellular bacteria from bronchoalveolar lavage in suspected ventilator-associated pneumonia. *Chest.* 1993;103:541-546.
61. Timsit JF, Misset B, Renaud B, Goldstein FW, Carlet J. Effect of previous antimicrobial therapy on the accuracy of the main procedures used to diagnose nosocomial pneumonia in patients who are using ventilation. *Chest.* 1995;108:1036-1040.
62. Niederman MS, Torres A, Summer W. Invasive diagnostic testing is not needed routinely to manage suspected ventilated-associated pneumonia. *Am J Respir Crit Care Med.* 1994;150:565-569.
63. Chastre J, Fagon JY. Invasive diagnostic testing should be routinely used to manage ventilated patients with suspected pneumonia. *Am J Respir Crit Care Med.* 1994;150:570-574.
64. Girou E, Buu-Hoi A, Stephan F, et al. Bacteriologic evaluation of continuous subglottic aspiration for preventing tracheal colonization in ventilated patients. *Am J Respir Crit Care Med.* 1995;151:A720.
65. Renz C, Christenson J, Bhorade S, et al. Prevention of ventilator associated pneumonia: outcome and resource utilization. *Am J Respir Crit Care Med.* 1997;155:A19.

have an opportunity to emphasize that point to any readers who may not have appreciated it.

Marian Garfinkel, EdD
Medical College of Pennsylvania
Hahnemann University
Philadelphia, Pa
David A. Allan, MD, PhD
University of Pennsylvania Health System/
Presbyterian Medical Center
Philadelphia
H. Ralph Schumacher, Jr, MD
University of Pennsylvania School of Medicine
Philadelphia

The Realities of Resident Research Requirements

To the Editor: The Resident Physician Forum by Dr Neale and colleagues[1] addressed the important topic of research during residency and provided a valuable and concise guide for young physicians. A common problem among residents is the need to identify a faculty mentor who would be willing to educate them in how to present a scientific report. Residents usually have limited experience in research and during their residency probably will complete fewer projects than a research assistant. Also, the mentor has to arrange his or her schedule around the resident's schedule.

A second problem is that most residents need to apply for fellowship positions before they would complete a 3-year project. As Neale et al notes, "research experience and publications are an asset when applying for jobs, . . . "[1] making it desirable that residents complete or nearly complete their project before applying for fellowship programs.

To identify a mentor who would be dedicated to teaching the basic skills of how to write and publish a scientific paper, we believe it would be better for residents to start with simple case reports. The cases could be identified by the resident, the possible mentor, or the program director. Local meetings such as those organized by the American College of Physicians might be a good opportunity for residents to present such reports. Such projects could be completed in the first half and probably the first year of a 3-year residency and can help prepare both the resident and the mentor for more extensive project(s) such as Neale et al describe in their article.

Eleftherios Mylonakis, MD
Polyxeni Koutkia, MD
Brown University School of Medicine
Providence

1. Neale AV, West P, French L. Surviving your resident research requirement. *JAMA.* 1998;280:1802.

In Reply: Drs Mylonakis and Koutkia highlight important issues related to residents' research projects. First, faculty mentors are essential for residents to have successful research experiences. The daily demands of graduate medical education constrain most residents from developing research projects on their own. Faculty mentors are invaluable in assisting residents in identifying pertinent topics, designing appropriate studies, and presenting their findings. Mills et al[1] identified faculty mentoring as 1 of 3 significant variables associated with higher research productivity in family practice residencies. A related issue, however, is the need to adequately prepare faculty for research mentoring. Faculty must have the skills, interest, and time to appropriately direct resident research. Faculty development programs such as the one suggested by Henry[2] outline essential skills for the research-focused teacher.

Second, we agree with the suggestion by Mylonakis and Koutkia to use case presentations as a means of starting residents' presentation experiences. Other activities providing similar experience in the initial organization of projects include case conferences at morning report, journal club presentations, and didactic lectures. Another helpful strategy is research workshops addressing critical research process components, as well as sessions on written and oral presentations of research findings. In the Detroit metropolitan area, the OHEP Center for Medical Education, a consortium of regional hospitals affiliated with the Wayne State University School of Medicine, provides such a workshop series for resident training programs that require a research project. OHEP also encourages resident collaborations with faculty research mentors with its resident research grant program. In addition, although our central focus was not on augmenting the curriculum vitae, studies in progress are important indicators of a candidate's academic interests and will be beneficial for a fellowship or job.

Anne Victoria Neale, PhD, MPH
Wayne State University
Detroit, Mich
Patricia West, PhD, RN
St John Hospital and Medical Center
St Clair Shores, Mich
Linda French, MD
Oakwood Healthcare System
Dearborn, Mich

1. Mills OF, Zyzanski SJ, Flocke S. Factors associated with research productivity in family practice residencies. *Fam Med.* 1997;27:188-193.
2. Henry R. Developing research skills for medical school faculty. *Fam Med.* 1997; 29:258-261.

CORRECTIONS

Incorrect Wording and Number: In the Medical News & Perspectives article entitled "Leading Sites of New Cancer Cases and Deaths—1999 Estimates" published in the February 3, 1999, issue of THE JOURNAL (1999;281:405), wording and a number in the graphic are incorrect. The heading over the pair of figures on the left should have read "Cancer Cases by Site and Sex." In the Male figure of the same pair, the number under "All Sites" should be 623 800.

Incorrect Wording: In the Review entitled "Influence of Airway Management on Ventilator-Associated Pneumonia: Evidence From Randomized Trials" published in the March 11, 1998, issue of THE JOURNAL (1998;279:781-787), incorrect wording appeared in the introduction. In the third paragraph, the fifth sentence should have read as follows: "The relationship between body position and tracheobronchial aspiration has been highlighted by 3 randomized trials showing that scintigraphic evidence of aspiration occurs less [not more] often in patients placed in the semirecumbent position than in the supine position.[6-8]"