Bacterial Colonization and Home Mechanical Ventilation: Prevalence and Risk Factors

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OBJECTIVE: To investigate the prevalence of bacterial contamination of ventilators and colonization of patients, the bacteria implicated, and predisposing factors in noninvasive home ventilation.

MATERIAL AND METHODS: Forty patients on a home noninvasive ventilation program (mean [SD] age: 63.1 [12] years; time on ventilation: 30.7 [25] months; daily use: 8.1 [2] hours) were enrolled in this descriptive cross-sectional study. Microbiological samples for semiquantitative cultures were swabbed from the ventilator (mask and tubing) and the nostrils. A questionnaire was completed on the underlying disease, time on the ventilation program, type of ventilator, presence of a humidifier, and attention to ventilator cleanliness and maintenance. We defined "colonization" as the presence of microorganisms in the nostrils without evidence of a host immune response, and "contamination" as the presence of surface microorganisms (on tubing or the nasal mask).

RESULTS: Potentially pathogenic bacteria were isolated from 6 ventilators (15%) and the nasal swabs of 10 patients (25%). *Staphylococcus aureus* was the most frequently isolated one (in 5 ventilators and 6 patients—contamination coinciding with colonization in 3 cases). Other potentially pathogenic bacteria isolated were *Proteus* species (from the nostrils of 2 patients) and an unidentified gram-negative bacillus from the ventilator. On analysis by underlying disease, 60% of the patients with obesity had been colonized. No other findings of note were obtained for other diseases. Contamination and colonization correlated with attention to cleanliness and maintenance of the ventilator but not with type of ventilator, time on the ventilation program, or use of a humidifier.

CONCLUSIONS: Home mechanical ventilators are a potential source of nasal colonization. The most frequently encountered microorganism was *S. aureus*. The degree of ventilator cleaning and disinfection seems to affect contamination; thus it is necessary to impress on patients the need for adequate maintenance of their ventilators.

Key words: *Colonization. Contamination. Home mechanical ventilation.*

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Colonización bacteriana y ventilación mecánica domiciliaria. Prevalencia y factores de riesgo

OBJETIVO: Conocer la prevalencia de contaminación bacteriana de los ventiladores utilizados en la ventilación mecánica no invasiva domiciliaria, la colonización en los pacientes, los microorganismos implicados y los factores favorecedores.

MATERIAL Y MÉTODOS: Se realizó un estudio descriptivo transversal en 40 pacientes en programa de ventilación mecánica no invasiva domiciliaria (edad media: 63,1 ± 12 años; tiempo en ventilación: 30,7 ± 25 meses; utilización diaria: 8,1 ± 2 h). Se tomaron muestras microbiológicas mediante escobillado del equipo de ventilación (mascarilla y tubuladuras) y de las fosas nasales para realizar cultivos semicuantitativos, y se completó un cuestionario que incluía enfermedad de base, tiempo en programa de ventilación, tipo de ventilador, existencia de humidificador y hábitos y grado de limpieza. Definimos como "colonización" la presencia de microorganismos en las fosas nasales sin evidencia de respuesta orgánica por parte del huésped, y "contaminación" como la presencia de microorganismos en una superficie (tubuladura y mascarilla nasal).

RESULTADOS: Se aislaron microorganismos potencialmente patógenos en las conexiones de 6 equipos (15%) y en el frotis nasal de 10 pacientes (25%). *Staphylococcus aureus* fue el aislado con mayor frecuencia (5 equipos y 6 pacientes; fue coincidente en 3 casos). Otros gérmenes aislados fueron *Proteus* spp. (2 casos en fosas nasales), *Streptococcus pneumoniae* (2 casos en fosas nasales) y un bacilo gramnegativo no tipificable en las conexiones. Por patologías, el único dato destacable fue que en el 60% de los pacientes con obesidad existía colonización, sin que hubiera datos significativos en el resto de enfermedades. Existe correlación positiva entre el grado de limpieza macroscópico y los aislamientos, pero no entre la contaminación, la colonización y factores como tipo de ventilador, tiempo en ventilación o uso de humidificador.

CONCLUSIONES: Los equipos de ventilación mecánica domiciliario pueden representar una fuente potencial de colonización nasal. El microorganismo más representativo encontrado fue *S. aureus*. El grado de limpieza de los equipos parece influir en la contaminación, por lo que es necesario insistir en el adecuado mantenimiento de estos equipos.

Palabras clave: *Colonización. Contaminación. Ventilación mecánica domiciliaria.*

Introduction

In recent years, home mechanical ventilation with positive pressure ventilators, whether invasive or noninvasive, has proved effective in chronic respiratory insufficiency caused by chest-wall deformities (kyphoscoliosis and sequelae of tuberculosis), neuromuscular disorders, and various hypoventilation syndromes (obesity, primary, central apnea, and neurological). The indication of home mechanical ventilation in patients with chronic obstructive pulmonary disease remains controversial, although several studies support its usefulness in such patients.[1,2]

Noninvasive ventilation (NIV) requires a (volume or pressure-limited) ventilator to generate a positive pressure, and auxiliary components, such as a corrugated tube (tubing) and a nasal mask, to deliver the air to the patient. The circuit also contains an expiratory valve and, often, a humidifier.[3] The different components of this circuit (nose-airways, mask, tubing, humidifier) are at risk of contamination or colonization by microorganisms. Over the last couple of decades, many studies have been published that investigate bacterial contamination of circuits of invasive mechanical ventilators and colonization of patients submitted to this type of ventilation in intensive care units.[4-6] In contrast, very few studies have analyzed patients on home NIV.[7,8]

The objective of this study was to determine the prevalence of bacterial contamination of home devices for NIV and bacterial colonization of patients who use such ventilators and the microorganisms most often implicated, and to investigate predisposing factors to contamination and colonization.

Material and Methods

Population

A consecutive series of 40 patients using home noninvasive ventilators (where noninvasive indicates without tracheostomy) were prospectively studied. The patients belonged to the NIV program of the Ventilatory Support and Sleep Disorders Unit of the Hospital Gregorio Marañón in Madrid, Spain. To be included, patients had to have been on ventilation for at least 3 months. Patients were excluded if they had shown clinical change, a history of infection, or had taken antibiotics or corticosteroids in the 3 months prior to enrollment (that is, they had to be clinically stable). To prevent "extra" cleaning of the ventilator, neither the patients nor the service provider were informed about the study in advance. The service provider informed the patients verbally and in writing about recommendations for maintenance and cleaning of equipment, with particular emphasis on the need to clean the mask with soapy water every day and change the filters regularly. The provider also checked the home ventilators every 3 to 4 months.

Methods

All patients enrolled in the study underwent the following procedures:

1. A questionnaire that determined diagnosis of the underlying disease and its causes, current symptoms, date of enrollment in the home ventilation program, compliance (hours/day of use), type of ventilator (volume or pressure-limited), whether or not a humidifier was used, and, finally, cleaning habits (equipment, frequency, and method of cleaning).

2. Visual inspection of the ventilator (mask and tubing) to assess state of cleanliness, with classification as either acceptable or unacceptable depending on whether organic residues, turbidity, or dirt were found. The same person always performed the classification to ensure that the assessment was as objective as possible.

3. Sampling for microbiological study. Two samples were swabbed, one from the nostrils of the patient and the other from the mask and region of tubing closest to the mask. For bacteriological analysis, samples were cultured on blood agar and the colonies were counted semiquantitatively after 24 to 48 hours. "Colonization" was defined as the presence of microorganisms in the nostrils of the patients without evidence of a host immune response, and "contamination" as the presence of surface microorganisms (on the tubing and nasal mask).

Statistical Analysis

Qualitative data were presented as percentages whereas quantitative data were presented as means (SD). The χ^2 test was used to analyze the relationship between qualitative data. Comparison between mean values of the different groups (age, number of hours on ventilation, duration of treatment) was performed by the Student *t* test. Significance was set at $P<.05$.

Results

Forty patients (21 men, 19 women) with a mean age of 63.1 (12) years were included. The mean time they had spent on the home NIV program was 30.7 (24.7) months, and the mean daily ventilator usage was 8.1 (2) hours. Table 1 shows the underlying diseases for which NIV was indicated. Half the patients used a volume ventilator (Breas Medical Mölnlycke, Sweden) and the other half a pressure-limited ventilator (BiPAP ST from Respironics®, Murrysville, USA). All subjects used a commercial nasal mask as interface (Respironics®, Murrysville, USA). Forty percent had a humidifier connected between the ventilator and the interface.

Nineteen patients (47%) cleaned their ventilator weekly, 9 (23%) cleaned it monthly, and 6 (15%) cleaned it sporadically. Six patients (15%) had never cleaned their ventilators. Visual inspection showed 13 ventilators (32.5%) had acceptable cleanliness, whereas 27 ventilators (67.5%) were classed as unacceptable.

Potentially pathogenic microorganisms (PPMs) were isolated from the interfaces of 6 ventilators (15%) and from the nasal swab of 10 patients (25%). Figure 1 shows the PPM isolated from the masks (Figure 1A) and from the nostrils of the patients (Figure 1B). The most commonly isolated PPM was *Staphylococcus aureus,* which appeared in 5 ventilators (12.5%) and in the nostrils of 6 patients (15%)—contamination coinciding with colonization in 60% of the cases. Other

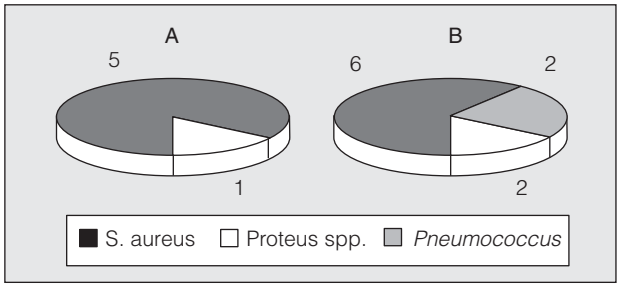

Figure 1. Microorganisms isolated from masks (A) and nostrils (B).

PPMs isolated from the nostrils were *Proteus* species in 2 cases, and *Streptococcus pneumoniae* in a further 2 cases. A gram-negative bacillus that could not be speciated was isolated from 1 ventilator. *Streptococcus viridans* is not considered potentially pathogenic, but it was isolated from 4 of the ventilators (10%) and from the nostrils of 2 of the patients (5%). Saprophytic flora—*Corynebacterium* species and/or coagulase-negative *Staphylococcus*—were isolated in the noses of all patients. Saprophytic flora isolated from the nostrils of the patients coincided with flora isolated from the corresponding ventilators except in 2 cases (1 ventilator was found to be sterile and *Neisseria* species was isolated from another).

Table 1 shows the number of PPMs isolated from the ventilator and from the nostrils of the patients by underlying disease responsible for indication of NIV. *S aureus* was isolated from the ventilators of 2 patients with thoracoplasty, 1 with neuromuscular disorder, 1 with chronic obstructive pulmonary disease, and 1 with obesity–hypoventilation syndrome, and from the nostrils of 2 patients with thoracoplasty (both coinciding with contamination), 3 patients with obesity (1 of whom also had contamination of the ventilator by *S aureus*) and 1 patient with kyphoscoliosis.

The level of cleanliness correlated with isolates of PPMs ($P<.05$). Thus, of the 13 patients with an acceptable level of cleanliness, only 1 (7.7%) had contaminated ventilators and 1 (7.7%) had colonization of the nostrils by PPM. In contrast, of the 27 patients with unacceptable ventilator cleanliness, 5 (12.5%) had contamination of the ventilator and 9 (22.5%) had colonization of the nostrils (Table 2 and Figure 2). We found no significant relationship between contamination, colonization, and other factors such as the type of ventilator (20% of BiPAP ventilators were contaminated and 80% were not, 25% of the patients using BiPAP ventilators had colonization of the nostrils and 75% did not; 20% of volume ventilators were contaminated and 80% were not), time on ventilation program (28 [18.1] months for those with contamination of the mask compared to 31.9 [26.4] months without; 33.3 [15] months for patients with colonization of the nostrils compared to 29.6 [27.7] months for patients without), or whether or not a humidifier was connected.

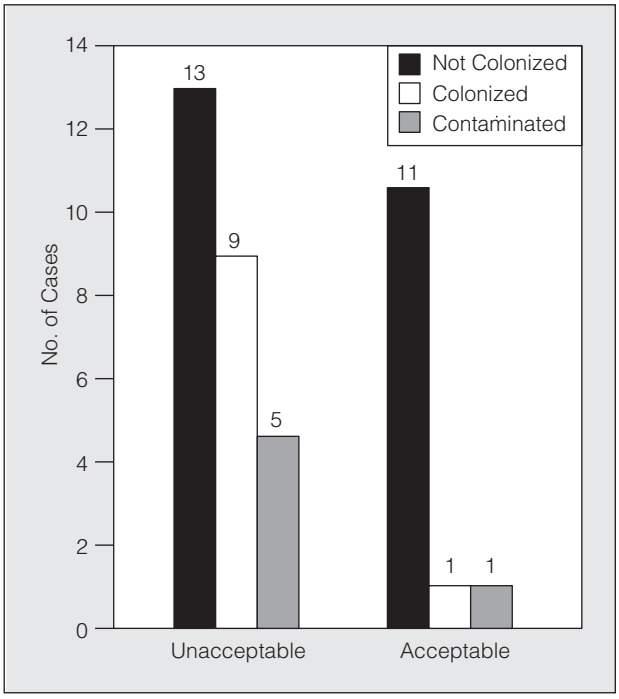

Figure 2. Number of cases of contamination and colonization according to cleanliness of the ventilator. The number of positive cases is significantly greater among patients with ventilators in a poor state of cleanliness ($P<.05$).

Discussion

Anomalous colonization of airways after external inoculation by contaminated aerosols from respiratory devices (nebulizers, ventilators, etc) is a particularly important source of nosocomial respiratory infection. Even devices to measure pulmonary function may be a potential source of contamination,[9] but no studies

TABLE 1
Underlying Diseases of the Patients in the Home Ventilation Program and Number of Microorganisms Isolated*

	Isolates	
	Ventilation Equipment	Nostrils
Obesity-hypoventilation syndrome (n=10)	2	6
Neuromuscular disorders (n=7)	1	1
Tuberculosis sequelae (n=10)	2	2
Kyphoscoliosis (n=5)	0	1
COPD (n=5)	1	0
Others (n=3)	0	0

*COPD indicates chronic obstructive pulmonary disease.

TABLE 2
Microorganisms Isolated According to Cleanliness of the Ventilators

	Mask	Nostrils
Acceptable cleanliness (n=13)	1 (7.7%)	1 (7.7%)
Unacceptable cleanliness (n=27)	5 (12.5%)	9 (22.5%)

corroborate such microbial transmission. Few studies have investigated home devices for NIV even though such therapy has become more widespread in recent years. In survey carried out by our group in 1999, Spain had more than 1821 patients on home ventilation programs.[10] Currently, the number is higher, and would be higher still if we included patients diagnosed with sleep apnea syndrome who use continuous positive airway pressure (CPAP) devices. Our working hypothesis is that material used for home NIV could become contaminated by PPMs, given the similarity with hospital devices. Such contamination might cause anomalous colonization of the airways, which in turn could cause respiratory infections in such patients.

We approached the study by taking a cross-section of the population to determine the prevalence of contamination of these ventilators, colonization of the patients, and what microorganisms were involved. Finally, we tried to identify risk factors that favor contamination. Our results showed that 15% of the NIV equipment used for home treatment of chronic respiratory insufficiency was contaminated and 25% of the patients were colonized by PPM. The most commonly isolated microorganism was *S aureus*, found in 12.5% of the ventilators and in the nostrils of 15% of the patients. The study is limited in that there was no control population with the same underlying diseases and similar characteristics, and there was no measurement prior to initiation of ventilation for comparison of the percentages of colonization. The results are therefore merely limited to a description of the situation. However, comparison with the literature shows that the percentage of patients with colonization lies within ranges described—*S aureus* colonizes the nostrils of between 10% and 40% of hospital patients, and colonization is more common in patients with diseases such as diabetes mellitus, immune deficiencies, those undergoing hemodialysis, and intravenous drug users.[11,12] The frequent coincidence of colonizing and contaminating bacteria is noteworthy (in 60% of the isolates of *S aureus*, contamination coincided with colonization), but it is impossible to tell whether colonization preceded contamination or vice versa. We cannot draw definitive conclusions about whether the underlying disease influences the susceptibility of the patient due to the low number of isolates, but no relationship is apparent. The higher percentage of patients with obesity-hypoventilation syndrome with nasal colonization could be due to a higher incidence of metabolic diseases such as diabetes mellitus among this subgroup of patients.[11,12] The microbial flora isolated differed from those found in patients on invasive mechanical ventilation in intensive care units in whom gram-negative microorganisms (enterobacteria) are more predominant,[13] but in whom *S aureus* may also be found.

Analysis of the possible risk factors shows that adequate cleaning of the ventilation equipment, particularly the mask, decisively affects contamination—Figure 2 shows that colonization and, above all, contamination of ventilators in which cleanliness is considered unacceptable ("dirty") are greater than in ventilators with acceptable cleanliness. The type of ventilator, time on the ventilation program, and, surprisingly, the presence of a humidifier, do not appear to influence contamination. Risk factors for patients on invasive mechanical ventilation include orotracheal tube, decubitus position of the patients, sedation, ventilator use, presence of a nasogastric tube, and treatments such as prophylaxis for peptic ulcer.[14,15] Many of these factors are not present in patients on NIV, but others such as the ventilator, the humidifier, and their circuits are unavoidable. The literature contains several studies that analyze acute use of NIV for respiratory infections in hospitals. These show lower infection rates for patients who undergo acute NIV compared to invasive or conventional ventilation.[7,16-18] We could not find corresponding studies for home NIV, but Sanner et al[8] have published a retrospective study of 206 patients diagnosed with obstructive sleep apnea syndrome treated with CPAP. The authors found that upper respiratory tract infections were more frequent in patients who used CPAP than in control patients (13.6% vs 2.5%) and that use of a humidifier was associated with a greater risk of infection (11.8% vs 22.2%).

In summary, the findings of this study suggest that devices used for NIV at home are a potential source of bacterial contamination (mainly by *S aureus),* but, given the lack of a control population, the results are merely descriptive. Nevertheless, the prevalence of nasal colonization in our study appears similar to prevalences found in patients with other chronic diseases. Despite the descriptive nature of the study, the findings warrant distribution of guidelines for microbiological control in these ventilators, particularly since few recommendations are available for home portable ventilators and CPAP ventilators. In any case, such recommendations should be included in the next guidelines on microbiological control of devices used in pulmonology. In the meantime, it is necessary to impress on both patients and service providers the importance of an adequate cleaning of their ventilators. The study leaves the door open for prospective study of whether contamination and/or colonization are responsible for a higher incidence of respiratory infections in patients on home NIV, particularly by pathogens such as *S aureus* that are not commonly found in the community.

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