Heat and Moisture Exchanger vs Heated Humidifier during Long-Term Mechanical Ventilation*

A Prospective Randomized Study

Benoit Misset, M.D.; Bernard Escudier; M.D.; Daniel Rivara, M.D.; Bernard Leclercq, M.D.; and Gérard Nitenberg, M.D.

Adequate humidi6cation of inspired gases with HMEs during long-term MV remains controversial. In this study, a comparison is made between tracheal secretions during long-term MV either with HME or conventional HH. Both the HME and HH groups were similar with respect to age, sex, diagnosis, duration of MV, SAPS and mortality. Temperature of gases in the tracheal tube was lower and the amount of tracheal instillations was greater in the HME group than in the HH group. Tracheal secretions became thicker between day 1 (control) and day 5, in the HME group than in the HH group. Four and two tube occlusions occurred in HME and HH groups, respectively. Tracheal bacterial colonization was similar in the two groups. Given the advantages of HME (reduced nurses' work and financial cost), HME could be routinely used under cautious surveillance and replaced by HH if difficulty in suctioning occurs.
(*Chest* 1991; 100:160-63)

UU = heated humidiSer; UME = heat and moisture exchanger; SAPS = simplified acute physiologic score; UA = upper airway

The main functions of UAs are to warm and humidify inspired gases' for adequate protection of respiratory mucosa and to decrease viscosity of secretions. The use of MV requires tracheal intubation bypassing the UAs. During MV, the devices used artificially to replace *VA* functions are either HH or HME.

Heated humidifiers have been associated with increased inspiratory work load, bacterial infections,[2] overhydration or underhydration, hyperthermia and tracheal burns." Heat moisture exchangers are simple to use and good results have been reported during anesthesia for surgery *(ie,* short-term MV).4,5 However, their efficacy is debated for long-term MV in ICUs. During MV in the ICU, Cohen et al" found a very high rate of endotracheal tube occlusion using HME in a noncomparative study, whereas Tenaillon et al,? through a randomized study, observed that HH and HME were equivalent regarding tracheal secretions, cannulae obstructions, pulmonary complications and cannulae resistance at the time of extubation.

The aim of this study was to compare prospectively the efficacy of a HME (the one used by Cohen et al[6] and Tenaillon et al,? Pall BB2215) and a HH on the characteristics of the tracheal secretions.

*From the Service de Reanimation Medieochirurgicale, Institut G. Roussy, Villejuif, France.
Supported in part by a grant from the Institut G. Roussy (CRC 88023).
Manuscript received November 5; revision accepted December 13.

PATIENTS AND METIIODS

All consecutive patients mechanically ventilated in our ICU from June 1988 to June 1989 were preincluded in this study at the onset of MV if their expected duration of MV was more than five days. They were then randomly assigned to MV either with HH or with HME. Only patients who underwent MV for at least five days were ultimately included for analysis. The duration of evaluation was limited to ten days.

In the HH group, the humidifier was either a Bennett Cascade II when a Servo 900 B ventilator (Siemens) was used or a Fisher-Paykel MR 450 when a CPU I ventilator (Ohmeda) was used. The humidifier was set in order to achieve an inspiratory temperature between 32° and 34°C. For bacteriologic safety, the ventilatory circuit was changed every 48 h."

In group HME, the filter (Pall Ultipore Breathing Filter BB2215) was placed between the Y connector of the ventilator tubing and the endotracheal tube and was changed daily. The ventilatory circuit was changed only every eight days on the basis that the antibacterial properties of PALL filters are well established *in vitro*.[9]

Tracheal secretions were evaluated separately by the nurses during tracheal aspirations and by a fiberoptic examination on days 1,5 and 10, with this last examination being made only if the patient was still undergoing MV. Tracheal aspirations were performed every 4 h or more frequently as judged by the nurses in care of the patient. A quantitative method was used to assess the viscosity (fluid = 1, intermediate = 2, thick = 3) and the quantity (nonabundant = 1, intermediate = 2, abundant = 3) of the tracheal secretions. Frequency and volume of tracheal instillations were decided by the nurses, in case of thick aspirates or when difficulty in suctioning was encountered.

The fiberoptic aspect of tracheal secretions was assessed on days 1,5 and 10 by a physician (B.M. or B.E.) of the ICU as follows: no secretions = 1; fluid and proximal secretions in the trachea and/or lobar bronchi (*ie*, not abundant) = 2; fluid and distal secretions (*ie*,

Table 1 -*Number of Patients and Diagnoses on Admission in ICU*

Randomized 77			
Excluded 18 (MV <5 days)			
Included 56			
Diagnosis on admission	HH Group	HME Group	p Value
Postoperative infection	11	10	NS
Acute parenchymal lung disease	14	11	NS
COPD	1	3	NS
Septic shock	0	3	NS
Coma	0	3	NS

abundant) = 3; dry secretions (impossible to be aspirated without perifiberoptic instillation) =4. Assessments by both the nurses (aspirations) and physicians (6beroptic bronchoscopy), were compared between the two groups for values obtained on days I, 5 and 10, respectively Besults at day 1 (considered as the control day) were substracted from results at day 5 in order to assess the evolution of the criteria in the two groups.

Temperature of gases was measured every 6 h at the inlet of the endotracheal tube with an electronic thermistance (CGR, 3100 A, France). No attempt was made to separate expiratory from inspiratory temperature of gases.

Bacterial colonization of bronchi was assessed using a qualitative examination of a tracheal aspirate on days I, 5 and 10.

Statistical comparisons between groups were made by chi square test for qualitative data and by the Student t test for quantitative data. A P value less than 0.05 was considered signi6cant.

RESULTS

Study Population

Seventy-four patients entered the study and underwent randomization (Table 1 and 2). Eighteen of them were excluded because MV was stopped before the fifth day In the remaining 56 patients, 26 were assigned to MV with HH and 30 with HME. In the HH group, a Cascade II Bennett humidifier was used in 21 patients and a Fisher Paykel humidifier in five. The two groups were similar in terms of diagnosis on admission in the ICU, age, sex, SAPS at the time of inclusion, duration of MV before randomization, total duration of MV, type of ventilator, type of tracheal device (tracheostomy vs nasotracheal intubation) and mortality However, although not statistically significant, there were more patients with COPD, septic shock or coma in the HME group. These nine patients had individual data on day 1 (particularly; viscosity and abundance of secretions as well as fiberoptic aspects) similar to the data of the other patients of the HME group (data not shown).

Table 2 — *Characteristics of Patients**

	HH Group	HME Group	p Value
No. of patients	26	30	
Age, yr	49±13	53±14	NS
Sex ratio (%M)	65%	67%	NS
SAPS	13±5	14±4	NS
Duration of MV before randomization (h)	13±16	17±11	NS
Total duration ofMV (days)	11±6	12±7	NS
Type of ventilator			
Siemens Servo 900B	19%	27%	NS
OhmedaCPUI	81%	73%	NS
Type of humidifier			
Cascade II Bennett	19%		
Fisher-Paykel MR 450	81%		
% Intubation/tracheostomy	**50%**	**30%**	NS
Mortality	64%	44%	NS

*Quantitative data are expressed as mean ± SEM.

Table 3 — *Assessment of Tracheal Secretions by the Nurses Using a Quantitative Method**

	HH Group	HME Group	p Value
Volume of instillations (mJlday)	3O±12	44±20	0.01
Frequency of aspirations (per day)	12±3	13±4	NS
Viscosityt			
Day 1	1.8±0.S	1.4±0.S	0.01
DayS	1.6±0.6	1.6±0.6	NS
Evolution (day 5-day I)	-0.3±0.5	0.2±0.5	0.001
Abundance;			
Day 1	1.7±0.6	1.4±0.4	NS
DayS	1.6±0.S	1.4±0.4	NS
Evolution (day 5-day I)	-0.1±0.7	O.O±O.S	NS

*Quantitative data are expressed in mean ± SEM.
†1 = fluid; 2 = intermediate; 3 = thick.
‡1 = not abundant; 2 = intermediate; 3 = abundant.

Assessment ofTracheal Aspirates by the Nurses

Frequency of aspirations was not different in the two groups throughout the study period (12 ± 31day in the HH group vs 13 ± 31day in the HME group), and during the first, fifth and tenth days, respectively (Table 3). The amount of tracheal instillations was larger in the HME group. Aspirates were thicker (p=0.01) and more abundant (p=O.04) in the HH group on the first day, whereas no difference was found on days 5 and 10. Thickness decreased between days 1 and 5 in the HH group and increased in the HME group (p=0.(01) but no difference was observed between days 1 and 10 or between days 5 and 10 (only 11 patients in the HH group and 16 in the HME group were mechanically ventilated at least during ten days). The evolution of the abundance of secretions was similar in the two groups.

Assessment ofTracheal Secretions by Fiberoptic Bronchoscopy

The proportion of fiberoptic examinations performed by the two physicians was similar in each group (Table 4) (31 percent were performed by B.M. in the HH group vs 51 percent in the HME group, not significant [Table 4]). There was no difference

Table 4—*Assessment of Tracheal Secretions by Fiberoptic Bronchoscopy Using a Quantitative Method**

	UU Group	UME Group	p Value
Day 1 (control day)	2.1±1	1.8±1	NS
DayS	2.0±1	2.3±1	NS
Day 10	1.8±0.6	1.9±1	NSt
Day 5-day 1	-O.1±1	0.5±1	0.05

*Quantitative data are expressed as mean ± SEM. 1 = no pus; 2=8uid and not abundant pus; 3=8uid and abundant pus; 4=dry pus.

tOnly 11 (UU group) and 16 patients (UME group).

between the two groups regarding fiberoptic aspect on days 1, 5 and 10. However, the fiberoptic gradation decreased between days 1 and 5 in the HH group, whereas it increased in the HME group. These differences in evolution were statistically significant between the two groups (p = 0.05).

Endotracheal Tube Occlusion

Two (8 percent) and four (13 percent) endotracheal tubes were removed and replaced because of occlusion in the HH and HME groups, respectively (not significant). In all these cases, occlusion was confirmed by cutting the tube and by clinical evidence of amelioration of the patient after removal of the tube.

The average temperature of the respiratory cycle at the inlet of the endotracheal tube was 33.8°±0.9°C in the HH group and 32.4° ± 0.8°C in the HME group (p = 0.00(1).

Bacterial colonization of the trachea was 76 vs 55 percent, 59 vs 53 percent and 70 vs 61 percent on days 1, 5 and 10, respectively (HH group vs HME group). None of these differences was significant. Aerobic Gram-negative bacteria, Gram-positive cocci and yeast cells were similarly distributed between the two groups. No attempt was made to assess the incidence of nosocomial pneumonia.

DISCUSSION

Heat and moisture exchangers might replace the functions of the UAs by avoiding loss of heat and moisture during expiration and returning them to the inhaled gas. Their main advantages are high bacterial filtering capacity" and simplification of the ventilator tubing. Therefore, the use of a HME should be generalized if an equivalent humidification of inspired gases could be demonstrated between HME and HH.

During the last decade, many HME proved to be effective by in *vitro* assays.[3,10-13] Innocuousness and efficacy have been clinically proved only during short-term MV for anesthesia." During long-term MV filters were not studied so intensively: in a nonrandomized study, HMEs were associated with a higher rate of endotracheal tube occlusion than HHs,6 whereas in a more recent randomized study, no difference was observed between HH and HME either for assessment of tube resistance after extubation or for clinical tube occlusion." These discrepancies led us to appraise the safety of HME during long-term MV using a fiberoptic criterion independently of the respiratory course.

Characteristics of our two groups were similar. Opposite the results observed in the HH group, fiberoptic data as well as assessment by the nurses showed an impairment of tracheal secretions between first and fifth days in the HME group. Replacement of the tracheal tube because of occlusion was not significantly more frequent in the HME group, but the populations were small and therefore the risk is high to erroneously conclude (type 2 error) that HME and HH are equivalent regarding tube occlusion. The subjective aspect of our clinical (assessment of the tracheal aspirations by the nurses) and fiberoptic evaluations could be criticized. However, a double-blind study is not easily conceivable, and no objective test representative of the fluidity of tracheal secretions currently is available for clinical studies. Moreover, replacement of the endotracheal tube is a subjective criterion (that we and other authors used[6,7]) to assess the incidence of tube occlusion; except in extreme cases such as circulatory arrest, there is no universally admitted criterion to decide tube replacement. In fact, several other attitudes could be considered in such clinical settings: washing of the tube either with isotonic serum or with a brush" and clearing during bronchoscopy

The use of greater amounts of instillation fluids in the HME group could be related either to the observation by the nurses of thicker secretions or to the fear of tube occlusion in the HME group, which was considered by them to be at higher risk. This difference between groups could have biased our results. However, despite greater amount of instillations in the HME group, abundance of aspirates was not different from the HH group and thickness was greater than in the HH group. Moreover, we did not observe fewer tube occlusions. Finally, the inclusion of patients with high minute volume MV might have disadvantaged the HME group. In fact, several authors found a negative correlation between efficacy of HMEs and minute volume" or tidal volume." The critical level of minute ventilation is usually 10 Izmin:" however, we found no difference in terms of abundance, thickness or fiberoptic aspect of the tracheal secretions between patients ventilated with more than 10 Umin and those ventilated with less than 10 Umin (data not shown).

As Tenaillon et al? found, we also found no difference between HH and HME in maintaining permeability of the tracheal tube and we observed adequate temperature of the gases with either HME or HH even

if, like these authors, we found a statistically lower temperature at the inlet of the tube in the HME group." We did not separately analyze expiratory from inspiratory gases because these values varied similarly in the two groups of Tenaillon et al.? These authors observed that resistance of endotracheal tubes, measured at the time of the extubation, was higher than resistance of control (new) tubes, without a difference between groups," In contrast, we observed that thickness of tracheal secretions increased in the HME group but not in the HH group. An explanation for this discrepancy could be the difference in the time chosen to assess the safety of HME. In the study of Tenaillon et al,? the assessment measuring the resistance of the endotracheal tube was performed at the time of extubation, whereas our patients underwent assessment (fiberoptic bronchoscopy) during the course of MV. Usually except in case of tube occlusion, at the time of extubation, patients do not present any sign of respiratory distress. Though this may be, extubation cannot be considered as a good indicator for the whole period of MV. That is why periodic assessment of tracheal secretions, independent of the respiratory course, seemed to us more accurate.

The remaining question is to know if thicker tracheal secretions have any clinical impact, especially for tube occlusion. Cohen et al" observed a strong difference between HME and HH for tube occlusion (17 and 1 percent of 150 and 81 patients, respectively) that we did not find in our study In a preliminary report, Martin et al[15] also found a higher incidence of tube occlusion (19 percent of 31 patients in the HME group and 0 percent of 42 patients in the HH group). Several explanations can be stressed. First, we studied fewer patients than Cohen et al"and the small difference we observed (four vs two tube occlusions) could become significant with more patients. Second, the use of great ventilator minute volume and high FIo_2 by these authorsv" could have decreased the efficacy of HME.3 However, the ventilator minute volume of our patients was frequently above 10 Umin (11.9 ± 2.5 Umin HME vs 11.2±2.9 Umin HH, no significant difference). Third, Cohen et al[6] did not specify the timing of tracheal instillations. Recently it has been shown'" that resistance of the endotracheal tube at extubation after MV with HME was Significantly higher in the absence of periodic instillations (at least every 4 h). Finally Cohen et al[6] used a historical comparison which could have overestimated the observed differences.

CONCLUSION

Our results suggest that tracheal secretions during MV with periodic tracheal instillations become thicker with PALL BB 2215 HME than with HH. The number of patients is too small to state that these features are associated with a greater incidence of tube occlusion with HME. In view of the advantages of HME (reduction of nurses' work and of financial cost) it seems reasonable to carry on their use in long-term MV, but it is advisable to replace them by HH when difficulty in suctioning occurs. Finally; other recently available filters could be more appropriate'? than PALL BB 2215 and have to be assessed in further clinical trials.

REFERENCES

1 Moritz AR, Weisinger JR. Effects of cold air on the air passages and lungs. Arch Intern Med 1945; 15:33

2 Reinars)A, Pierre AK, Mays BB. Potential role of inhalation therapy equipment in nosocomial pulmonary infection. J Clin Invest 1965; 44:831

3 Hay R, Miller WC. Efficacy of a new hygroscopic condensor humidifier. Crit Care Med 1982; 10:49-51

4 Chalon J, Patel C, Ali M, Ramanathan S, Capan L, Tang CK, et all Humidity and the anesthetized patients. Anesthesiology 1979; 50:195-98

5 Chalon J, Markham JP, Ali M, Ramanathan S, TumdorfH. The Pall Ultipor Breathing Circuit Filter-an efficient heat and moisture exchanger. Anesth Analg 1984; 63:566-70

6 Cohen IL, Weinberg PF, Fein lA, Rowinski GS. Endotracheal tube occlusion associated with the use of heat and moisture exchangers in the intensive care unit. Crit Care Med 1988; 16:277-79

7 Tenaillon A, Cholley G, Boiteau R, Perrin-Gachadoat D, Burdin M. Filtre échangeur de chaleur et d'humidite versus humidificateur chauffant en ventilation mecanique prolongee. Réan Soins Intens Med Urg 1989; 5:5-10

8 Craven DE, Connolly MG, Lichtenber DA, Primeau PJ, McCabe WR. Contamination of mechanical ventilators with tubing changes every 24 or 48 hours. N Engl J Med 1982; 306:1505-09

9 Bouilhac M. Filtre bacterien pour circuit de ventilation. Agressologie 1984; 25:299-302

10 Shelly MP, Bethune DW, Latimer RD. A comparison for Bve heat and moisture exchangers. Anesthesia 1986; 41:527-32

11 Oh TE, Thompson WR, Hayward DR. Disposable condensor humidifiers in intensive care. Anaesth Intensive Care 1981; 9:331-35

12 Stoutenbeck CH, Miranda D, Zandstra D. A new hygroscopic condenser humidifier. Intensive Care Med 1982; 8:231-34

13 Weeks DB. A laboratory evaluation of recently available heat and moisture exchangers. Anesthesiol Rev 1986; 13:33-36

14 Boiteau R, TenaiUonA, Perrin-Gachadoat D, Burdin M, Gosgnac M. Etude d'un dispositif permettant de prevenir l'obstruction des sondes d'intubation [abstract]. Réan Soins Intens Med Urg 1988; 4:382

15 Martin C, Perrin G, Gevaudan MJ, Saux P, Albanese J, Gouin F. Filtre PALL ou humidiBcateur chauffant? [abstract]. Réan Soins Intens Med Urg 1988; 4:382

16 Boiteau R, Tenaillon A, Humbert M, BrailowslcyA, Burdin M, Perrin-Gachadoat D. Instillations periodiques de sérum salé isotonique et perméabilité des sondes d'tntubation [abstract]. Réan Soins Intens Med Urg 1989; 5:459

17 TenaiUon A, Boiteau R, Perrin-Gachadoat D, Burdin M, Forceville X. Comparaison in vivo des performances thermiques et hygrometriques de trois echangeurs de chaleur et d'humidité assurant une protection microbiologique [abstract]. Réan Soins Intens Med Urg 1989; 5:458