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Changing a hydrophobic heat and moisture exchanger after 48 hours rather than 24 hours: a clinical and microbiological evaluation

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Abstract *Objective:* Complications following ventilation with dry and cold gases may be prevented by the use of artificial noses or heat and moisture exchangers, which are a solution to both the problems of humidification and heat preservation. The aim of the present study was to determine whether changing hydrophobic heat and moisture exchangers (HMEs) every 48 h rather than 24 h would affect their efficacy to preserve the heat and moisture of inspiratory gases. The impact of a prolonged use of the HME on its microbial colonization was also assessed.
Design: Prospective observational study.
Setting: ICU of a university hospital.
Patients: Twelve patients requiring controlled mechanical ventilation for more than 2 days were evaluated.
Interventions: The patients were ventilated with a heat and moisture exchanger (HME) (Maxipleat Filter, Europe Medical, France). The hydrophobic HME was placed between the Y-piece and the connecting tube and changed after 48 h of continuous use. Temperature (°C), relative humidity (%) and absolute humidity (mgH_2O/l) were obtained using the capacitive sensor principle. Bacterial colonization (tracheal secretions and ventilator side of the HME) were obtained on days 1 and 2.
Measurements and results: After 48 h of ventilation with the same HME, tracheal tube occlusion was never observed. Using the same hydrophobic HME for 48 h rather than 24 h did not affect its technical performance : temperature at 24 h: 32.5 ± 1.3 °C, at 48 h: 32.7 ± 1.8 °C; relative humidity(RH) at 24 h: 99.0 ± 1.4 %, at 48 h: 99.0 ± 1.4 %; absolute humidity(AH) at 24 h: 34.0 ± 2.4 mgH_2O/l, at 48 h: 34.4 ± 3.5 mgH_2O/l. Peak and mean airway pressures did not change over the 48-h study period, with identical tidal and minute volumes in the study patients. Total respiratory heat losses were not modified during the 48-h study period (at 24 h: 152 ± 47 cal/min, at 48 h: 149 ± 65 cal/min). Evaporative and convective heat losses were not modified either. On day 1, eight patients had positive cultures of their tracheal secretions at a colony count of 10^3 or higher cfu/ml. After 48 h of use of the same HME, only six patients had a positive culture of their tracheal secretions. Cultures from the ventilator sides of the HMEs were all sterile (12/12) after 48 h of use.
Conclusions: Changing the hydrophobic HME after 48 h rather than 24 h did not affect its technical performance in terms of heat and water preservation of ventilatory gases. There is also some indirect evidence of very little, if any, change in HME

resistance. No bacterial colonization of the ventilator sides of the HMEs was observed after 48 h of use. However, other large clinical trials should be undertaken to confirm the safety of extending the time between HME changes.

Key words Heat and moisture exchanger · Humidification of inspired gases · Mechanical ventilation · Tracheal intubation

Introduction

It is well recognized that delivering warm, humidified gas to patients ventilated through an endotracheal or tracheostomy tube is of primary importance [1, 2, 3, 4, 5, 6, 7]. The upper airway and the normal heat and moisture exchanging process of inspired gases is bypassed during mechanical ventilation with endotracheal intubation or tracheostomy. A continuous loss of moisture and heat occurs and predisposes patients to serious airway damage [1, 2, 3, 4, 5, 6, 7]. In addition, medical gases are dried to avoid condensation damage to valves and regulators in the distribution network. To prevent complications associated with ventilation with cold and dry gases, the addition of exogenous heat and humidity through the use of heated hot water systems (vaporizers or nebulizers) can be considered. Vaporizing humidifiers have some disadvantages: condensation of water that may be a source of infection, malfunctions, high maintenance cost and increased workload for nursing staff [8]. Heat and moisture exchangers (HMEs) with microbial filtration capacity (HME filters, HMEFs) might be a simple solution to the problems of conditioning respiratory gases and, possibly, of reducing the contamination of apparatus and subsequent bacterial pneumonia [9, 10, 11, 12, 13, 14, 15, 16, 17, 18].

An important advance in the design of HMEs was made with the introduction of plastic foam impregnated with a hygroscopic substance as the active element [12, 15, 19]. The hygroscopic substance chemically absorbs a portion of the expired water vapor on the humidifier element that is collected by dry inspiratory gases. Paper-based condensation surfaces have also become available and their efficiency is reinforced after impregnation with a hygroscopic substance [13, 20, 21]. The HMEs preserve patients' heat and water and globally they recover 70 % of expired heat and humidity. HMEs can safely be used for long-term mechanical ventilation and must be changed every 24 h, as recommended by the manufacturers' instructions. Whether prolonging HME use for more than 1 day is safe and effective remains poorly documented. In one study, the incidence of tracheal tube occlusion was not increased after changing hygroscopic HMEs after 2 days of use [22]. We, therefore, prospectively assessed whether changing hydrophobic HMEs every 48 h would affect their efficacy by evaluating the technical performance and the microbial colonization of the HMEs after use for such a prolonged period of time.

Materials and methods

Twelve consecutive patients were included at the time of entry to the intensive care unit (ICU), in a prospective, cohort study. With institutional approval and informed consent obtained from the closest relative, we studied tracheally intubated mechanically ventilated patients sedated with sufentanil (0.3μg/kg per h) and midazolam (0.06 mg/kg per h). In a given patient we planned to replace the HME after 48 h of continuous use, unless a serious clinical event occurred (endotracheal tube occlusion, HME obstruction). The hydrophobic HME tested in the present study was the Maxipleat Filter (Europe Medical, France). The HME was placed between the Y-piece and the connecting tube and positioned above the patient's head, to avoid mucus deposits on the filter membranes. To be included in the study, the patients had to require controlled mechanical ventilation for 2 days or more. Patients were not included in the study if they were hypothermic (body temperature <35 °C) or had a bronchopleural fistula.

The ventilative circuit consisted of inspiratory and expiratory lines connected by a Y-piece. The ventilator used was a Purittan Bennett 7 200. Respiratory rates, tidal volumes, FIO_2 and PEEP were adjusted to maintain PaO_2 at 10.5 kPa (80 mmHg) and $PaCO_2$ at 5.5 kPa (40 mmHg), and were not modified during the study period. Temperature, relative humidity (RH) (%) and absolute humidity (AH) (mgH_20/l) were obtained using the Gibeck Humidity Sensor System [23]. RH is the ratio of the AH to the saturated humidity at a given temperature ; saturated humidity is related to the maximum vapor capacity, whereas AH is the actual amount of water contained in a given volume of gas at a given temperature and pressure. The system consists of an extremely fast reacting humidity sensor and a fast reacting temperature sensor, both integrated in an angled connector (15 M-15 F ISO Gibeck, Sweden) placed in the breathing circuit between the tracheostomy tube and the heat and moisture exchanger or the T-tube. The method used by the Humidity Sensor System is based on the capacitive sensor principle [23]. A very thin layer of hygroscopic polymer compound is placed in between two conductive layers to make up a condensator. This condensator is placed in an oscillator system, the frequency of which is a function of the condensator capacity.

The Humidity Sensor System capacity changes as the hygroscopic polymer withdraws water molecules from air or gives water molecules back to air. The rate of transportation of water molecules to and from the Humidity Sensor System is highly dependent on the sensor's "free" surface areas. A largely open sensor, with a very open conductive layer attracts and dissipates water molecules faster than a more covered surface area. This type of sensor is used in the Humidity Sensor System. The specifications of the Humidity Sensor System are as follows:

- Relative humidity; range: 0–120 % RH; accuracy: ± 4 % RH; sampling time: 21 times/s.
- Temperature; range: 0–100 °C; rise time: <150 ms (90 % of °C difference); fall time: <150 ms (90 % °C difference); accuracy: ± 1 °C; sampling time: 21 times/s.
- Absolute humidity; range: calculated from corresponding RH and temperature values.

- Calculation formula:

$$\frac{(3.939 + 0.5019 \times T + 0.008004615 \times T^2 + 0.0004188 \times T^3) \times RH}{100}$$

where T is temperature in °C and RH is relative humidity in %.

- Computer specifications needed: IBM or compatible computer; MS-DOS 2 or higher; hard disc; > 512 kb RAM; VGA screen; RS 232 connection with 9 pins (9600 band rate, 8 data bits, 1 stop bit, no parity); 3.5" disc station with 1.44 MB format.

Each sensor was calibrated over saturated NaCl and LiCl solutions before use. The calibration procedure (Swedish National Testing and Research Institute, Energiteknik Department, Borås, Sweden) was as follows: the humidity calibration was performed at + 20 °C and + 40 °C. Corrections for RH measurements were between ± 0.0 and ± 2.2 % RH at + 20 °C and between –1.7 and 1.3 % RH at + 40 %. For each calibration, eight sets of measurements were performed. Five levels of temperature were used for the temperature calibration and eight sets of measurements were performed for each level. Temperature corrections were as follows: 19.7 °C: ± 0.0 °C; 25.3 °C: –0.07 °C; 30.3 °C: –0.07 °C; 35.2 °C: –0.17 °C; 40.3 °C: –0.26 °C.

The humidity and the temperature sensors were connected to a computer interface which transformed the signals into a computer readable signal of the ASCII type. The polymeric humidity sensor changed its capacitance according to the RH, which was registered 21 times each second. The thermoelement (outside diameter: 0.25 mm) was also read 21 times each second and the temperature values were transformed into ASCII signs. The signs were transformed into graphs and values by an IBM-compatible computer and a specially designed computer program. The program transformed temperature and RH into AH and all values were displayed as graphs in which each separate value could be read. The computer program made it possible to compare different graphs on the computer screen as well as calculate average values of all parameters from any part of the graph. The following measurements were performed: mean values of temperature, RH and AH of gases during the inspiration phase. For a given patient, values were averaged over three consecutive ventilative cycles. In each patient, measurements were performed after 1 h of use of the HME and then daily for 2 days at 9.00 a.m.

Total respiratory heat exchanges of breathed gases were computed by summing the algebraic values of the convective or sensible heat exchanges (Wcv) and the evaporative, latent or insensible heat exchange (W_{EV}):

- $Wcv = V \cdot \varrho \cdot Cp\ (T_{ex} - T_{insp})$
- $W_{EV} = V \cdot \lambda \cdot (AH_{exp} - AH_{insp})$

where: V = minute ventilation; ϱ = volumetric mass of the ventilative gas (N_2 = 1.25 g/l^{-1}, O_2 = 1.43 g/l^{-1}); Cp = specific heat of the inspired and expired gases (N_2 = 0.2487 cal/g^{-1} per °C^{-1}, O_2 = 0.2198 cal/g^{-1}.per °C^{-1}); T_{ex}: temperature of expired gas; T_{insp}: temperature of inspired gas; λ = latent heat of water evaporation (585 cal/gH_2O); AH_{exp}: absolute humidity of expired gas calculated from T_{ex} with the hypothesis that expired gases were fully saturated in water vapor (RH: 100 %); AH_{insp} = absolute humidity of inspired gas [24].

Tracheal tube occlusion was suspected on the basis of an unexplained rise in peak pressure without evidence of HME obstruction and inability to insert a suction catheter through the previously patent tube. Obstruction of the HME was suspected by a sudden increase in airway pressure and confirmed by normalization of airway pressure after HME removal, and by visual inspection of the HME. Episodes of pulmonary atelectasis were recorded from chest X-ray. Tracheal suctioning and instillations were recorded by the ICU nursing staff. Airway pressures (peak and mean pressures) were collected every 8 h and averaged.

Bacterial colonization was assessed on days 1 and 2 during the study. At study inclusion (day 1), tracheal secretions were obtained as well as swabs (about 1 cm_2) from the ventilator side of the HME. Similar bacteriological samplings were performed on day 2. Quantitative surveillance cultures were obtained by plating samples onto different media agar and incubating them for 48 h. The following media were used: *Staphylococcus*: tryptic soy agar; *Streptococcus*: Columbia agar supplemented with 5 % sheep blood; *Enterobacteriaceae*: McConkey agar; *Haemophilus influenzae*: chocolate agar. Colonies were quantified and the genus identified.

The results are presented as mean ± SD. Normal distribution of data was checked for each tested parameter. Chi-square test was used to test quantitative data. Intra-group comparisons were performed using the Friedman test. A p value less than 0.05 was considered significant.

Results

Twelve patients were included in this study (Table 1). The mean age was 43.5 ± 18.8 years. The reason for mechanical ventilation was coma in 11 patients and pancreatic resection in 1 patient. The endotracheal tube was not changed during the study period. Minute volume, tidal volume and respiratory rate did not significantly differ between days 1 and 2 (Table 2). Peak airway pressure and mean airway pressure were used as indirect indicators of humidifying activity. As shown in Table 3, no significant change was observed between days 1 and 2. Patients underwent the same number of tracheal aspirations and instillations on days 1 to 2. No endotracheal tube occlusion or atelectasis was observed during the study period (Table 3). The assessment of the technical performance of the heat and moisture exchanger is presented in Table 4, which gives the mean value for temperature, RH and AH of inspired gases measured over the whole inspiration phase. No significant differences between days 1 and 2 were observed. Using a HME for a longer period did not affect its performance in preserving the heat and humidity of ventilative gases. Total respiratory heat loss did not differ between the 2 days of the study period (Table 5).

Data on bacterial colonization are provided in Table 6. On day 1, eight patients had colonization of their tracheal secretions at a significant bacterial count ($\geq 10^3$). Ventilator side cultures of the HMEs were all sterile. On day 2, six patients still presented with significant bacterial colonization of their tracheal secretions. All cultures from the ventilator sides of the HMEs remained sterile after 2 consecutive days of use.

Table 1 Characteristics of the patients. (SAPS: Simplified Acute Physiologic Score; ISS: Injury Severity Score; GCS: Glasgow Coma Score; M: male; F: female)

Sex/Age (year)	Diagnosis at admission	SAPS 2	ISS	GCS	Duration of ventilation (days)	ICU length of stay (days)	Onset of pneumonia (day)	Outcome
F/43	Cardiac arrest	32		3	6	8	–	dead
M/72	Cardiac arrest	85		3	11	11	–	dead
F/46	Subarachnoid hemorrhage	40		7	20	20	5	dead
M/45	Subarachnoid hemorrhage	39		10	22	40	6	alive
M/23	Head trauma	45	41	13	7	14	–	alive
M/42	Head trauma	54	59	5	16	48	36	alive
F/45	Head trauma	56	34	4	4	31	–	alive
M/40	Head trauma	54	50	4	9	39	–	alive
F/67	Head trauma	31	35	9	14	26	5	alive
M/24	Head trauma	47	34	6	20	20	8	dead
M/26	Head trauma	32	35	6	6	11	–	alive
M/62	Head trauma	24	34	7	17	23	–	alive

Table 2 Characteristics of the ventilatory parameters. The heat and moisture exchangers were changed after 48 hours. No sigificant difference were observed for any parameter at any measurement periode. (PEEP: positive end-expiratory pressure; figures in parenthesis are range)

	1 h	24 h	48 h
Endotracheal tube size (N° of patients)			
7.5 mm	4	4	4
8.0 mm	5	5	5
8.5 mm	3	3	3
Minute volume (L/min)	9.0 ± 2.1 (6.0–12.8)	9.3 ± 2.8 (6.0–14.4)	9.4 ± 2.4 (5.5–14.0)
Tidal volume (mL)	690 ± 110 (510–870)	600 ± 100 (470–870)	590 ± 100 (430–850)
Respiratory rate (/min)	18 ± 6.9 (10–33)	21 ± 5.6 (13–30)	21 ± 5.3 (14–30)
FiO_2	0.48 ± 0.18 (0.25–0.7)	0.48 ± 0.12 (0.3–0.6)	0.47 ± 0.11 (0.35–0.7)
Peak airway pressure ($cm H_2O$)	27.1 ± 8 (15–41)	22.9 ± 9.2 (10–38)	21.2 ± 10.5 (10–41)
Mean airway pressure ($cm H_2O$)	10.5 ± 3.8 (5–17)	9.1 ± 4.4 (4–15)	8.7 ± 5 (4–17)
PEEP ($cm H_2O$)	2 ± 3 (0–7)	1.9 ± 2.6 (0–7)	1.5 ± 2.5 (0–7)

Table 3 Clinical assessment of heat and water preservation. The HMEs were changed after 48 hours (HME: Heat and moisture exchanger; figures in parenthesis are range)

	Day 1	Day 2
No of tracheal Suctionning	9 ± 3.1	5.7 ± 1.6
No of tracheal instillation	7.7 ± 2.8	5.4 ± 3.1
Tracheal tube occlusion	0	0
No of HMEs replaced for obstruction	0	0
No of patients with atelectasis	0	0
Body temperature (°C)	37.5 ± 0.8 (35.6–38.6)	37.5 ± 1 (35.4–39.3)

Discussion

The results from the present study clearly show that the technical performance of the hydrophobic Maxipleat Filter was perfectly maintained over the 48 h of the study period. In a group of unselected ICU patients submitted to prolonged mechanical ventilation, the preservation of heat and humidity was not affected by prolonged use (48 h) of the same HME.

Because of their numerous advantages, HMEs are used more and more. They keep ventilative circuits clean, they reduce nurses' workload and they generate substantial financial savings in the care of mechanically ventilated patients [22, 25]. Despite the lack of scientific data, the manufacturers state that HMEs should be changed every 24 h. However, there are some data in the literature demonstrating that the same HME can safely be used for 48 h. No endotracheal tube occlusion was observed by Djedaini et al. after changing the HMEs after 48 h rather than 24 h [22].

However, one limitation of this study was the lack of information on the heat and water preservation of ventilative gases after use for 48 h. Obviously, there is a need to know the actual values of temperature and humidity of ventilative gases after a prolonged use of the HME.

Table 4 Averaged values ± SD (range) of maximal and mean temperature, relative humidity and absolute humidity of inspired gases, recorded during the inspiration phase. The HMEs were changed after 48 hours. There was no significant difference for any parameter at any period of measurement

	1 h	24 h	48 h
Maximal temperature of inspired gases (°C)	32.5 ± 2.1 (29.7–35.8)	32.5 ± 1.3 (30.6–34.6)	32.7 ± 1.8 (29.8–35.5)
Maximal relative humidity (%)	98.7 ± 1.9 (95–100)	99.0 ± 1.4 (95.6–100)	99.0 ± 1.4 (95.3–100)
Maximal absolute humidity (mg H_2O/L)	34.1 ± 4 (28–40)	34.0 ± 2.4 (31–38)	34.4 ± 3.5 (29–40)
Mean temperature of inspired gases (°C)	28.3 ± 1.5 (26.1–30.8)	28.8 ± 1.3 (27–30)	28.8 ± 1.6 (27–32)
Mean relative humidity (%)	82.5 ± 14.1 (47–97)	81.5 ± 9.5 (61–90)	85.2 ± 9.6 (65–97)
Mean absolute humidity (mg H_2O/L)	22.7 ± 4.4 (12–29)	22.9 ± 2.8 (18–26)	24.0 ± 2.7 (18–29)

Table 5 Mean values ± SD (ranges) of total respiratory evaporative and convective heat loss in cal/min. The HMEs were changed after 48 hours. There was no significant difference for any parameter at any period of measurement

	1 h	24 h	48 h
Total respiratory heat loss (cal/min)	171 ± 645 (77–318)	152 ± 47 (90–240)	149 ± 65 (75–290)
Evaporative heat loss (cal/min)	144 ± 57 (69–282)	131 ± 43 (75–222)	128 ± 60 (61–258)
Convective heat loss (cal/min)	26 ± 9 (6–37)	21 ± 7 (12–37)	21 ± 8 (9–36)

In a study conducted in 29 patients it has been demonstrated that AH, RH and temperature of inspired gases were not affected after changing a hygroscopic HME every 48 h rather 24 h [25].In addition, we have routinely used hygroscopic HMEs in several hundreds of patients over the last few years and the peak and mean airway pressures of these patients were monitored at least 3 times a day. In those parameters no significant changes were observed that could have been explained by a deterioration of the HMEs. This represents an indirect evaluation of the stable technical conditions of the hygroscopic HMEs used for 24 h. However, there are no data in the literature on the prolonged use of a hydrophobic HME such as the one used in the present study. In our unit, all mechanically ventilated patients have had their inspiratory gases conditioned with HMEs for more than 5 years.

The optimal humidity of the inspired gases of ICU patients has not been well established yet, and the minimal acceptable level is still a matter of controversy. Some data suggest that 23–33 mg H_2O/l is a desirable range [6, 7, 26, 27] with a tracheal temperature of 32 °C. However, others have suggested that higher temperatures (35–37 °C) are adequate, leading to absolute humidity up to 44 mg H_2O/l [1, 28, 29]. Actually, values published in the literature range from 17 to 44 mg H_2O/l [30].

During this study, the technical performance of the tested HME was not significantly altered when used for 48 h instead of 24 h. In this study, no patient had AH less than 22 mg H_2O/l and there was no significant change in total respiratory heat loss when the same HME was used for 48 h. In the present study, the efficiency of the HME after 48 h of use was also evaluated by calculating total respiratory heat loss. When inadequately heated gases are inspired, more heat is extracted from the respiratory tract during inhalation for the conditioning of inspired air [31]. The basis for the influence of inspired air composition upon the expired air is to be found in the reciprocal exchanges of heat between the respiratory tract and the respired air steam during the inspiration and expiration phases. The explanation for this effect is that the heat extracted from the respiratory tract during inhalation is correspondingly extracted from the exhaled air. Thus, if inadequate heat is provided to the inspired air by the HME, total respiratory heat exchanges, or heat loss, will be significantly increased.

One concern with high total respiratory heat loss is that it may be responsible for abnormal viscosity of bronchial secretions and subsequent atelectasis or endotracheal tube obstruction. In this study no significant changes in total respiratory heat loss were noticed when the same hydrophobic HME was used for 48 h, suggesting that heat extraction from the respiratory phase during inspiration was not altered by the prolonged use of the HME. In the present study we did not directly evaluate expiratory resistance of the HMEs. Small changes in this parameter may cause a significant dynamic lung hyperinflation, increased work of breathing and patient distress and discomfort. This important problem needs to be evaluated in further studies. There is some indirect evidence of very little, if any, change in HME resistance over the 48 h study period since no modifications were observed in peak and mean airway pressures, with identical tidal and minute volumes in the study patients.

Table 6 Mean bacterial colonization of the HMEs. The HMEs were replaced after 48 h (Day 2) (NG: no bacteria growth)

Patients	Day 1		Day 2	
	Tracheal secretions	HME ventilator side	Tracheal secretions	HME ventilator side
1	S. aureus 10^5 H. influenzae 10^6 Strepto. α viridans 10^5	NG	NG	NG
2	NG	NG	S. aureus 10^6	NG
3	S. aureus > 10^6 Enterobacter aerogenes > 10^6 Strepto. α viridans 10^6	NG	S. aureus 10^6 Enterobacter aerogenes > 10^4	NG
4	S. aureus > 10^4 Strepto. α viridans > 10^4	NG	S. aureus 10^4	NG
5	Strepto. α viridans. 10^5	NG	NG	NG
6	S. aureus < 10^3	NG	S. aureus > 10^4	NG
7	NG	NG	NG	NG
8	P. aeruginosa < 10^4	NG	NG	NG
9	NG	NG	NG	NG
10	S. haemolyticus > 10^6	NG	NG	NG
11	H. influenzae > 10^6 S. aureus 10^6 Strepto. α viridans 10^6	NG	H. influenzae 10^6	NG
12	NG	NG	Acinetobacter anitratus > 10^6	NG

Humidity measurements can be made using different methods and the mass transfer method (i. e., gravimetric method) is considered to be the gold standard [23]. This technique requires the humidifier to be weighed before and after a period of operation under strictly controlled conditions. However, this method is time-consuming and requires running times of 4 h or more in order to reduce weighing errors. In the present study we used a capacitance-type hygrometer, which has gained wide acceptance as a versatile instrument for measurement of humidity. It is important that this instrument is perfectly accurate when used to assess medical humidifiers, where humidity often approaches 100 % RH. The capacitance hygrometer has been shown to produce results very close (within 7 %) to those provided by the absolute gravimetric method over a wide range of RH (67–95.5 %) [23]. For the purpose of the present study and the proposed clinical application, this has been considered as an acceptable figure. It is also important to note that the humidity sensor used in the present study lacks the ability to resolve small differences in the range of RH found in our patients (> 95 %).

Using the same HME for a prolonged period of time could be the cause of a deterioration of the bacterial filtration properties of the filter and subsequent ventilator circuit colonization. Thus, we also studied the properties of bacterial filtration of the hydrophobic HMEs. At the beginning of the study eight patients had positive cultures, at a significant bacteriological count, of their tracheal secretions. After 48 h of mechanical ventilation with the same HME, only six patients still presented with bacterial colonization of their bronchial tree. All cultures of the ventilator sides of the HME were sterile. Thus, despite 48 h of use of the same HME, bacterial colonization was not increased in the study patients and the ventilator side of the HME did not become colonized by the patients' bronchial flora. These results are comparable to those of a previous study by Djedaini and colleagues [22]. The present study was not designed to evaluate the rate of nosocomial pneumonia following prolonged use of the same HME and the impact of such a practice remains to be evaluated.

In conclusion, the present study strongly suggests that a prolonged use (48 h instead of 24 h) does not affect the technical performance of a hydrophobic HME, in terms of conditioning of inspiratory gases. Also, the bacteriological properties of the HME were not affected by its prolonged use and the ventilator side of the filter remained sterile at the end of the study period, despite a significant bacterial colonization of the patients' bronchial secretions. However, other large clinical trials should be undertaken to confirm the safety of extending the time between HME changes from 24 h to 48 h.

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