

Recommendations for hygiene of masks and circuits in mechanically home ventilated patients

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ABSTRACT

Home mechanical ventilation requires equipment, consisting of a generator of pressure, a tubing and an interface to deliver air to the patient. Instructions for equipment maintenance are generally not based on scientific evidence. Studies however have reported that tubing and masks used at home are the most commonly found as very dirty and contaminated. Dirtiness and contamination of equipment potentially expose patients to a higher risk of airway colonization, which, in turn, should cause respiratory infections. For this reason, published hygiene instructions include the use of disinfectant solution. Nevertheless, they generally fail to explain how basic maintenance may be achieved by simple cleaning with soap and water. The instructions for post-cleaning disinfection will depend upon the relative sensitivity of patients to respiratory tract infections and the related risks for bacterial colonization of the airways. Restrictive and obstructive disease patients are not equally sensitive to infections and, as a consequence, should not require similarly elaborate disinfection level. According with the restrictive or obstructive origin of respiratory insufficiency, the current educational review suggests simple and adequate rules for hygiene of tubing and masks in the home setting. Written instructions on how to clean the equipment for home ventilation are useful and sufficient in restrictive patients. In obstructive patients, cleaning always precedes disinfection. After cleaning, rinsing and drying are important. An effective weekly 20-minute disinfection may be achieved by using an hypochlorite solution of soaking in a concentration of 0.5%.

Keywords: contamination, colonization, disinfection, home mechanical ventilation, hygiene, maintenance, non-invasive ventilation.

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INTRODUCTION

Home mechanical ventilation has become standard of care to effectively treat chronic respiratory failure both in patients with restrictive diseases, such as neuromuscular and thorax cage disorders, and in patients with obstructive diseases, such as selected cases of lung and airways disorders. Depending on the group of patients, home ventilation may improve survival and quality of life in the long-term and may decrease the rate of low respiratory tract infections.¹

Equipment for home mechanical ventilation

Home mechanical ventilation requires equipment, consisting of a generator of pressure (volume or pressure cycled ventilator), a circuit with tubing (with or without expiratory

valve), and an interface to deliver air to the patient. In the majority of patients, a nasal mask is the most appropriate interface for nocturnal use. Full face masks may be used in the rare cases where nasal masks are useless. Finally, mouthpieces are preferentially used in waking patients for daytime non-invasive ventilation. Invasive ventilation via tracheostomy may be required when non-invasive ventilation is no longer possible.

Dirtiness, contamination and colonization at home

Contamination of circuits implies the transient presence of bacteria in the circuits and/or in the airways, while colonization implies the multiplication of germs in the airways of patients that may lead to chronic respiratory infection. In contrast with the hospital setting, transmission of infection by cross contamination is rare

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in the home setting, since patients receiving home mechanical ventilation use their own equipment and have no direct or indirect contact with other patients. In home use, the question is to what extent home ventilation circuits (HVC) must be disinfected. Is dirtiness of HVC a risk factor for HVC contamination and patient's self-colonization? What is the best protocol for cleaning? Is disinfection needed and how often is it recommended? The aim of this review is to answer these questions and to suggest an adequate protocol for maintenance of HVC.

Maintenance is empirically driven

Although home ventilation is widely used around the world, maintenance of HVC is empirically driven. Instructions given before discharging patients home are mostly taken from the recommended guidelines from other areas, such as lung function tests, nebulization techniques or respiratory monitoring. These instructions are generally based upon tradition rather than scientific evidence and vary depending upon countries and centres. Instructions are often too elaborate and not specifically adapted for patients receiving home ventilation. Current instructions often include the use of disinfectant solution, vinegar mixed with water or a quaternary ammonium compound, but generally fail to explain how basic maintenance may be achieved by simple cleaning with soap and hot water or with the dishwasher.

A European survey on maintenance

In a European survey² including more than 20,000 patients receiving home ventilation (2/3 restrictive, 1/3 obstructive patients), only 60% of the participating centres provided written instructions on equipment cleaning and maintenance. There was a significant positive correlation between the size of centres and the proportion of written instructions ($p < 0.001$). On average, only 56% of the centres had protocols for correct cleaning and maintenance of circuits and interfaces. These findings clearly demonstrate that a huge effort is needed to improve the communication to patients regarding adequate rules of maintenance before hospital discharge.

Patients do not clean their equipment

In a recent study, 2/3 of the patients who were taught cleaning instructions prior to discharge did not adequately clean their equipment at home.³ Tubing and masks were most commonly found as "unacceptably" dirty. It was hypothesized that dirtiness of equipment exposes circuits and masks to a higher risk of contamination. Indeed, the dirtiest circuits were found significantly more contaminated than the cleanest ones.^{3,4} Dirtiness and contamination potentially expose patients to a higher risk of airway colonization, which, in turn, should cause respiratory infections. However, this relationship has not yet been demonstrated with evidence.

Sensitivity to infections

Clearly, regular cleaning appears to be the most important instruction that needs to be followed by all patients for HVC maintenance. As previously seen, however, considerable effort to target and institute this basic effective cleaning is necessary. In contrast with cleaning rules, the instructions for post-cleaning disinfection will depend upon the relative sensitivity of patients to respiratory tract infections and the related risks for bacterial colonization of the airways. Two groups of patients need to be considered here: restrictive and obstructive disease patients. Clearly, both groups are not equally sensitive to infections and, as a consequence, should not require similarly elaborate disinfection level.

DISCUSSION

Restrictive disorders

In contrast with patients affected by obstructive respiratory diseases, patients affected by restrictive respiratory diseases or hypoventilation syndrome are *a priori* at low risk for bacterial colonization of airways.

In an uncontrolled study with stable patients receiving written and verbal information on HVC maintenance (recommendation was for daily cleaning with soap and water), a Spanish group questioned patients regarding their cleaning habits.³ They conducted both visual inspection of HVC and sampling of masks (contamination) plus nostrils (colonization) in each patient. As a result, the frequency of cleaning was found as follows: 47% cleaned their HVC once a week, 23% cleaned once a month, 15% cleaned sporadically and 15% never cleaned their equipment. In total, 67% of HVC were deemed as very dirty and a positive relationship between circuit contamination and nostril colonization was highlighted. Bacterial colonization was more important in those patients in which HVC were dirtier. The authors could not conclude whether colonization preceded or followed contamination. However, they suggested that adequate cleaning decisively decreased the rate of contamination. However, these authors did not provide a protocol for adequate maintenance of HVC.

In another study,⁴ visual and bacterial inspection of HVC was assessed before and after cleaning in a first experiment. In a second experiment, the authors randomly compared cleaning either with household dishwasher or low level disinfection with an ammonium-chlorhexidine complex. Their findings were in agreement with the findings of Rodriguez *et al.*³ Prior to cleaning, circuits were found dirty in 69% of the cases. HVC were dirtier in invasive ventilation. There was a significant positive correlation between visual dirtiness level and bacteriologic contamination of HVC ($r = 0.56$; $p < 0.001$). Bacteriologic contamination reached 22% of non-invasive HVC with little presence of fungi. Nevertheless, by contrast with invasive HVC, contamination of non-inva-

sive HVC did not include potentially pathogenic organisms (PPO), such as *Serratia marcescens*, methicillin-resistant *Staphylococcus aureus* (MRSA), or *Pseudomonas aeruginosa*. In invasive HVC, contamination affected 81% of HVC, including important presence of fungi; 19% of HVC were PPO, including *Serratia marcescens* in 2 cases, and MRSA in 1 case, but there were no *Pseudomonas aeruginosa* contaminated HVC in this group. In the second experiment of this study, cleaning in the dishwasher was shown to be superior to the chemical compounds for both cleaning and disinfecting home ventilation circuits. In addition, Gram-negative bacteria and fungi survived in the chemical complex, but not in the dishwasher.

According to the findings of Ebner *et al.*,⁵ we suggest using either a dishwasher at 65 °C or basic soap and hot water as the best means of cleaning HVC used by restrictive patients (Figure 1). Nevertheless, a disinfective agent may be recommended (1) in very dirty HVC; (2) in circuits from invasive ventilation; and (3) in HVC from patients known for their high susceptibility to respiratory infections, such as

obstructive patients. Effective cleaning must always precede any disinfection. It is important to be sure that a thermostable HVC is used before cleaning or disinfecting at temperatures > 60 °C. Effective disinfection is described below.

Obstructive disorders

The situation regarding hygiene of non-invasive ventilation device is slightly different in obstructive respiratory diseases, such as cystic fibrosis (CF) and chronic obstructive pulmonary disease (COPD), as compared to restrictive respiratory diseases. The major reason for this difference consists in a higher susceptibility to bacterial colonization of the airways in these patient populations. The airway colonization rate often correlates with the severity and/or the speed of obstructive disease progression. In addition, there is evidence that the need for non-invasive ventilation becomes more frequent after airway colonization in these patients.

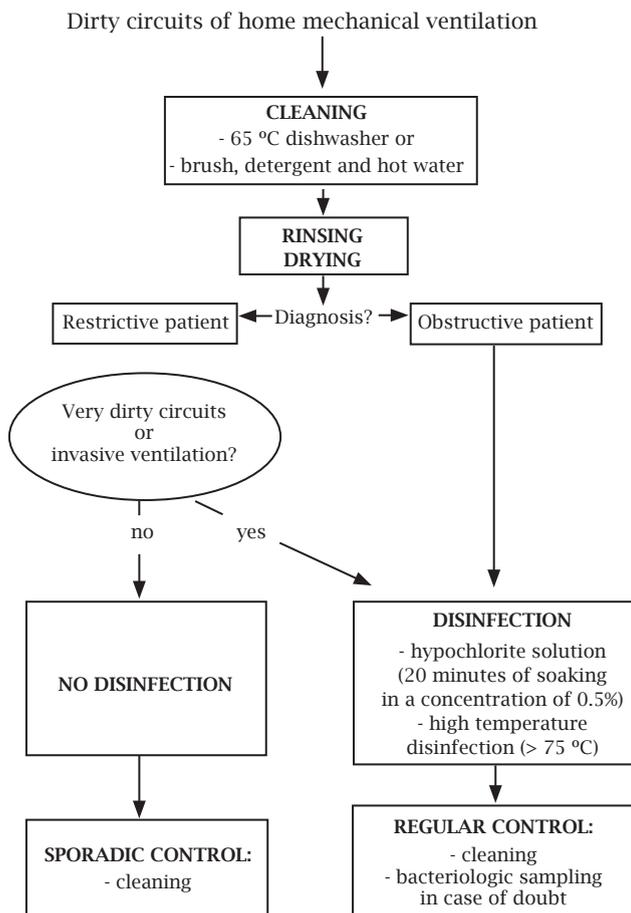
Ventilator associated pneumonia is well documented. In intensive care units, the use of mechanical ventilation is an important risk factor for the development of nosocomial pneumonia. Moreover, current risk is greater with the use of invasive mechanical ventilation as compared with non-invasive ventilation.⁶⁻⁹ Unfortunately, the relationship between the use of non-invasive ventilation and an increased risk for nosocomial pneumonia is not demonstrated.

The greater number of manipulations and the presence of an endotracheal tube associated with invasive ventilation contribute to HVC contamination. It can be hypothesized that manipulations related to non-invasive ventilation also represent a potential risk for contamination. This implies a rigorous implementation of classical non-specific rules of hygiene, including hand washing. Nevertheless, the ventilator, the circuit, and the interface do not represent major risk factors for contamination and colonization, but monitoring potential bacterial contamination of devices and paying attention to the basic rules of hygiene probably remain important challenges.

There is little published research to support the relationship between hygiene and non-invasive ventilation devices in obstructive diseases. Nevertheless, one can extrapolate findings from therapies such as respiratory physiotherapy devices into obstructive patients receiving long-term non-invasive ventilation. Indeed, the material involved in non-invasive ventilation is part of the semi-critical devices that are in contact with mucous membranes, as defined by the Centers for Disease Control and Prevention. Fortunately, recommendations on hygiene of these devices are available.

In patients affected by CF and COPD, nebulizers are considered potential vectors of bacterial colonization of airways. Notably, studies showed that nebulizers of CF patients are frequently contaminated.¹⁰⁻¹³ Similarly, it was suggested that nebulizers can lead to nosocomial disease

Figure 1: Dirty circuits of home mechanical ventilation. Protocol of maintenance of circuits and interfaces for home mechanical ventilation.



in COPD patients.¹⁴ Bacterial contamination of HVC is related to the duration of its use and the airway colonization of the patient.

Based on these evidences, several recommendations were proposed and could be applied to circuit pieces involved in non-invasive ventilation in obstructive diseases. As shown in figure 1, regular cleaning of HVC and masks is mandatory, at least as a basic hygiene procedure, and, more specifically, to eliminate the biofilm deposited on the surfaces which further decreases the efficacy of disinfectants.¹⁵ The necessary frequency of cleaning is still being debated. Based on the results of studies on nebulizers,^{13,16} daily cleaning could theoretically be the recommended timing. However, less regular cleaning, for instance, once a week, could be acceptable in the practice. The possibility of using tap water for cleaning must be taken in account whether HVC are contaminated by *Serratia marcescens*¹⁴ and *Stenotrophomonas maltophilia*.¹⁷

When considering disinfection, different methods may be proposed. The choice of the optimal method largely depends on the material chosen to disinfect. A thermal disinfection (i.e. sterilizer, boiling water) may be not suitable for some non thermo-stable pieces of HVC, even though its efficacy is evident for all germs. There are a number of chemical methods and each one has its own characteristics. The duration of soaking and the concentration of the chemical will depend on the particular substance used and the guidelines for each must be followed carefully. Acetic acid is not recommended due to its lack of efficacy on Gram-positive and Gram-negative bacteria.¹⁸⁻²⁰ In contrast with acetic acid, hypochlorite solution (20 minutes of soaking in a concentration of 0.5%) may be the best alternative of those readily available chemical solutions.

After disinfection, rinsing and drying is the last part of the cleaning and disinfection sequence. Drying seems important as a higher contamination rate was related to non-dried nebulizers in CF patients.¹⁰ Because there is a paucity of specific data related to non-invasive ventilation, precise recommendations cannot be made. However, it could justify more studies on this topic. Finally, it appears critically important to investigate the relative effectiveness of the different established protocols for HVC cleaning and disinfecting in order to maintain their integrity.

CONCLUSION

Instructions for home mechanical ventilation equipment hygiene are not evidence-based. However, several major recommendations of maintenance can be suggested according to the severity of patient groups to respiratory infections. Cleaning ventilator, circuits and interfaces is required 2-4 times per month in all patients receiving mechanical ventilation at home. Written instructions on how to clean the equipment for home ventilation are useful. Regular assessment of whether or not circuits and interfaces are correctly

cleaned and maintained is mandatory. In restrictive patients, cleaning in the dishwasher is effective and sufficient for thermo-stable circuits and interfaces. Cleaning with soap and hot water may be sufficient for all pieces. Disinfection is not mandatory. In obstructive patients, cleaning must be more frequent than for restrictive patients. Cleaning always precedes disinfection. After cleaning, rinsing and drying are important. An effective weekly disinfection may be achieved by using a hypochlorite solution (20 minutes of soaking in a concentration of 0.5%). The expiratory valve must be washed specifically, with care, so that the balloon is not laid underwater.

Abbreviations

- CF – Cystic Fibrosis
- COPD – Chronic Obstructive Pulmonary Disease
- HVC – Home Ventilation Circuits
- MRSA – Methicillin Resistant *Staphylococcus aureus*
- PPO – Potentially Pathogenic Organism

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