RECOMMENDATIONS FOR PREVENTION AND CONTROL OF INFECTION IN NON-INVASIVE VENTILATION IN HOSPITAL ENVIRONMENT

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Abstract: There are numerous studies and recommendations on the complications associated with invasive mechanical ventilation, but few on prevention and control of infection in non-invasive ventilation (NIV), especially at the hospital environment. Healthcare workers (HCW) should be alert to the potential risk of transmission of infection in NIV. The main goal of this manuscript is to establish and promote good practices in the prevention and control of infections associated with NIV, as well as the development of a document that can serve as a guideline for HCW. A review of the literature on cleaning and disinfection of devices in NIV was carried out between February 2019 and August 2020 and the technical specifications of NIV devices, published by the manufacturers, were also analyzed. NIV devices require a high level of disinfection using chemical disinfectants. It is necessary to clean

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and disinfect the surface of the ventilator daily, while the rest of the components should be cleaned and disinfected with a weekly frequency. It should avoid active humidification when possible, favoring passive humidification. Using a bacteriological filter is extremely important in a hospital environment and should be considered. In patients with COVID-19, it is also recommended to use non-ventilated interfaces and 2 filters, one bacteriological at the outlet of the ventilator and another preferably Heat and Moisture Exchanging Filter (HMEF) in the interface. The cleaning and disinfection instructions for NIV are based on recommendations for decontamination of semi-critical material and basic infection control precautions. This document provides an orientation guide of the main procedures to be implemented in the prevention and control of infection in NIV that must be adapted to each hospital.

Keywords: contamination; disinfection; infection; non-invasive ventilation (NIV), prevention; antibacterial filter

Introduction

Non-invasive ventilation (NIV) is a therapy that consists in the application of a ventilatory support without using invasive airway methods. It is used for the treatment of acute and chronic respiratory failure caused by airway and lung pathologies, thoracic abnormalities, and neuromuscular diseases. The objectives of NIV are to increase pulmonary ventilation, decrease respiratory work, and improve airborne gas exchange (Ferreira et al, 2009).

The use of this therapy has increased in recent years, as it provides a better quality of life, an increase in survival, and a reduction in healthcare costs, by reducing the number and days of hospitalization. The infections associated with health care are a major current concern. According to the World Health Organization (WHO), every year, hundreds of millions of patients around the world are affected by infections associated with health care (WHO, 2019). Measures to reduce these infections include the

promotion and optimization of infection control measures. The equipment needed for NIV is considered semi-critical because of contact with mucous membranes and can become contaminated with organic fluids and infectious agents, so it can be a source of infection if it is improperly decontaminated (Rutal et al, 2019). There are numerous studies and recommendations on the complications associated with invasive mechanical ventilation, but few on the prevention and control of infection in non-invasive ventilation, especially in the hospital environment.

The final purpose of this manuscript is to promote good practices in the prevention and control of infections associated with NIV, as well as the development of a document to serve as a guideline.

Materials and Methods

A review of the literature on cleaning and disinfection of devices in NIV was carried out by conducting a literature search between February 2019 and August 2020, using the descriptors: contamination, disinfection, non-invasive ventilation, antibacterial filter, and their association, in EBSCOhost, PubMed, and UpToDate.

Only those documents that informed about infection control in non-invasive ventilation and semi-critical equipment over the last 15 years were selected. The technical specifications of the main manufacturers of devices used in NIV were also analyzed.

The manuscript includes a brief review of the literature, as well as an original response to the current need for a recommendation on cleaning and disinfection procedures in NIV devices in a hospital environment, to encourage the formation and standardization of disinfection procedures of NIV.

Results and Discussion

Review of the literature

The prevalence of bacterial contamination of ventilators used in NIV and the microorganisms involved, reveal that NIV devices may represent a potential source of nasal colonization. The kind of cleanliness of the devices seems to influence the contamination, so it is necessary to institute adequate maintenance and cleaning of these equipment (Rodriguez González-Moro et al, 2004). Healthcare workers should be alert to the potential risk of transmission of infection in NIV. Appropriate disinfection between patients is recommended when reusable equipment is used, in addition, the use of the antibacterial filter and external cleaning of the ventilator is especially important (Singh et al, 2008).

Adequate cleaning and disinfection are very important at home and even more in the hospital environment (Toussaintet al, 2010). The ventilator can constitute a vector of hospital-acquired infection transmission, this fact has already been evidenced in Portugal, the crossbars of the correspondence of Klebsiella pneumoniae strains isolated in a ventilator and those isolated in patients with nosocomial infection in the same hospital department (Narcisoet al, 2011). Non-invasive ventilation is a therapy increasingly used in the hospital environment. One in 10 patients suffer an infection while receiving health care, recommendations to reduce and avoid this type of complication include proper hand hygiene of the healthcare workers, monitoring of acquired infections, and above all the existence of appropriate plans for cleaning and disinfecting the environment and medical devices (European Centre for Disease Prevention and Control, 2013)

The hospital environment is a place propitious for the generation and diffusion of infections. The pathogenic microorganisms proliferate and cause severe alterations or even death in patients admitted to health institutions. The infections associated with healthcare, cause an increase in length of stay in hospital, disability, and an increase the resistance to antimicrobials, which entails a huge cost for patients to their families, and of course for the health systems of the countries (WHO, 2019). The lung is the most vulnerable organ to infections and injuries due to the constant exposure to the external environment (Forum of International Respiratory Societies, 2017), so respiratory devices are a key point for combating infections, especially nosocomial pneumonia.

Activities to prevent infection are always a challenge and resources are insufficient. The heterogenicity of the various institutions makes it difficult (Rodriguez-Bañoet al, 2015). The risk of nosocomial infection, especially nosocomial pneumonia in patients with NIV is remarkably high so it is especially important to develop guidelines for good practices and thus minimize this risk. Infection control should be a priority of the institutions, but in the current reality, we know that it faces several challenges among which we can highlight the structural problems of the institutions to be able to properly develop these practices, the lack of training programs for healthcare workers as well as the lack of written documents to support these practices (Rodriguez-Bañoet al, 2015). NIV devices are in contact with mucous membranes and sometimes nonintact skin, so they are considered semi-critical. These medical devices should be free from all microorganisms however small numbers of bacteria are permissible. Semi-critical items contact mucous membranes or nonintact skin, so they require high-level disinfection using chemical disinfectants. When a certain chemical disinfectant is selected, chemical compatibility should be checked for long-term use (European Centre for Disease Prevention and Control, 2013).

Recommendations for Prevention and Control of Infection in Non-invasive Ventilation in hospital environment

Cleaning is the removal of foreign material from objects. It is usually done using water with detergents or enzymatic products. Complete cleaning is necessary because if the devices are dirty, the disinfection process becomes more difficult and is less effective or ineffective.

Disinfection traditionally is defined as the complete elimination of all microorganisms in or on an instrument, except for small numbers of bacterial spores. Cleaning followed by disinfection should eliminate enough pathogens to prevent transmission of infection (European Centre for Disease Prevention and Control, 2013). Disinfectants are used alone or in combinations. Commercial formulations based on chemicals must be registered and authorized by the government authorities of each country.

Products are designed for a certain purpose and to be used in a certain way. Healthcare workers should read labels carefully to ensure that the product is selected for the intended use and is used efficiently (Rutala et al, 2019).

There are several devices necessary in NIV that need to be cleaned and decontaminated. The cleaning frequency is summarized in Table 1.

Table 1. Recommendations for frequency of cleaning and disinfection device on a single patient.

Device	**Frequency of cleaning and disinfection**
Ventilator	Daily
Interface	Daily
Harness	Weekly
Expiratory valve	Weekly
Oxygen adjuvant connector	Weekly
Circuit	Weekly
Bacteriological Filter	Change: 24 hours of use
Passive humidification: HMEF	Change: 24 hours of use
Active humidification (Preferably not use in hospital)	Daily
As main option used enzymatic detergent, alternatively use disinfectant detergent	

The recommendations for each device are detailed below:

• Ventilator: must be kept on a flat and stable surface, away from sources of heat and humidity. Clean the external parts with disinfectant detergent (spray or wipe) before use by a new patient and daily when used on single patient.

• Filters: there are several filters for clinical use. The filters filter through a matrix of fibers and by two mechanisms, one by depth and the other mechanism is through the bipolar charge that the attracts the particles. In addition, they are hydrophobic to prevent contamination by liquid secretions

(Jarillo Quijada et al, 2015) .

Air filters: They filter the atmospheric air that the ventilator will introduce into the patient by means of positive pressure. It is recommended to check the ventilator air filter every 2 weeks and to put a new one according to the manufacturer's instructions.

Bacteriological filter: The hospital environment is at high risk of contamination, and it is recommended to always use it in a hospital environment. It should be changed according to the manufacturer's instructions (usually 24 hours of use). It is single-use (Sociedade Portuguesa de Pneumologia, 2020).

The Heat Moisture Exchanger Filter (HMEF) is a bacteriological filter with performs bacteriological functions and regulates humidity and temperature too. This filter has the advantage of performing both functions, but it must be kept in mind that this device presents greater resistance than the bacteriological one. It must be changed according to the manufacturer's indications and in case of condensation or excess of humidity. Generally, it is 24 hours of use. It is single use.

Table 2 shows some types of filters on the market (Draegeret al, 2020].

Table 2. Filtering and humidification characteristics of some filters on the market.

Check the manufacturer's instructions		Filter capacity	Filtration efficiency	Passive Humidification	Resistance 30-60ml (mm H2O)	Minimum volume tidal (ml)	Maximum effectiveness time
Filters	 *Intersurgical®*	Yes	Medium	No	0,9-1,9	>200	
	 *Sterile Intersurgical®*	Yes	Medium	No	0,8-2	>150	
	 *Intersurgical®*	Yes	High	No	1-2.3	>200	

	 *(Deadspace 90ml) Dragger ®*	Yes	High	No	1,4-3,2	>300	24 hours
	 *(Deadspace 55 ml) Dragger ®*	Yes	Medium	No	1,3-2,9	>300	
HME (Heat moisture exchanger)	 *Intersurgical ®*	No		Yes	0,2-0,8	>200	
		No		Yes	0,4-1	>300	
	 *Dragger ®*						
	 *Sterile DAR™ Medtronic*	Yes	High	Yes	1-2,8	>150	
	 *Intersurgical ®*	Yes	High	Yes	1,1-2,5	>200	
HMEF (Heat moisture exchanger filter)	 *Intersurgical ®*	Yes	Medium	Yes	0,8-2,1	>200	
	 *Sterile Intersurgical ®*	Yes	High	Yes	1,6-2,7	>180	

 *(Dead space 90ml) Dragger ®*	Yes	High	Yes	1-2,2	>300
 *(Dead space 55ml) Dragger ®*	Yes	Medium	Yes	0,9-9	>300

The filters used in non-invasive ventilation must combine the high filtration efficiency with the lowest possible resistance to the required current volume. The hospital environment is contaminated so the recommended filters for hospital use must always be of high filtration efficiency. In intensive care units where we find critical and chronic patients in the acute phase, it´s preferable to use a sterile filter before invasive ventilation but it´s not necessary for non-invasive ventilation.

• Circuit: They are single use but should be washed weekly with enzymatic detergent ideally, but in the absence, use as an option disinfectant detergent, rinse with water, and dry before use. Due to the difficulty of processing this device, consider within each hospital institution if there are favorable conditions for this decontamination. Maybe evaluate the cost-benefit of this device and change to a new one each week.

• Oxygen adjuvant connector: Wash weekly with enzymatic detergent ideally, but in the absence of this, use as an option disinfectant detergent, rinse with water, and dry before use. Check if it is reusable for use between patients and follow the manufacturer's reprocessing instructions.

• Expiratory valve: When used on the same patient, wash weekly with enzymatic detergent as the first option, and in the absence use disinfectant detergent, rinse with water, and dry before use. Discard before a new patient.

• Interface: Many patients in NIV have coughs and abundant secretions, so it should be washed

daily with enzymatic detergent or disinfectant, rinsed with water, and dried before use. Check if it is reusable, in this situation, it should be reprocessed following the manufacturer's instructions, preferably in the Sterilization Department.

• Harness: When used by the same patient, wash weekly with disinfectant detergent and rinse with water. Perform this procedure again when used by a new patient.

• Humidification: It can be done in 2 ways:

Passive: with a humidifying filter, which should be changed according to the manufacturer's instructions (usually 24 hours of use) or in case of condensation or excess humidity. Its use should be considered in patients with an intentionally leaked mask, as the patient does not exhale sufficient tidal volume to replenish the heat and humidity to adequately condition the inspired gas and may increase respiratory effort by increasing dead space and resistance (Torres et al, 2017).

Active: Active humidification is sometimes suggested for NIV as it may improve adherence and comfort. Wash daily with enzymatic detergent or disinfectant, rinse with water, and place distilled water up to the indicated level. With this humidification and intentional leaks, aerosolized contaminated condensate may increase the risk for infection, so you should consider that use in a hospital environment (Zunyou et al, 2019) and avoid COVID-19 or suspected patients.

The use of the enzymatic detergent is preferable for the higher bactericidal spectrum, but the manufacturer's instructions must be properly applied, in its absence the disinfectant detergent can be used. Disinfecting detergents are a concentrated mixture of biocidal surfactants, surfactants, alkaline additives, and sequestration agents that effectively remove dirtiness with disinfecting properties against a variety of vegetative forms of micro-organisms. Enzyme cleaning protects devices composed of PH-sensitive materials and is therefore more suitable for medical devices. Enzymes are natural, biodegradable substances that optimize detergent formulas that make cleaning processes faster and more effective and make them have a higher bactericidal and viricidal spectrum (European Parliament and of

the Council of the European Union., 2012).

Currently, facing the pandemic that is suffering from the SARS-CoV-2 virus, the concern of cross-contamination also arose for the need for oxygen therapy and ventilation in the COVID-19 disease, which constitutes a high risk of contagion for healthcare workers due to aerosolization of droplets. The implementation of infection control measures to minimize aerosol production, as well as the correct use of individual protection equipment, is extremely important to provide safe and quality health care (Zunyou et al, 2019).

In this situation, the recommendation is NIV should be, preferably in rooms with negative pressure due to the risk of aerosolization. Preferably use single circuits with passive exhalatory valves, because the double or single with active valves have no benefits for these patients. Use circuits that minimize the aerosolization with two filters, a bacteriological one in the ventilator, and an HMEF in the interface, which should be oronasal or full face, like shown de Figure 1.

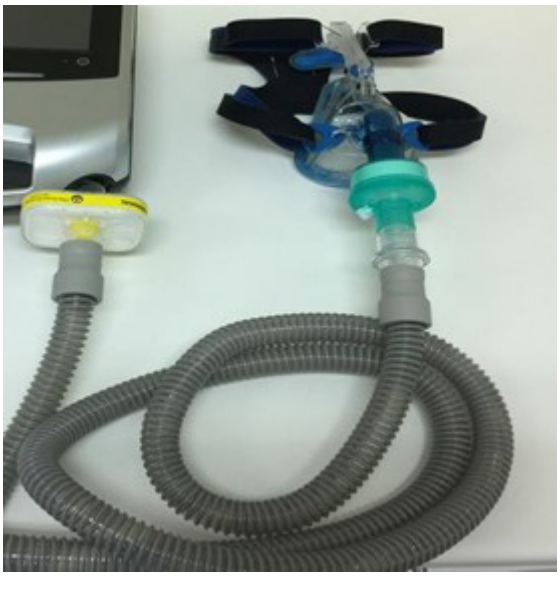

Figure 1. NIV is recommended for COVID-19 or suspected patients. It is recommended to place a bacteriological filter at the outlet of the ventilator, after the circuit, then the exhalatory valve, and immediately another filter (preferably HMEF type to improve comfort). Finally, the interface that is recommended

is not ventilated.

The use of a nasal mask is not recommended (Sociedade Portuguesa de Pneumologia, 2020). The recommended mask is non-ventilated, when this possibility does not exist, as an alternative, use ventilated masks and occlude the holes with adhesive. (National Health Service, 2020). It is not recommended to use active humidification with an external humidifier, due to the high risk of aerosolization as referred to above (Sociedade Portuguesa de Pneumologia, 2020). Switch off the equipment before removing the interface in order to minimize droplet dispersion. Whenever possible, there should be a minimum distance of 2 meters between other patients.

The lack of studies on prevention and infection control in NIV in the hospital environment was a limitation to the development of this paper and highlighted the lack of scientific evidence in this area of research, but also revealed the need for guidelines for the prevention and control of infections in NIV, so it is necessary to write the recommendations referred in this article, as well as the development of further research in this area and encourage the training of healthcare workers in this techniques.

The recommendations are based on instructions for the decontamination of semi-critical material, basic infection control precautions, and manufacturer's specifications. These recommendations are especially important to avoid cross-infection among healthcare workers and among patients. It is necessary to create procedures to standardize the decontamination of the devices used in NIV in the hospital environment. This information should be known by all professionals involved in this therapy. Training in this area is very important and the existence of written recommendations too.

The recent pandemic situation with the SARS-CoV-2 virus highlights the need for strict cleaning interventions and disinfection of equipment. These interventions should be universal regardless of the pathology of the patient or reason for admission to the hospital because the risk of nosocomial infection is always present. The standardization of cleaning and disinfection processes in NIV will allow for the reduction of the load of potentially pathogenic microorganisms in the hospital environment and thus

optimize the resources of the institutions. It can also contribute to strengthening multidisciplinary staff since there are different healthcare workers involved in the care of these patients. This will contribute to the efficiency of healthcare, namely due to increased quality of care and patient safety in the provision of healthcare services.

Conclusions

In conclusion, this manuscript provides a guideline on the main procedures to be implemented in the prevention and control of infection in NIV that must be adapted to each hospital.

Conflicts of Interest: The authors declare no conflict of interest.

References

Ferreira, S., Nogueira, C., Conde, S., & Taveira, N. Ventilação Não Invasiva. Rev Port Pneum 2009, Vol 15(4), 655-667.

World Health Organization. Prevencion de las Infecciones Nosocomiales. Guia Practica. Aviable online: https://www.who.int/csr/resources/publications/ES_WHO_CDS_CSR_EPH_2002_12.pdf (accessed on 1 march 2019).

Rutala, W. A., Weber, D. J., & Committee, H. C. Guideline for Disinfection and Sterilization in Healthcare Facilities. Avaliable online: www.cdc.gov/infectioncontrol/guidelines/disinfection/ (accessed on 1 may 2019).

Rodriguez González-Moro, J. M., Andrade Vivero, G., Miguel Díez, j., López Martín, S., Sánchez, C., Izquierdo Alonso, J. L., & Lucas Ramosa, P. Bacterial Colonization and Home Mechanical Venti-

lation: Prevalence and Risk Factors. Arch de Bronconeumol 2004, Vol 40(9), 392-396. Doi:10.1016/S1579-2129(06)60341-8.

Singh, P., & Sterk, P. J. Non Invasive Ventilation and the Potencial Risk of Transmission of Infection. Eur Respir J 2008, Vol 32, 816. Doi:10.1183/09031936.00052208.

Toussaint, M., & Gregory, R. Recomendations for Hygiene of Masks and Circuits in Mechanically Home Ventilated Patients. Braz J of Infect Dis, 2010, vol 14(4), pag 380-384. Doi:10.1590/S1413-86702010000400013

Farre, R., Lloyd-Owen, S. J., N, A., Donaldson, G., Escarrabill, B., Faurouxl, D and Wedzicha, J. A. Quality Control of Equipment in Home Mechanical Ventilation: a European Survey. Eur Resir J, 2005, vol 26, 86-94. Doi:10.1183/09031936.05.00066904

Narciso, A., Gonçalves, L., Costa, A., Godinho, A., Fernandes, F., & Duarte, A. Ventilator touchscreen as source of ESBL-producing Klebsiella pneumoniae outbreak. International Conference on Prevention & Infection Control. Geneva – Switzerland, 2011. Avaliable online: http://www.biomedcentral.com/1753-6561/5/S6/O78 (accessed in 2 May 2019)

European Centre for Disease Prevention and Control. Core Competencies for Infection Control and Hospital Hygiene Professionals in the European Union. March 2013. Doi 10.2900/7778. Avaliable online: https://www.ecdc.europa.eu/en/publications-data/core-competencies-infection-control-and-hospital-hygiene-professionals-european (accessed on 20 April 2019).

Forum of International Respiratory Societies. The Global Impact of Respiratory Disease – Second Edition. Sheffield, European Respiratory Society, 2017, pp 13-33.

Rodriguez-Baño, J., Del Toro, M. D., J, L.-M., Mutters, N. T., & Pascual, A. (2015). Minimum Requirements in Infection Control. Clin Microbiol Infect, 2005, Vol 21, 1072-1076. http://dx.doi.or-

g/10.1016/j.cmi.2015.08.025

Minimum requirements for infection prevention and control. Geneva: World Health Organization; 2019. Licence: CC BY-NC-SA 3.0 IGO. Avaliable online: https://apps.who.int/iris/bitstream/handle/10665/330080/9789241516945-eng.pdf / (accessed on 15 May 2019).

European Parliament and of the Council of the European Union. Biocidal Products Regulation. O J European Union, 2012, L 167/1-167/121, 528.

Jarillo Quijada, A. Humidificación y Filtrado de la Via Aerea Artificiall; V. L. Guzman, Ed; Mexico, 2015. Avaliable online: http://himfg.com.mx/descargas/documentos/planeacion/guiasclinicasHIM/Humidiffiltrado_vaartificial.pdf (accessed on 12 April 2019).

National Health Service .Guidance for the role and use of non-invasive respiratory support in adult patients with COVID19 (confirmed or suspected). NHS England and NHS Improvement(001559). England, 2020. Avaliable online: https://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/03/specialty-guide-NIV-respiratory-support-and-coronavirus-v3.pdf (accessed on 2 June 2020).

Harari S. A.; Vitacca M.; Blasi F.; Centanni S.; Santus P. A.; Tarsia P. Managing the respiratory care of patients with COVID-19: Italian recommendations, March 2020. Avaliable online: http://www.aiponet.it/ (accessed on 15 June 2020).

European Center for Disease Prevention and Control. (March 2020). Disinfection of environments in healthcare and nonhealthcare settings potentially contaminated with SARS-CoV-2., March 2020. Avaliable online: https://www.ecdc.europa.eu/en/publications-data/disinfection-environments-covid-19 (accessed on 7 May 2020).

Sociedade Portuguesa de Pneumologia. Terapias Respiratórias Não Invasivas em Contexto de Doente

Agudo/Cronico agudizado na Covid-19-Algumas Notas Practicas no Adulto, 2020. Avaliable online: https://www.sppneumologia.pt/uploads/subcanais2_conteudos_ficheiros/terapias_spp.pdf (accessed on 9 May 2020).

Intersurgical, Product Catalogue. Avaliable online: https://www.intersurgical.com/ (Accessed on 14 June 2020).

Medtronic, Specifications of manufacter: Avaliable online: https://www.medtronic.com/covidien/en--us/products/mechanical-ventilation/filters/dar-filters.html (Accessed online 10 June 2020).

Draeger, Accessory Catalogue. Avaliable online: https://www.draeger.com/Library/Content/accessory-ca-9066485-en-1811-11.pdf (Accessed on 12 June 2020).

Torres, A., Niederman, M. S., & Chastre, J. International ERS/ESICM/ESCMID/ALAT guidelines for the management of hospital-acquired pneumonia and ventilator-associated pneumonia: Guidelines for the management of hospital-acquired pneumonia (HAP)/ventilator-associated pneumonia (VAP) of the European. Eur Respir J, 2017, Vol 50(3). Doi:10.1183/13993003.00582-2017

Ergan, B., Oczkowski, S., Rochwerg, B., Carlucci, A., Chatwin, M., Clint, E and Windisch, W. European Respiratory Society Guideline on Long-tern Home Non-invasive Ventilation for Management of Chronic Obstructive Pulmonary Disease. Eur Respir J, 2019, Vol 54(3). Doi:10.1183/13993003.01003-2019

Zunyou Wu, M. D., & McGoogam, J. M. Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China. JAMA, 2020, Vol 323(13), 1229-1242. doi:10.1001/jama.2020.2648