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Hygroscopic condenser humidifiers in chronically tracheostomized patients who breathe spontaneously

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Hygroscopic condenser humidifiers in chronically tracheostomized patients who breathe spontaneously. M. Vitacca, E. Clini, K. Foglio, S. Scalvini, S. Marangoni, A. Quadri, N. Ambrosino. ©ERS Journals Ltd 1994.

ABSTRACT: The aim of this study was to test the usefulness of hygroscopic condenser humidifiers on secretion and on inspired gas temperature in tracheostomized patients.

Forty spontaneously breathing chronically tracheostomized patients were divided into two groups: Group 1 received a hygroscopic condenser humidifier connected to the tracheostomy, 24 h daily for 10 days; Group 2, without any protection system, was chosen as the control group. The daily number of tracheal suctions, quantity of aspirate and thickness and colouring of secretions was evaluated. At baseline, and at days 5 and 10, patients were submitted to blood gas analysis, respiratory function tests and sputum analysis. The temperature of gases breathed was measured at rest and during a hyperventilation test, with and without the hygroscopic condenser humidifier.

Statistically significant differences were found in thickness and colouring of secretions between the two groups during the period of 10 days. Group 2 showed a significantly greater trend in number of bacteria than Group 1. The group with the hygroscopic condenser humidifier showed respiratory function improvement over time for forced expiratory volume in one second (FEV_1) and tidal volume (V_T), maximal inspiratory pressure (MIP), and maximal voluntary ventilation (MVV) in comparison to the control group, who did not. Significant differences in the temperature between rest and hyperventilation, with and without a hygroscopic condenser humidifier were also found.

In conclusion, a hygroscopic condenser humidifier may be useful in chronically tracheostomized patients who breathe spontaneously, improving viscosity and colouring of secretions, preventing further bacterial colonization, heating inspiratory flow, and helping to improve the functional outcome.

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Tracheostomy bypasses the normal heat and moisture exchanging process of inspired gases, which is one of the main functions of the upper airways. Chronically tracheostomized patients may suffer from chronic infections, and increased amount of secretions, so that they must be frequently suctioned. Furthermore, these patients may need long-term ventilation, which could increase the risk of infection. In these patients, poor or absent humidification causes a decrease in cough reflex, an increase in bronchial secretion and a decrease in mucociliary clearance [1–4]. A destruction of cilia and mucous glands and subsequent alteration in pulmonary function, and a heat loss with reduction of core body temperature can also be caused by bad airway humidification [1–5].

Most investigators believe that both airway cooling and drying, due to water loss by evaporation, may induce airflow-related bronchospasm in asthmatics [6, 7]. A lack of information about bronchial hyperreactivity in tracheostomized patients was found in recent literature.

A passive method of conditioning inspired gases by means of a hygroscopic condenser humidifier (HCH) is based on recovery of a part of the heat and humidity contained in expiratory gases, with subsequent heating and humidification of incoming respiratory gases.

HCH is used during anaesthesia [3], and during short-term postoperative mechanical ventilation [8]. However, the effectiveness of HCH in patients who need long-term mechanical ventilation in Intensive Care Units is controversial [9–15] in the following respects: whether HCH provides adequate humidification of the patients' respiratory tract; whether it reduces heat loss perioperatively; whether it effectively prevents contamination of ventilatory circuits; and whether it reduces nursing and financial costs in comparison to conventional hot water humidifiers [9–11, 13–15].

To our knowledge, no data are available regarding the possible effectiveness of HCHs in chronically spontaneous breathing tracheostomized patients. The aim of

the present study was to evaluate whether the addition of an HCH to chronically tracheostomized patients who breathe spontaneously can induce changes in bronchial secretion and obviate the temperature loss of inspired gases induced by tracheostomy.

Methods

Patients

We studied 40 spontaneously breathing, chronically tracheostomized in-patients (27 males and 13 females) in a respiratory rehabilitative department, who have successfully performed a programme of weaning from mechanical ventilation. They were all in stable condition and had been tracheostomized for many months (range 1–13 months) due to problems in weaning from mechanical ventilation required during an episode of acute respiratory failure. Some patients came to our department to be studied and evaluated for the removal of the tracheostomy cannula. A group of patients maintained the tracheostomy cannula for a length of time because our institution decided this was necessary for clinical reasons (age, hypercapnia swings, hypersecretion, repeated hospitalizations required for relapses). Another group comprised patients who had recently been weaned and, although breathing spontaneously and in stable condition, maintained the tracheostomy cannula for at least 3–4 months with repeated blood gases analysis and clinical controls to avoid any possible or sudden ventilation or bronchial cleaning necessities. All patients were performing their usual medical therapy.

Oxygen therapy was required by 24 out of 40 patients, in order to maintain a resting arterial oxygen saturation >90%. Oxygen was delivered by means of a tube fitted to the HCH connection. In controls, oxygen was directly delivered by a small catheter inserted into the cannula. The tracheostomy cannula used during the study was a fenestrated and cuffed model (Shiley & Fen, Irvine, Ca, USA). The population studied consisted mostly of chronic obstructive pulmonary disease (COPD) patients (12 in the HCH group and 13 controls), but also of cardiac patients (10 cases) who had experienced an acute respiratory failure (ARF) during a severe episode of left ventricular failure with subsequent cardiogenic shock or other cardiac sequelae. The other five patients (three in the HCH group) experienced an ARF associated with different diseases (chest traumatic event, narcolepsia and neuromuscular disease). No tracheal instillations with drugs or saline were performed. None of the patients had experimented with an HCH before entering the study. Exclusion criteria were: 1) pneumonia confirmed at chest X-ray; and 2) antibiotic and mucolytic therapy.

Study design

Patients were randomly divided into two groups: Group 1 (20 patients) received an HCH (Mediflux HCH-6V ICOR AB Sweden) connected to the tracheostomy cannula 24 $h \cdot day^{-1}$ for 10 days: HCH was changed every 24 h. Group 2 (n=20) (control group) continued to breathe through their tracheostomy without any protection system.

Measurements

Throughout the study period, necessity for suction was evaluated at least every 2 h with suctioning catheters (Suction Catheter Rusch, Waiblingen, Germany) and, when necessary, even more frequently according to nurses' judgement or patient's request. Nurses recorded the daily number of suctions; a subjective score for the amount of aspirate (0=absent, 1=low, 2=intermediate, 3=abundant, 4=very abundant); for sputum viscosity (1=thick; 2=dry; 3=fluid); and for colour of secretions (1=light, 2=yellowish, 3=dark). This subjective score was proposed to the nursing staff, who were uninformed about the purpose of the study.

As baseline, and at days 5 and 10 postoperation, all patients were submitted to: 1) radial arterial blood gas analysis (Ciba Corning EGA System 288, Milan, Italy); 2) spirometry performed using a portable spirometer (Pocket monitor, Markos, Monza, Italy) and measured in sitting position; 3) a hyperventilation test performed by asking the patients to sustain the maximal voluntary ventilation (MVV) until exhaustion (Pocket monitor-Markos, Monza, Italy); 4) maximal inspiratory pressure (MIP) measured in sitting posture performing a maximal inspiratory manoeuvre starting from functional residual capacity (FRC) by means of a portable manometer (Mouth Pressure System, Markos, Monza, Italy). All the respiratory manoeuvres were performed through the mouth, after closing the proximal end of the tracheostomy cannula.

At the same intervals, blood leucocyte count and bacterial colonization of aspirates were also assessed; sputum was collected by means of a tracheal catheter (Lukens catheter, Vygon, Ecouen, France) designed for bacterial cultural tests. Tracheal secretion specimens were cultured for bacteria only if >25 polymorphonuclear leucocytes and <10 squamous epithelial cells were present per low power field on the Gram stain (according to the criteria of MURRAY and WASHINGTON) [16]. Sputum specimens were considered in data analysis if the predominant organism was cultured in significant growth ($>2\times10^5$ colony forming units ($cfu \cdot ml^{-1}$). Results were expressed by recording bacterial presence; the score was related to the number of different species found.

At the beginning of the study, the temperature of breathed gases for all 40 patients was measured at the end of the tracheostomy tube with a thermal probe (Kolormon-Kontron Instruments, Watford, UK) inserted into the end of the cannula at a fixed distance of 18 cm from the cannula external hole. No attempt was made to separate expiratory from inspiratory temperature of gases. These measurements were performed at rest and during the hyperventilation test, with and without the HCH. The thermal probe was maintained in the tracheal access by a physician during the described measurements.

The cylindrical thermal probe (3 mm in diameter) continuously recorded the temperature variations, visualized on a monitor (Kolormon-Kontron Instruments, Watford, UK) connected to the probe. After reaching the steady-state (15 min of HCH application) the highest temperature was chosen for statistical analysis. During the study, no statistically significant variations in room temperature were allowed. Also, the patients usually on oxygen therapy performed all the measurements breathing room air (after 45 min without oxygen).

HCH description

The HCH was connected to the patient through the external part of the tracheostomy cannula. The Mediflux HCH-6V retains heat and moisture during the expiratory phase, releasing them during the next inspiratory phase. According to the manufacturer, heating and moisture efficacy is guaranteed by the hygroscopic condensation (the property of taking on water chemically) and superabsorption (the property of absorbing high quantities of water compared to weight) capacities of a sponge which is soaked in lithium chloride.

HCH presents a dead space of 12 ml, a weight of 5 g, a pressure fall (at 60 $l \cdot min^{-1}$) of about 0.25 cmH_2O, and a percentage of moisture efficacy of about 70% with a tidal volume of 400 ml. The best efficiency is reached at an ambient temperature ranging 25–32°C.

Statistical analysis

Analysis of variance (ANOVA) was used to test differences between group, trends for qualitative and quantitative assessment of aspirates, and to estimate differences between groups at indicated times for the respiratory parameters and for observed microbiological changes. Whenever necessary, a *post hoc* test was added to evaluate the contrast between and within groups. ANOVA was used to test differences in temperature at rest and during hyperventilation, with and without HCH. A p value of less than 0.05 was considered to be statistically significant. Results are expressed as mean±SD.

Results

Table 1 shows that there was no significant difference in diagnosis, demographic or functional characteristics of the two groups on admission to the study. Thirteen Group 1 patients and 11 Group 2 patients required oxygen therapy. Baseline arbitrary score of quantity of aspirates was significantly greater in Group 1 than in controls (mean±SD) (2.2 (0.7) *vs* (1.7 (0.8), respectively; $p<0.05$).

Figure 1a shows the effects of HCH on the amount of tracheal secretion produced as compared to control group. There was a great variability in score of sputum production. No statistically significant difference was found in either group (from baseline to day 10). Trends of daily number of suctions were found to be similar between groups (fig. 1b).

Figure 2a shows the change in fluidity of secretions as assessed by the subjective score. Secretions became significantly more fluid in the HCH group, whereas the fluidity of secretions in the control group remained unchanged over time.

Secretion colouring data were found to be different between groups over time ($p<0.01$). Only in the HCH

Table 1. – Baseline characteristics of patients

	HCH n=20	Control n=20	p-value
Diagnosis on admission: COPD	18	17	NS
LVF	2	3	NS
Age yrs	65±7	66±6	NS
pH	7.38±0.05	7.40±0.04	NS
$Paco_2$ kPa	6.80±1.31	6.24±1.41	NS
Pao_2 kPa	8.12±2.14	8.82±1.60	NS
FEV_1 *l*	0.66±0.26	0.62±0.17	NS
FVC *l*	0.95±0.45	1.10±0.41	NS
MIP cmH_2O	38±10	36±7	NS
VT ml	380±129	407±82	NS
f breaths·min^{-1}	19±4	18±4	NS
MVV $l \cdot min^{-1}$	15±6	19±9	NS
Blood leucocyte cells×$10^9 \cdot l^{-1}$	8.6±2.9	9.0±1.4	NS
Bacterial species range 0–3	0.75±0.63	0.60±0.59	NS
Quantitative assessment* range 0–4	2.20±0.72	1.70±0.82	<0.05
Qualitative assessment* range 0–3	1.70±0.80	1.70±0.70	NS
Aspirations·day^{-1} n	6.45±4.60	4.60±3.34	NS
Colouring assessment* range 1–3	1.40±0.50	1.36±0.51	NS

*: subjective score. HCH: hygroscopic condenser humidifier; COPD: chronic obstructive pulmonary disease; LVF: left ventricular failure; $Paco_2$ and Pao_2: arterial carbon dioxide and oxygen tension, respectively; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; MIP: maximal inspiratory pressure; VT: tidal volume; *f*: respiratory frequency; MVV: maximal voluntary ventilation; NS: nonsignificant.

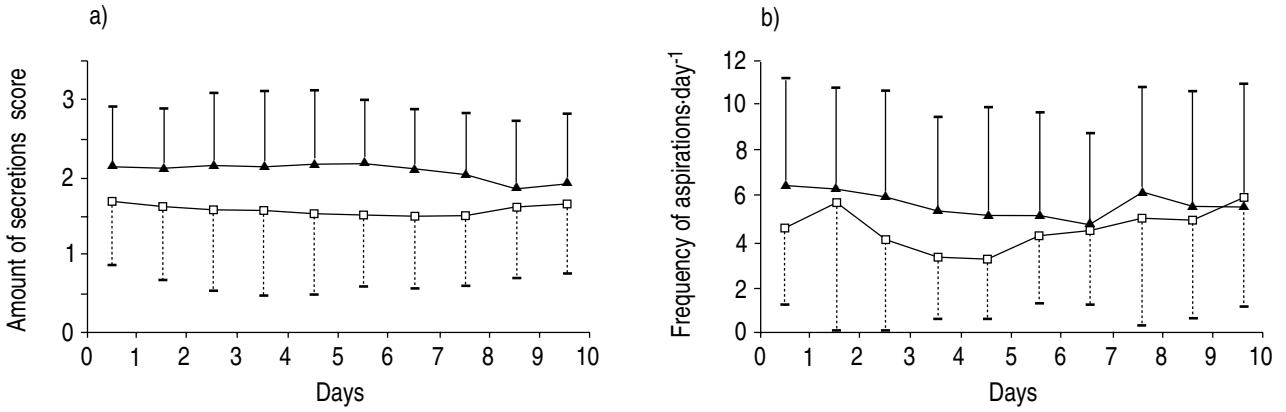

Fig. 1. – Data presented as mean+/-SD bars. a) Time course of change in amount of secretions (subjective score: 0=absent; 1=low; 2=intermediate; 3=abundant; 4=very abundant). b) Frequency of aspirations·day^{-1}. —▲— : HCH group; —❑— : control group. HCH: hygroscopic condenser humidifier.

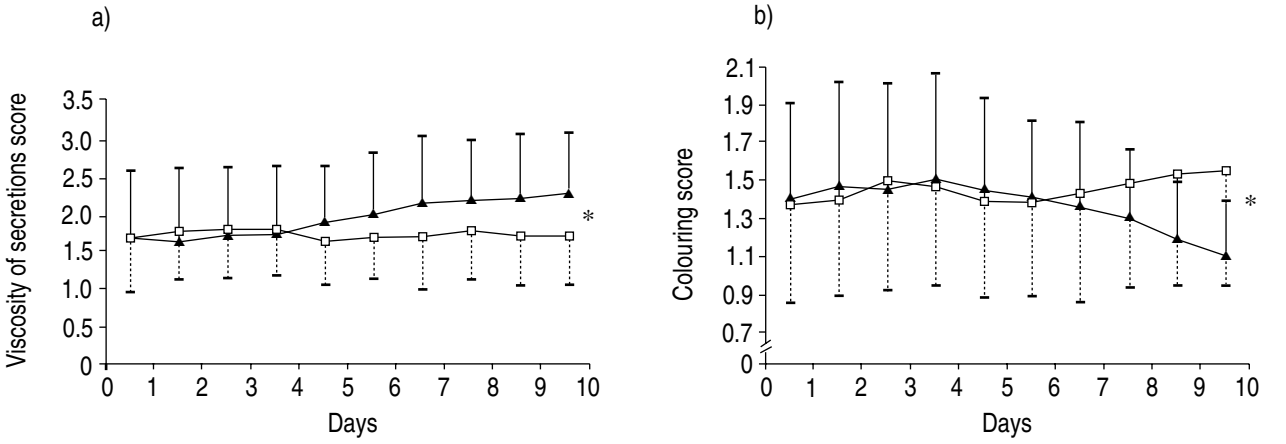

Fig. 2. – Data presented as mean+/-SD bars. a) Time course of change in viscosity of secretions (subjective score: 1=thick; 2=dry; 3=fluid). *: the two curves were statistically different ($p<0.05$ by ANOVA); only the HCH group curve presented significant differences over time ($p<0.01$ by ANOVA). b) Trend in secretion colouring (subjective score; 1=light; 2=yellowish; 3=dark). *: the two curves were statistically different ($p<0.01$ by ANOVA); only the HCH group curve presented significant differences over time ($p<0.005$ by ANOVA). —▲— : HCH groups; —❑— : control group. HCH: hygroscopic condenser humidifier.

group did the secretions become clearer during the study ($p<0.005$) (fig. 2b).

No significant changes were found in blood lymphocyte count, fever manifestation, new lung infiltrates or need for antibiotics during the whole study in either group. The oxygen requirement did not change over time for the HCH group; in the control group oxygen requirement changed from 11 patients to 15 during the period of the study. All patients were discharged after a rehabilitation trial. None had to be restarted on mechanical ventilation, and none died during hospitalization, but 8 out of 20 controls had drug therapy changed (increasing dosage of previous therapy or adding new drugs) in comparison to 4 HCH patients. None of the HCH patients suffered from any adverse effect, and in only 2 out of 20 patients in this group was a change of HCH necessary during the 24 h due to impaction of respiratory secretions in the HCH itself.

Table 2 shows the time course of respiratory function during the study. The HCH group improved in forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), MIP, tidal volume (V_T), and MVV over time. The control group experienced a worsening trend for pH, arterial carbon dioxide tension (Pa_{CO_2}), arterial oxygen tension (Pa_{O_2}), FEV_1, FVC and MVV.

On day 10 a greater number of Group 2 patients was colonized by 2 or 3 bacterial species. HCH patients who at baseline had not presented bacterial colonization or showed growth of only one species remained unchanged over time, unlike the control group which did not. During the study time, Group 2 showed a significantly ($p<0.001$) greater trend in increasing the number of bacteria than Group 1, who remained unchanged. Table 3 shows the qualitative distribution in bacteria between the two groups. The presence of Pseudomonas and Staphylococcus species in the HCH group remained similar over time; whereas, the control group showed a twofold increase in the presence of these bacteria. The total bacterial growth was similar between groups, the value over the 10 days ranging from 2.6×10^5 to 4×10^5 cfu·ml^{-1}.

The differences in temperature of breathed tracheal gases of all the 40 patients (HCH and controls) between rest and hyperventilation (HV) with and without HCH

Table 2. – Respiratory variables over time

		Baseline	Day 5	Day 10	p-value*
pH	HCH	7.38±0.05	7.39±0.03	7.39±0.03	NS
	Control	7.40±0.04	7.41±0.06	7.38±0.04	<0.01
$Paco_2$ kPa	HCH	6.80±1.31	6.63±1.03	6.47±1.06	NS
	Control	6.24±1.41	6.27±1.31	6.96±1.07	<0.005
Pao_2 kPa	HCH	8.12±2.14	8.71±1.54	8.54±1.20	NS
	Control	8.82±1.60	8.37±1.33	7.86±1.11	<0.01
FEV_1 *l*	HCH	0.66±0.28	0.76±0.29	0.77±0.30	<0.005
	Control	0.62±0.17	0.60±0.20	0.56±0.19	<0.02
FVC *l*	HCH	0.95±0.45	1.05±0.45	1.04±0.45	<0.005
	Control	1.10±0.41	1.07±0.42	1.02±0.38	<0.002
MIP cmH_2O	HCH	38±10	41±9	43±10	<0.02
	Control	36±7	35±7	34±9	NS
V_T ml	HCH	380±129	432±132	456±143	<0.005
	Control	407±82	399±112	370±165	NS
f breaths·min^{-1}	HCH	19±4	18±3	18±4	NS
	Control	18±4	20±4	19±4	NS
MVV *l*·min^{-1}	HCH	15±6	16±7	18±8	<0.003
	Control	19±9	19±8	17±8	<0.05

*: data obtained with a *post hoc* analysis of variance (ANOVA) test. For abbreviations see legend to table 1.

Table 3. – Qualitative microbiological data between groups and over time

		Candida	Pseudomonas	Staphylococcus	Providencia	Branhamella	Serratia	Klebsiella
Day 1	HCH	2	5	6	1	0	1	1
	Control	0	5	6	0	0	0	1
Day 5	HCH	1	5	5	1	0	1	1
	Control	1	9	10	1	1	0	0
Day 10	HCH	1	5	5	1	1	1	1
	Control	2	13	10	1	1	0	1

Numeric data show numbers of patients with positive microbiological sputum for specific infective agent. Each patient may be counted one or more times into the different infective agent column report.

are as follows: a statistically significant ($p<0.005$) difference was observed in resting position (34.4±1.5 *versus* 35.8±0.7°C without HCH and with HCH, respectively). Hyperventilation induced a significant temperature loss (mean ΔT 1.19 and 1.87°C during HCH application and without HCH, respectively). A statistically significant ($p<0.05$) difference in temperature was observed during hyperventilation (34.6±1.0 *versus* 32.5±1.6°C with and without HCH, respectively).

Discussion

This study shows that an HCH device, applied to tracheostomy in spontaneously breathing tracheostomized patients, decreases thickness and improves colouring of secretions over a period of 10 days. Forced expiratory flows, V_T, MVV and MIP improved significantly in the HCH group. In the control group, forced expiratory flows, MVV and blood gases worsened during the same period. Indices of bacterial colonization remained unchanged in the HCH group, whilst showing a trend to a greater colonization over time in the control group. Temperature of breathed tracheal gases was significantly lower during breathing without HCH than breathing with HCH, both at rest and during hyperventilation. The mean temperature loss was not different in the two conditions. To our knowledge no studies have been carried out on the effectiveness of HCH for tracheostomized patients who breathe spontaneously. For this reason, it was very difficult to compare our data with other papers, which usually compared standard vapourizing humidifiers with HCH.

After discharge, chronically tracheostomized patients may present many problems, such as poor tracheostomy hygiene, high flow of cool oxygen, high risk of exposure in a cool climate. These patients are frequently discharged without any system of tracheostomy protection. Recently, a detrimental effect on the patients' oxygenation status was recorded by a superimposed external heat and moisture nebulizer in an in-patient study [17].

A humidification system should maintain the airflow temperature, and should be microbiologically safe and not expensive. In our respiratory rehabilitation department, we tested a passive hygroscopic condenser humidifier as a solution to all these requirements over a short period of time. We can, therefore, extrapolate from our findings that similar results could be obtained after discharge.

Analysis of tracheal suctions showed that, although the amount of secretions assessed by the number of aspirations and by the subjective score was unchanged with HCH, after day 5 increasing fluidity and improved colouring was observed in the HCH group in comparison to controls. We can hypothesize that humidification, warming and protecting effects became stable after day 5. Whether the improvement in fluidity and colouring of secretions has a physiopathological effect remains to be clarified. The subjective score of our clinical assessment (quantitative and qualitative characteristics of the tracheal aspirations by the nurses) could be criticized. Nevertheless, another author used a subjective score [11], explaining that there is no objective test representative of the fluidity of tracheal secretions currently available for clinical studies. A limitation of our study is that we did not test moisture efficacy but only heating and filter capacity in avoiding bacterial colonization. Our data showed that the 6V ICOR-HCH has a protective capacity because it prevents new bacterial colonization (mainly *Pseudomonas aeruginosa* and *Staphylococcus aureus,* which are well-known contaminants of hospital environments), as demonstrated by the lack of increase over time of a number of bacterial species in the HCH group in comparison to controls. A heat and moisture exchanger may act as a barrier to the passage of bacteria; in fact it has been shown to be an efficient microbiological filter preventing ventilator contamination in 28 patients who required periods of mechanical ventilation for up to 22 days [18].

Increase in bronchial hyperreactivity due to bacterial or viral infection in COPD population is a matter of controversy [19], but this hypothesis could explain the beneficial effects on lung function and blood gases demonstrated in the HCH group who presented minor bacterial colonization. Bacterial distribution in our sample showed a slight prevalence in Gram-negative strains, as expected from these chronically ill patients. Pseudomonas species showed a threefold increase in nonprotected subjects. Although these protective effects may be considered controversial or insufficient for an intensive care unit environment, we believe that there would be a sufficient effect in a rehabilitative unit and at home where microbial agents are potentially less dangerous and lower in number.

During spontaneous breathing, the body loses heat; this loss is caused by expiratory gases which present a higher temperature and humidity in comparison with inspiratory gases. These differences may be enhanced during hyperventilation in a hypothetical acute respiratory relapse. Inspiratory temperature of asthmatic subjects breathing subfreezing air, falls from approximately 35°C at rest to 29.7°C during exercise [20]. AMIRAV and PLIT [21] demonstrated that, during cold dry air breathing, the response of normal human airways to inhaled histamine was greater than that observed during warm humid air breathing. One author has also shown that HCH reduces heat loss perioperatively [22]. Our results in spontaneously breathing tracheostomized patients are rather similar to asthmatic subjects. Hyperventilation induced a significant reduction in the temperature of breathed gases in both conditions, the mean variation in temperature (ΔT) between rest and hyperventilation being higher, although nonsignificantly, in the unprotected condition (1.87 *versus* 1.19°C). The problem of cool air exposure, respiratory moisture loss, or a combination of the two, as triggers for airflow-induced bronchospasm is debated. The HCH used in our study showed a preventive role in temperature loss during a hyperventilation test used as a simulated relapsing event. NIEDERMAN *et al*. [23], in 49 sets of cultures on 15 subjects with long-term tracheostomy, found that patients with persistent tracheobronchial colonization were more ill than those without this finding. They were treated with higher doses of prednisone, received antibiotics and developed purulent tracheobronchitis more often than patients without persistent colonization.

Although functional data have not been corrected for the mechanical changes imposed by the tracheostomy cannula, this fact was not a limitation because the functional measurements were performed at different times in similar conditions; statistical analysis was performed on trend data rather than on static indices.

Results of lung function tests (forced expiratory volumes and MIP improving in the HCH group, and simultaneous blood gases and spirometric values worsening with subsequent increase in number of controls requiring oxygen therapy) confirmed the hypothesis that adequate humidification, heating, maintenance of airway integrity, prevention of bacterial colonization and improving fluidity of secretions may influence functional outcome in these patients. Tidal volumes increased over time in the HCH group, probably explaining the fact that Pa_{O_2} and Pa_{CO_2} did not deteriorate as in the control group. More difficult to explain are the increasing values of MIP and FEV_1 in the HCH group; on the contrary, a negative trend was observed in controls. The hypothesis that an inspiratory load added to the patient could have trained him, ameliorating MIP, is possible but it is not supported by specific measurements in our study.

HCHs may increase the dead space, the flow resistances and the risk of cannula obstruction [9, 17]. The increase in flow resistance may cause respiratory muscle fatigue and ventilatory failure in debilitated patients [17]. CHIARANDA *et al*. [12] have shown that heat and moisture exchanging (HME) filters did not create a significant obstacle to airflow during medium term mechanical ventilation, but that these devices should be cautiously used in patients with heavy bronchial secretions. Our preliminary unpublished data do not seem to show significant changes in flow resistance when adding an HCH to a chronically tracheostomized patient. Our present data on a medium term trial should be supported by other studies on spontaneously breathing tracheostomized patients, particularly on the hypothetical side-effects on respiratory mechanics.

In conclusion, HCH may be useful in chronically tracheostomized patients who breathe spontaneously: 1) to improve viscosity and colouring of sputum, preventing new bacterial colonization; 2) to heat inspiratory airflow, possibly protecting against temperature loss during a hyperventilation test; and 3) to help in improvement of functional outcome.

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References

1. Pingleton S. Complications of acute respiratory failure. *Am Rev Respir Dis* 1988; 137: 1463–1493.
2. Forbes AR. Temperature, humidity and mucus flow in the intubated trachea. *Br J Anaesth* 1974; 46: 29–34.
3. Chalon J, Patel C, Ali M, *et al*. Humidity and the anaesthetized patient. *Anesthesiol* 1979; 50: 195–198.
4. Noguchi H, Takumi Y, Rochi O. A study of the humidification in tracheostomized dogs. *Br J Anaesth* 1973; 45: 844–847.
5. Alexopoulos C, Jansson B, Lindholm C. Mucus transport and surface damage after endotracheal intubation and tracheostomy. An experimental study in pigs. *Acta Anaesthesiol Scand* 1984; 28: 68–76.
6. Deal EC, MacFadden ER, Ingram RH, Jaeger JJ. Hyperpnea and heat flux: initial reaction sequence in exercise-induced asthma. *J Appl Physiol: Respirat Environ Exercise Physiol* 1979; 46: 476–483.
7. Anderson SD, Daviskas E, Smith C. Exercise-induced asthma: a difference in opinion regarding the stimulus. *Allergy Proc* 1989; 10: 215–225.
8. Sottiaux T, Mignolet G, Damas P, Lamy M. Comparative evaluation of three heat and moisture exchangers during short-term postoperative mechanical ventilation. *Chest* 1993; 104: 220–224.
9. Cohen IL, Weinberg PF, Fein IA, Rowinski GS. Endotracheal tube occlusion associated with the use of heat and moisture exchangers in the Intensive Care Unit. *Crit Care Med* 1988; 16: 277–279.
10. Tenaillon A, Cholley G, Boiteau R, Perrin-Gachadoat D, Burdin M. Filtre enchangeur de chaleur et d'humiditè *versus* humidificateur chauffant en ventilation mecanique prolonge. *Rean Soins Intens Med Urg* 1989; 5: 5–10.
11. Misset B, Escudier B, Rivara D, Leclercq B, Nitenberg G. Heat and moisture exchanger *vs* heated humidifier during long-term mechanical ventilation. A prospective randomized study. *Chest* 1991; 100: 160–163.
12. Chiaranda M, Verona L, Pinamonti O, Dominioni L, Minoja G, Conti G. Use of heat and moisture exchanging (HME) filters in mechanically-ventilated ICU patients: influence on airway flow-resistance. *Intensive Care Med* 1993; 19: 462–466.
13. Martin C, Perrin J, Gevaudan M, Saux P, Gouin F. Heat and moisture exchangers and vaporizing humidifiers in the ICU. *Chest* 1990; 97: 144–149.
14. Shelly MP, Lloyd GM, Park GR. A review of the mechanisms and methods of humidification of inspired gases. *Intensive Care Med* 1988; 14: 1–9.
15. Ploysongsang Y, Branson R, Rashkin MC, Hurst JM. Pressure flow characteristics of commonly used heat-moisture exchanges. *Am Rev Respir Dis* 1988; 138: 675–678.
16. Murray PR, Washington JA. Microscopic and bacteriologic analysis of expectorated sputum. *Mayo Clin Proc* 1975; 50: 339–344.
17. Hay R, Miller WC. Efficacy of a new hygroscopic condenser humidifier. *Crit Care Med* 1982; 10: 49–51.
18. Gallagher J, Strangeways JE, Allt-Graham J. Contamination control in long-term ventilation: a clinical study using a heat and moisture exchanging filter. *Anaesthesia* 1987; 42(5): 476–481.
19. Hunninghake GW. Infections and bronchial hyperreactivity in COPD. *Eur Respir Rev* 1992; 9: 166–168.
20. Gilbert IA, Fouke JM, McFadden ER. Heat and water flux in the intrathoracic airways and exercise-induced asthma. *J Appl Physiol* 1987; 63: 1681–1691.
21. Amirav I, Plit M. Temperature and humidity modify airway response to inhaled histamine in normal subjects. *Am Rev Respir Dis* 1989; 140: 1416–1420.
22. Linko K, Honkawarra P, Nieminen M-T. Heated humidification in major abdominal surgery. *Eur J Anaesthesiol* 1984; 1: 285–291.
23. Niederman MS, Ferranti RD, Zeigler A, Merrill WW, Reynolds HY. Respiratory infection complicating long-term tracheostomy. The implication of persistent Gram-negative tracheobronchial colonisation. *Chest* 1984; 85(1): 39–44.