ORIGINAL ARTICLE

Ventilator-Associated Pneumonia in the Home Care Setting

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OBJECTIVE. To describe the rate of infection, associated organisms, and potential risk factors for ventilator-associated pneumonia (VAP) in patients receiving mechanical ventilation at home.

DESIGN. Retrospective cohort study.

SETTING. University-affiliated home care service.

PATIENTS. Patients receiving mechanical ventilation at home from June 1995 through December 2001.

RESULTS. Fifty-seven patients underwent ventilation at home for a total of 50,762 ventilator-days (mean ± SD, 890.6 ± 644.43 days; range, 76-2,458 days). Seventy-nine episodes of VAP occurred in 27 patients (rate, 1.55 episodes per 1,000 ventilator-days). The first episode of VAP occurred after a mean (±SD) of 245 ± 318.07 ventilator-days. VAP was most common during the first 500 days of ventilation. Rates of VAP were higher among patients who required ventilation for longer daily durations, compared with those who required it for shorter daily durations. There was no association of VAP with age, sex, underlying disease, reason for ventilation, antacid therapy, or steroid use. Microorganisms isolated from 33 episodes of VAP with available culture results included *Pseudomonas* species (17 isolates), *Staphylococcus aureus* (11), *Serratia* species (7), and *Stenotrophomonas* species (5). Eight patients died during the study; no deaths were attributed to pneumonia.

CONCLUSIONS. Although the organisms associated with VAP in the home setting are similar to those associated with hospital-acquired VAP, the incidence and mortality is much lower in the home care setting. Interventions to reduce the risk of VAP among patients receiving home care should be focused on patients who require ventilation for longer daily durations or who are new to receiving mechanical ventilation at home.

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Ventilator-associated pneumonia (VAP) is a significant nosocomial complication among intensive care unit (ICU) patients. National Nosocomial Infection Surveillance System (NNIS) data from 2002-2004 show a VAP rate of 2.9-15.2 episodes per 1,000 ventilator-days in ICU patients.[1] Typical pathogens and resistance patterns are unique to each hospital and ICU, but in general, *Staphylococcus aureus* and antimicrobial resistant gram-negative bacilli, including *Pseudomonas aeruginosa,* are predominant causes of VAP in hospitalized patients.[2,3] The crude mortality attributable to VAP in the ICU setting is up to 40%.[4-6] Nosocomial VAP can prolong hospitalization by 4-11 days,[3,7,8] and each episode is associated with over $10,000 in additional hospital costs.[3,8]

In lieu of hospital-based mechanical ventilation, an increasing number of patients with spinal cord injuries, neuromuscular diseases, and chronic respiratory disorders are now supported at home with long-term mechanical ventilation (hereafter, home mechanical ventilation). However, little is known about the incidence, characteristics, and morbidity of VAP with respect to patients who receive ventilation outside the hospital.

We performed a retrospective cohort study to further characterize VAP in patients receiving home mechanical ventilation. We aimed to describe the rate and incidence of VAP in patients receiving ventilation at home, to identify demographic characteristics and potentially modifiable risk factors associated with the development of VAP in this setting, and to define the outcomes of VAP among this patient population.

METHODS

Setting and Patient Population

The MedEquip Home Care Services department at the University of Michigan Health System (UMHS) provides durable medical equipment and respiratory therapy services for home care. Respiratory services include the provision of oxygen for

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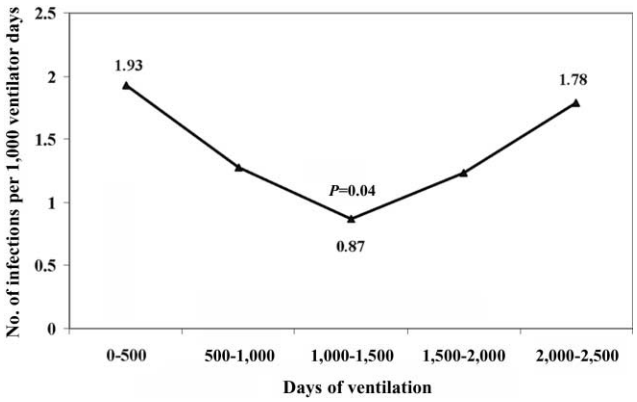

FIGURE. Rate of ventilator-associated pneumonia (VAP) over the duration of ventilation for 57 patients receiving mechanical ventilation at home. Overall rate of VAP, 1.55 infections per 1,000 ventilator-days.

home use, aerosol therapies, tracheostomy supplies, and home mechanical ventilation services. At the time of this study, MedEquip had provided services for 12,000 respiratory patients since the company was formed in July 1995. Staff members included 4 respiratory therapists, 1 nurse, and 15 technicians. The study population included all patients who received home mechanical ventilation through MedEquip who were referred through the UMHS and were followed up by MedEquip respiratory therapists. Visiting home nurses and respiratory therapists recorded changes in respiratory status, sputum, oxygen requirements, suctioning requirements, infections, and outpatient antibiotic use in the home care records. The study population represented approximately 80% of all patients receiving mechanical ventilation who were cared for by MedEquip.

Patients' primary care was provided by family members or home nursing agencies. Tracheostomy suctioning was performed using clean technique, as clinically indicated. Ventilator tubing was changed weekly for all patients. The ventilators used included bilevel ventilation to tracheostomy tube, standard pressure support or pressure control ventilation through tracheostomy tube, volume ventilation through tracheostomy tube, and external negative pressure ventilation with a thoracic chamber. Patients receiving noninvasive modes of ventilation via a mask were excluded.

Case Definition and Case Ascertainment

A case patient was defined as any study patient who developed pneumonia, as defined by Centers for Disease Control and Prevention criteria for nosocomial pneumonia, between June 1995 and December 2001.[9] Cases were ascertained through review of home nursing and respiratory therapy records, UMHS medical records, and microbiological laboratory data. Multiple episodes of VAP in individual patients were considered independent episodes if they were separated by at least 1 month, the patient had new or different x-ray findings, or the patient had new organisms isolated from sputum culture. Cultures of respiratory tract samples were performed at the clinical discretion of the treating physicians.

Cohort Study

A retrospective cohort study was performed to identify relative risk for VAP. Demographic and clinical variables were extracted from MedEquip and UMHS medical records using a standardized form. Variables for case patients were collected up to the time of onset of pneumonia.

Statistical Analysis

Statistical analysis was performed using the SPSS-10 statistical program (SPSS). Categorical variables were analyzed using the χ^2 test or the Fisher exact test. The Student t test was used to compare continuous variables. A 2-sided P value of .05 or less was considered statistically significant.

RESULTS

During the study period, 57 patients underwent a total of 50,762 days of ventilation. The mean duration of ventilation was 890.6 ventilator-days per patient (range, 76-2,458 ventilator-days per patient). Seventy-nine independent episodes of VAP were identified in 27 (47%) of 57 patients during the study period. The mean attack rate for the study population was 1.3 episodes of VAP per patient. Among those patients with at least 1 episode of VAP, the number of episodes ranged from 1 to 15 per patient. The first episode of VAP occurred after a mean ($\pm$SD) of 245 $\pm$ 318 ventilator-days. Forty-eight (61%) of the episodes of VAP occurred within the first 500 days of ventilation, with fewer episodes of VAP occurring later in the period during which the patient received ventilation.

TABLE 1. Microorganisms Associated with Ventilator-Associated Pneumonia (VAP) in Patients Receiving Mechanical Ventilation at Home

Organism, by type	No. (%) of organisms (N = 49)
Gram-negative bacilli	32 (65)
Pseudomonas spp	17 (35)
Serratia spp	7 (14)
Stenotrophomonas spp	5 (10)
Acinetobacter spp	1 (2)
Other	2 (4)
Gram-positive cocci	15 (31)
Staphylococcus aureus	11 (22)
Streptococcus pneumoniae	2 (4)
β-hemolytic streptococci	1 (2)
Other	1 (2)
Moraxella spp	1 (2)
Mycoplasma spp	1 (2)

NOTE. Culture results were available for 33 (41.8%) of 79 episodes of VAP, which occurred among 27 patients.

TABLE 2. Demographic and Clinical Characteristics of Study Patients Receiving Mechanical Ventilation at Home

Characteristic	Patients with VAP ($N = 27$)	Patients without VAP ($N = 30$)	P
Age, mean ± SD, years	19.3 ± 19.9	14.3 ± 16.2	.07
Male sex	13 (48)	13 (43)	.72
Indication for ventilation			
Congenital respiratory disease	12 (44)	13 (43)	.93
Nervous system disease	9 (33)	10 (33)	1.00
Obstructive respiratory disorder	2 (7)	5 (17)	.29
Myopathy	4 (15)	2 (7)	.32
Ventilator type			.45
Bilevel to tracheostomy tube	13 (48)	11 (37)	
Pressure/volume	6 (22)	9 (30)	
Volume	7 (26)	8 (27)	
External negative-pressure	1 (4)	2 (7)	
No. of ventilator-days, mean ± SD	1,012 ± 673	781 ± 572	.30
Underlying disease			
Respiratory	21 (78)	25 (83)	.72
Cardiovascular	15 (56)	17 (57)	1.00
Gastrointestinal	16 (59)	11 (37)	.23
Neurological	12 (44)	16 (53)	.50
Diabetes mellitus	0	2 (7)	.17
Renal	7 (26)	5 (17)	.39
Other	15 (56)	19 (63)	.76
Tobacco use	2 (7)	1 (3)	.49
Alcohol use	1 (4)	0	.29
Steroid therapy	7 (26)	6 (20)	.59
Sedative use	4 (15)	3 (11)	.58
Antacid therapy	17 (63)	10 (33)	.07
Aspiration event[a]	5 (22)	1 (4)	.06

NOTE. Data are no. (%) of patients, unless otherwise indicated.

[a] For aspiration pneumonia, data was available for 23 patients with VAP and 25 patients without VAP.

The overall rate of VAP was 1.55 infections per 1,000 ventilator-days. The rate of VAP was highest during the first 500 days, at 1.93 infections per 1,000 ventilator-days; it declined significantly to 0.87 infections per 1,000 ventilator-days in patients who had received ventilation for 1,000-1,500 days, but returned to 1.78 infections per 1,000 ventilator-days in patients who had received ventilation for 2,000-2,500 days ($P = .04$) (Figure).

Culture results were available for 33 (42%) of 79 episodes of VAP, which yielded 49 isolates (Table 1). Gram-negative bacilli accounted for 65% of these isolates. *Pseudomonas* species accounted for 17 (35%) of the isolates; other gram-negative pathogens recovered included *Serratia* species, *Stenotrophomonas* species, and *Acinetobacter* species. *Staphylococcus aureus* accounted for 11 (22%) of the isolates. Four (36%) of the staphylococci isolates recovered were methicillin resistant. Organisms typically associated with community-acquired pneumonia were identified in 4 patients, including *Streptococcus pneumoniae* in 2 patients, *Mycoplasma* species in 1 patient, and *Moraxella* species in 1 patient.

The study patients were mostly young, with a mean age (±SD) of 19.3 ± 19.9 years for patients with VAP and 14.3 ± 16.2 years for patients without VAP. Patients with VAP did not differ from those without VAP with respect to sex, indication for ventilation, or type of ventilator used. Patients with VAP received ventilation for a mean (±SD) of 1,012 ± 673 days, compared with 781 ± 572 days for patients without VAP, but this difference was not statistically significant ($P = .30$). There was no difference in underlying diseases, tobacco use, alcohol use, or steroid or sedative use between patients with and without VAP. There was a trend towards increased use of antacid therapy ($P = .07$), which included antacids or histamine-2 receptor blockers, and aspiration events ($P = .06$) for patients with VAP (Table 2). The indications for ventilation included congenital respiratory disease (mostly in young patients with severe congenital respiratory disorders), obstructive respiratory disorders (patients with tracheomalacia, obstructive sleep apnea, and a single patient with chronic obstructive pulmonary disease due to α-1 antitrypsin disorder), nervous system disease (patients with myasthenia

TABLE 3. Ventilation Characteristics for Study Patients Receiving Mechanical Ventilation at Home

Variable	No. (%) of patients		P
	With VAP (N = 27)	Without VAP (N = 30)	
Duration of ventilation			.04
<10 h per day	4 (15)	14 (47)	
11-16 h per day	3 (11)	2 (7)	
17-24 h per day	20 (74)	14 (47)	
Ventilator circuit type			.48
Heater-humidifier	6 (22)	4 (13)	
Heater-humidifier with heated circuit	20 (74)	23 (77)	
Heat-moisture exchanger	1 (4)	1 (3)	
Not applicable	0	2 (7)	
Suctioning frequency[a]			.61
⩽5 times per day	10 (37)	13 (46)	
6-10 times per day	12 (44)	9 (32)	
11-20 times per day	5 (19)	5 (18)	
Primary caregiver			.83
Parent	20 (74)	24 (80)	
Spouse	5 (19)	4 (13)	
Nursing agency	2 (7)	2 (7)	
Enteral feeding method			.54
Via nasogastric tube	3 (11)	5 (17)	
Via gastrostomy tube	15 (56)	11 (37)	
Via jejunostomy tube	1 (4)	1 (3)	
Frequency of tracheostomy tube change[b]			.36
Weekly	18 (67)	22 (79)	
Monthly	8 (30)	4 (14)	
As needed	1 (4)	2 (7)	

[a] Data available on 28 patients without VAP.
[b] Data available on 28 patients without VAP.

gravis, post-polio syndrome, Lewy body disease, amyotrophic lateral sclerosis, and spinal cord injury), and myopathies (including muscular dystrophy and rare congenital myopathies).

The daily duration of ventilation was significantly associated with the occurrence of VAP, with 20 (74%) of 27 patients with VAP requiring 17-24 hours of ventilation per day, compared with 14 (47%) of 30 patients without VAP ($P = .04$). There was no association of ventilator type or suction requirements with the occurrence of VAP. There was also no significant difference in type of primary caregiver, type of enteral feeding, or frequency of tracheostomy tube changes between patients with and patients without VAP (Table 3).

Sixty-nine (87%) of 79 episodes of VAP resulted in hospitalization. The mean duration of hospitalization ($\pm$SD) for an episode of VAP was 7.0 $\pm$ 9.0 days. Forty-two (74%) of 57 patients were still receiving respiratory care services from MedEquip at the end of the study period. Two patients no longer required ventilation, and 5 patients changed respiratory care services. There were 8 deaths during the study period; 4 deaths occurred in patients with VAP and 4 deaths occurred in patients without VAP. No deaths were attributable to VAP.

DISCUSSION

VAP in ICU patients has been extensively studied, and rates range from 2.9 infections per 1,000 ventilator-days in pediatric ICUs to 15.2 infections per 1,000 ventilator-days in trauma ICUs.[1] Multiple risk factors for VAP in ICU patients have been identified, and significant attention is currently focused on modifying risk factors in order to prevent VAP in ICU patients.[10] In contrast, there has been little evaluation of VAP in patients receiving long-term ventilation who are cared for in non-ICU settings, including non-ICU hospital environments, long-term ventilation care units, or the home.

Despite the growing popularity of home mechanical ventilation, there is little published data on VAP in patients receiving ventilation in this setting. Bertrand and colleagues[11] studied children receiving home mechanical ventilation in Chile and reported an annual rate of 1.6 episodes of tracheitis or pneumonia requiring hospitalization. The study included only children and involved both invasive and noninvasive methods of ventilation. In our study population of 57 patients receiving ventilation at home, 27 (47%) of the patients had at least 1 episode of VAP, with a mean rate of 1.3 episodes per patient. The overall rate of VAP was 1.55 infections per 1,000 ventilator-days, which is significantly lower than the rate observed in most ICU populations.

The lower VAP rate in patients receiving home mechanical ventilation likely reflects differences in VAP risk factors, demographic characteristics, and acuity of illness in this population. These patients tend to be significantly younger (mean age, 16.4 years) than the average ICU patient and tend to have fewer comorbidities, which may translate into lower mortality. While patients receiving home mechanical ventilation commonly have underlying lung disorders and neuromuscular disease, many of the other traditional risk factors for VAP in ICU patients are absent.

Among our study group, we found that sex, age, and specific indications for mechanical ventilation were not associated with increased risk of VAP. We did find that patients who required ventilation for longer periods per day had a higher risk of VAP, but the total number of ventilator-days did not seem to increase risk. A possible explanation is that patients requiring longer daily periods of ventilation had increased severity of underlying illness and less respiratory reserve, placing them at higher risk of VAP. Additionally, a longer daily duration of ventilation may be associated with increased opportunity for bacterial contamination, resulting in higher VAP rates. The first 500 days of home mechanical ventilation carried a higher risk for VAP than did later days. This higher early rate may reflect the fact that patients are more acutely ill early in the period during which they receive ventilation, or it may reflect a learning curve for home care providers.

Use of a nasogastric tube has been associated with an increased rate of VAP in the ICU population.[12,13] Enteral feeding was not associated with VAP in our study group, despite a 71% incidence of enteral feeding requirements; the majority of patients had gastrostomy tubes. Antacid therapy and aspiration events approached but did not meet statistical significance as risk factors for VAP. Patients who require enteral feeding but reside at home may be more likely to be upright than patients in the ICU who require enteral feeding, and less likely to have a nasogastric tube, resulting in a decreased risk of aspiration, compared with ICU populations. In addition, the colonization of the upper intestinal tract with pathogenic organisms that is thought to play a role in ICU-associated VAP[14] may not occur in the more stable patient receiving home mechanical ventilation.

Interventions that could potentially introduce bacterial contamination into the respiratory tract, including ventilator circuit type, frequency of suction, and frequency of tracheostomy-tube change did not impact the rate of VAP in patients receiving home mechanical ventilation. In addition, there was no difference in VAP rate depending on the type of primary caregiver, suggesting that family members and nurses are equally effective at providing care for patients receiving ventilation. However, VAP was more likely to occur during the first 500 days of home mechanical ventilation, which may in part reflect a caregiver learning curve for providing ventilator care. There was no specific ventilator type that appeared to increase VAP risk, but all but 3 patients in the study group received invasive, positive-pressure ventilation or bilevel ventilation through a tracheostomy tube.

VAP in patients receiving home mechanical ventilation is a serious infection, as reflected by the 87% hospitalization rate. However, there was no apparent increased mortality attributable to VAP for this population. This is in contrast to the high attributable mortality of VAP for ICU patients. The lower mortality in patients receiving home mechanical ventilation, compared with ICU patients, does not stem from differences in the microbial pathogens that cause VAP. The predominant organisms in patients receiving home mechanical ventilation were similar to those typically seen in ICU patients, which include gram-negative bacilli, such as *Pseudomonas* species, as well as *Staphylococcus aureus* (36% of *S. aureus*isolates were methicillin resistant in this study). The lower mortality in the population receiving home mechanical ventilation likely reflects a lower acuity of underlying illness and fewer comorbidities.

One limitation of this retrospective cohort study of VAP in patients receiving mechanical home ventilation is the difficulty of making a diagnosis of VAP on the basis of clinical findings. Only 33 (42%) of 79 episodes of VAP had culture results available. In addition, while the study period included a large number of ventilator-days, there was a small number of individual patients, resulting in decreased power to detect minor risk factors. Further, our results reflect a homogeneous population from a single home care service, referred from a single health center.

In conclusion, VAP rates are much lower in the population of patients receiving home mechanical ventilation than in the ICU population. Although the causative organisms are similar, mortality rates are much lower in the home care population. VAP is more likely to occur in these patients during the first 500 days of home ventilation and is more frequent among those requiring longer daily periods of ventilation. Interventions may be directed at the education and support of caregivers and focused toward those patients requiring longer daily periods of ventilation. Future studies should include a prospective evaluation of risk factors in a larger, heterogeneous population of patients receiving home mechanical ventilation. This should be followed by studies of interventions aimed at risk factor modification, potentially including those that have been successful in preventing VAP in ICU patients, such as the groups of interventions for patients receiving ventilation ("ventilator bundles"). In general, additional understanding of infections occurring in home care patients is important as we shift toward non–hospital-based care of increasingly complicated conditions.

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