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Physicians' attitude to use heat and moisture exchangers or heated humidifiers: a Franco-Canadian survey

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Abstract *Objective:* To understand the national utilization pattern of heat and moisture exchangers (HME) and heated humidifiers (HH) in mechanically ventilated ICU patients. *Design:* Cross-sectional survey. *Population:* ICU directors in French and Canadian university-affiliated hospitals. Response rate was 89%. *Measurements:* We asked respondents whether they primarily used HME or HH. We recorded whether HME were used in all patients and for how long, how often they were changed, for whom, and why they were not used. *Results:* HME were used more often in France HH in Canada. HME were more likely to be used for all patients in France than in Canada (63% vs. 13% and for any duration of ventilation (93% vs. 35%). Short-term use of HME was more common in Canada than in France (59% vs. 7%). HME were primarily changed every day in both countries. The patients for whom HME were not used and reasons for nonutilization were similar in France and Canada. The variable of country was the strongest predictor of HME utilization for every patient (France vs. Canada, odds ratio 11) and utilization for periods of 5 days or less (Canada vs. France, odds ratio 22). *Conclusions:* HME were reportedly used more in often in France than in Canada for the entire duration of mechanical ventilation. This survey highlights perceptions and practices related to the determinants and consequences of airway humidification and suggests differences in the cost of mechanical ventilation between countries

Keywords Mechanical ventilation · Airway humidification · Heat and moisture exchangers · Heated humidifiers · Survey · Inspired gases

Introduction

Mechanical ventilation of critically ill patients requires adequate airway heating and humidification to counterbalance bypassing of the upper respiratory tract occasioned by the endotracheal tube. Such conditioning may be obtained either with heated humidifiers (HHs; based on a hot water system) or with more recent disposable devices called heat and moisture exchangers (HMEs). Several types of HMEs which exhibit different humidifying and antibacterial properties (depending on the material with which they are built) are available. Purely hydrophobic HMEs were among the first HMEs to be developed. They possess very high antibacterial properties but perform poorly in terms of humidity output and have been responsible for endotracheal tube occlusions [1, 2, 3, 4, 5]. Hygroscopic HMEs have better humidifying performance than the hydrophobic HMEs but do not possess antibacterial filtration properties. Lastly, more recent HMEs comprise together hydrophobic and hygroscopic properties and therefore exhibit both adequate humidifying qualities and antibacterial filtration properties [6, 7, 8, 9, 10, 11].

Although the need for adequate humidification during mechanical ventilation is not questioned, the best way to

reach it is still a matter of debate. Several clinical studies have shown that HMEs offer the advantage of being more economic, easier to use, and clinically as efficient as HHs in heating and humidifying the inspired gases during mechanical ventilation [6, 7, 12, 13, 14]. On the other hand, HMEs have several potential drawbacks which may restrict their use. Due to their important internal volume they increase circuitry deadspace, which may in turn increase minute ventilation, $PaCO_2$, and work of breathing during pressure support ventilation [15, 16, 17]. However, Pelosi and coworkers [16] have shown that increasing the level of pressure support easily overcomes this effect. Use of HMEs during reduced-tidal volume ventilation of patients with ARDS has been shown to increase $PaCO_2$ [9], and it may be preferable in this situation to use HHs.

It therefore appears that HMEs may not be applicable in all circumstances. Unfortunately, there are no existing published practice guidelines on the management of airway humidification. In addition, several issues concerning airway humidification and the use of HMEs are still debated, including the type of patients who can be ventilated with HMEs, the exact duration of HME use before its replacement, and the appropriate duration of mechanical ventilation with an HME. Although clinical practices of critical care medicine have been evaluated, most of these studies are regional or national surveys and were not designed to enable comparisons between countries. Specifically, mechanical ventilation practices have been studied in several national surveys in France [18], Spain [19], and the United States [20]. Although these studies have highlighted diverse approaches to caring for critically ill patients within a particular country, little is known about the similarities or differences that exist between clinical practices used in different countries based on direct comparison. Such differences and reasons for their existence may be important to know before devising and implementing international clinical practice guidelines.

We have previously shown that considerable differences exist between France and Canada concerning the utilization of ventilator circuit and secretion management strategies in critically ill patients [21]. Among several other strategies, it appeared that airway heating and humidifying management differ between the two countries. Therefore we surveyed ICU directors in France and Canada to learn more extensively about utilization patterns of HMEs and HHs in critically ill mechanically ventilated patients.

Methods

We followed questionnaire design methodology, including item generation, reduction, presentation, and pretesting [22]. Briefly, to generate items for potential inclusion we conducted a bibliographic search of Medline and Embase using the text words ventilator, inspired gases, humidification, randomized trial, critically ill, and intensive care. We retrieved and reviewed all randomized trials of ventilator circuit and secretion management strategies in critically ill patients which had been evaluated with respect to the inspired gases conditioning. We excluded children and immunocompromised patients.

Five interventions were identified: use of HME or HH, type of patients on each device, length of stay with the device, duration of HME use before change, and indication and contraindication to the use of the devices.

To ensure clarity and to remove redundant or illogical items the questionnaire was pretested by eliciting feedback through semistructured interviews with eight ICU practitioners (four physicians and four respiratory therapists). It was then translated from English into French, pretested for sensibility in French [23], and then back-translated into English to ensure cross-cultural validity [24]. Respiratory therapists work in university-affiliated ICUs in Canada but not in France; therefore this response option about decisional responsibility was included in the Canadian survey only. We mailed the survey to all ICU directors of university-affiliated ICUs in France and Canada and contacted nonrespondents twice either by phone, mail, or facsimile. ICU assistant directors were approached if directors did not respond. Participation was voluntary, and all responses were kept confidential.

The number of ICU beds is expressed as means ±SD. We used the two-tailed Smith-Satterthwaite modified *t* test to compare bed capacity between countries. We used the two-tailed Fisher's exact test to compare the distribution of responses between countries.

We conducted logistic regression analysis to identify predictors of the utilization of HMEs in every ICU patient. The independent variables were the number of ICU beds, population (medical, surgical, or mixed) and country. Forward selection was used if $p<0.05$ in the univariate analysis to determine significant predictors. Odds ratios (OR) and 95% confidence intervals (CIs) are reported for significant predictors. A second regression analysis was performed using the same independent variables to evaluate determinants of the utilization of HMEs and filters for short periods of mechanical ventilation for 5 days or less.

Results

The overall response rate was 89% (72 of 84 French ICUs, representing 55 different hospitals; 31 of 32 Canadian ICUs, representing 29 different hospitals). The total number of beds represented by 103 respondents was 1054 in France and 639 in Canada. More ICUs in France were medical, whereas more Canadian centers were mixed medical-surgical ICUs ($p=0.0004$).

Figure 1 presents the use of HMEs and HHs, which differed significantly between the two countries. HMEs were more likely to be used in France and HHs in Canada. The predominant type of HMEs used in France was hydrophobic and hygroscopic HMEs. Other findings are presented in Table 1. HMEs were more often used for all mechanically ventilated ICU patients in France than in Canada (62.9% vs. 13.3%, $p<0.0001$). They were more likely to be used for any duration of mechanical ventilation in France than in Canada (93% vs. 35.3%, $p<0.0001$), whereas they were more likely to be used for periods of ventilation lasting 5 or fewer days in Canada than in France (58.8% vs. 7.0%, $p<0.0001$). Approximately 65% of respondents in both countries reported changing HMEs every 24 h.

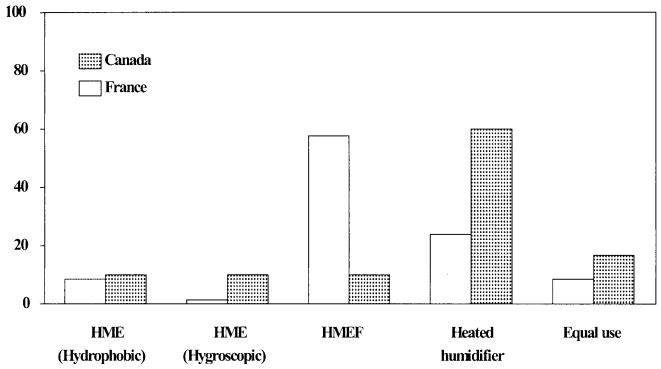

Fig. 1 Percentages of use of each humidifying device reported by 103 ICU directors. *HME* Heat and moisture exchangers; *HMEF* HME with both hydrophobic and hygroscopic properties

Respondents reporting that they do not use filters in every ventilated patient identified several populations for which filters were not used (Table 1). These populations were similar in the two countries and included chronic obstructive airway disease, acute respiratory distress syndrome, burn injury, copious secretions, hemoptysis, and hypothermia. Reasons for nonuse of HMEs were similar in France and Canada and included concerns about possible increased resistance, difficult weaning, insufficient humidification, fear of tube obstruction, and policies inconsistent with research evidence. General ICU policy was cited more commonly by French ICU directors as the main determinant of HME use (92.5% vs. 72.4%, p=0.02). In Canadian centers individual respiratory therapists determined the use of filters in 24.1% of ICUs.

Table 1 Utilization of heat and moisture exchangers (*HME*) reported by 103 ICU directors (*HH* heated humidifiers, *HMEF* HMEs with both hydrophobic and hygroscopic properties, *ARDS* acute respiratory distress syndrome, *COPD* chronic obstructive pulmonary disease)

	France		Canada		*p*
	n	%	*n*	%	
Utilization					
Primarily heated humidifiers	17	23.9	18	60	0.0004
Primarily hydrophobic HME	6	8.5	3	10	
Primarily HMEF[a]	41	57.7	3	10	
Primarily hygroscopic HME	1	1.4	1	3.3	
Equal use of HH and HME	6	8.5	5	16.7	
Use of HME in all ICU patients	39	62.9	4	13.3	<0.0001
Duration of HME use					
Primarily for <5 days	4	7	10	58.8	<0.0001
Primarily for >5 days	0	0	0	0	1
Any duration of ventilation	53	93	6	35.3	<0.0001
Uncertain	0	0	1	5.9	0.23
Frequency of HME change					
Every 24 h	38	65	11	64.7	1
Every 48 h	17	29.3	2	11.8	0.21
Every week	1	1.7	2	11.8	0.13
Other	3	5.2	2	11.8	0.32
Uncertain	1	1.7	1	5.9	0.4
Patients in whom HME are not used					
COPD patients	2	10	4	18.2	0.67
ARDS patients	3	15	3	13.6	1
Immunocompromised patients	0	0	2	9.1	0.49
Other[a]	18	90	18	81.8	1
Uncertain	0	0	2	9.1	0.49
Reasons for nonutilization of HME					
Fear of adverse effects	10	62.5	9	45	0.34
Cost	2	12.5	7	35	0.24
Not available	2	12.5	1	5	0.57
Other	8	50	8	40	0.74
Uncertain	0	0	1	5	1
Decisional responsibility for HME					
Individual intensivists	2	3	1	3.5	1
Individual respiratory therapists	na[b]	–	7	24.1	–
Individual nurses	2	3	0	0	1
General ICU policy	62	92.5	21	72.4	0.02
Other	2	3	3	10.3	0.16

[a] Includes: burns, trauma, high humidity requirement, hypothermia, chronic ventilation, pulmonary hemorrhage, atelectasis, bronchopleural fistula, high minute ventilation, and difficult weaning

[b] Not applicable in France (see text for detail)

Table 2 Factors associated with using HMEs in every ICU patient: factors associated with use of heat and moisture exchangers for every mechanically ventilated ICU patient The only factor that was predictive in the univariate and the multivariate analyses was country (France)

Variable	Univariate OR (95% CI)	*p* value	Multivaria5e	*p* value
Number of beds	0.98 (0.92–1.03)	0.35		–
Type of ICU		0.07		0.053
Medical vs. medical/surgical	0.87 (0.28–2.52)			
Surgical vs. medical/surgical	3.74 (1.13–14.77)			
Country (France vs. Canada)	11.02 (3.74–40.98)	<0.0001	11.02 (3.74, 40.98)	<0.0001

Table 3 Factors associated with using HMEs primarily for max. 5 days: factors associated with use of heat and moisture exchangers for max. 5 days of mechanical ventilation. In the univariate analysis, size of ICU and country were predictive of short-term use of HMEs, but in the multivariate analysis only country (Canada) was predictive

Variable	Univariate OR (95% CI)	*p*	Multivariate	*p*
Number of beds	1.2 (1.1–1.3)	<0.00007		
Type of ICU		0.22		0.053
Medical vs. medical/surgical	0.2 (0.01–1.3)			
Surgical vs. medical/surgical	0.5 (0.1–2.2)			
Country (France vs. Canada)	22.1 (5.7–104.4)	<0.0001	22.1 (5.7–104.4)	<0.0001

Table 2 presents factors associated with the use of HMEs for ventilated patient. In the multivariate analysis only country was a significant predictor; the relative odds of using HMEs and filters for each new patient was 11.0 (95%CI 3.7–41.0%, $p<0.0001$) in France vs. Canada. Table 3 presents factors associated with the use of HMEs for short periods of 5 or fewer days of mechanical ventilation. In the univariate analysis larger ICUs and Canadian ICUs were associated with use of filters fort short periods. In the multivariate analysis only country was a significant predictor; the relative odds of using HMEs for 5 or fewer days in Canada vs. France was 22.1 (95%CI 5.7–104.4, $p<0.0001$).

Discussion

This cross-national survey was conducted to better understand differences in airway heating and humidifying strategies for mechanically ventilated ICU patients between France and Canada. Interestingly, HMEs were reportedly used more often in France for all mechanically ventilated patients and for any duration of mechanical ventilation than in Canada, where HHs were more frequently used. Despite these important differences in humidification practices between the two countries, contraindications and reasons cited for not using HMEs were the same in the two countries. This utilization review sheds light on the way in which data from clinical research are put into practice, provides important background information when designing and implementing international practice guidelines, and suggests different economic consequences of management approaches.

The basic principles of HMEs were described in the late 1950s [25] and the early 1960s [26] but have undergone considerable development since the end of the 1970s [27]. Their use was initially limited to the operating room before being extended to the ICU by the middle 1980s. Although their technical performances are dictated by international standards [28, 29], published practical guidelines concerning their use are not readily available. Reasons for using or not using these devices may therefore be based on the clinical experience, prevailing practice patterns, and the knowledge of research evidence of each individual care provider. This may explain in part why we found that over two-thirds of the French ICUs surveyed use HMEs but less than one-quarter of the Canadian ICUs. Indeed, a North-American team has studied HME implementation in the ICU and proposed an algorithm to help clinicians decide whether to use an HME [13, 30]. Based on the algorithm, Branson and colleagues [13] found that only 19% of medical patients and 67% of surgical patients were eligible for mechanical ventilation with an HME. These figures greatly contrast with those reported in clinical research undertaken in Europe and more specifically in France where all medical patients are eligible for HME use as long as the rare contraindications are respected [2, 3, 12, 31, 32, 33]. This difference could have been explained by a different interpretation of the contraindications of the use of HMEs between the two countries. However, our survey results do not support that this is the case since respondents in two countries provided the same reasons for not using HMEs (Table 1). Two other findings obtained from this survey offer a possible explanation for these differences between the countries. First, decisional responsibility for HME use was more often

implemented through general ICU policy in France (92.5%) than in Canada (72.4%), and, second, respiratory therapists who had decisional responsibility for HMEs in approximately one-quarter of ICUs in Canada do not exist in France. The North American expertise in the field of airway humidification of respiratory therapists may influence Canadian colleagues in North America to restrict the use of HMEs. In contrast, French studies on HMEs may influence clinical practice and increase use in France [2, 3, 4, 7, 8, 11, 12, 32].

Another important difference between countries observed in this survey was the duration of use of the HMEs (Table 1). While the vast majority (93%) of the French intensivists use HMEs for any duration of ventilation, a clear majority of Canadian intensivists limit the duration of use of HMEs to 5 days or less. There again the reasons for these differences may reside in the data from the literature. Limitation of HME use to a certain period of time has not been taken into account in the French studies on airway humidification. Indeed, several clinical trials have shown that patients have been ventilated with HMEs without any problem for more than 40 days [7, 8, 32]. The North American perspective appears different. Even if patients are considered eligible for mechanical ventilation with an HME, they are often placed on a HH after 5 [13, 30] or 7 [14] days of mechanical ventilation. Often cited are modified respiratory epithelium alterations due to decreased humidifying performances of the HME over time. Interestingly, Hurni and colleagues [9] found that although there was a slight decrease in the integrity of the tracheobronchial ciliated epithelium (assessed by a cytological score based on examination of endotracheal aspirates) after 5 days of mechanical ventilation; this decrease was similar whether the patients were placed on a HH or on an HME. There is now a large body of evidence showing that HMEs can be used for long-term mechanical ventilation; initial time restrictions were primarily based on reports of endotracheal tube occlusions [1, 2, 3, 4, 5] among patients ventilated with poorly performing HMEs such as purely hydrophobic HMEs [2, 6, 10, 34]. Such endotracheal tube occlusions are nowadays seldom seen with HMEs exhibiting both hydrophobic and hygroscopic properties, and this may well account for the large utilization of these HMEs in France (Fig. 1).

The optimal frequency of HME changes is an ongoing debate [35]. Manufacturers recommend that HMEs be changed every 24 h, although this is not supported by objective data. More than 5 years ago a randomized clinical trial that studied over 150 patients for 23 months showed that changing HMEs every 48 h rather than every 24 h did not affect their efficacy nor the incidence of nosocomial pneumonia [8]. More recently other studies have confirmed these results [11, 33]; however, these studies were published after this survey was conducted. Therefore after the 1995 randomized trial results were available [8] approximately 30% of the French ICUs but only 10% of the Canadian ICUs in this survey reported changing their HMEs every 48 h. The impact of published recommendations or of results from original studies on practice patterns of individuals and groups are dynamic and complex and depend on many factors such as the ICU population, caregiver perception of the risk:benefit and cost:benefit ratios of different interventions, the volume and quality of evidence supporting or refuting their effectiveness, local issues such as availability, and individual and ICU policy, and broad cultural variables.

Use of HMEs may have potential drawbacks that may incline clinicians to favor HHs in certain circumstances. As shown in Table 1, some respondents did not use HMEs in patients with acute respiratory distress syndrome or chronic obstructive pulmonary disease. In the former, withdrawal of the HME during permissive hypercapnia ventilation may result in a significant fall in $PaCO_2$ [9]. In the latter, use of HMEs has been shown to increase minute ventilation, $PaCO_2$ and work of breathing during pressure support ventilation [15, 16], although these effects may be easily overcome by simply increasing level of pressure support [16, 36]. These adverse effects are related to the important internal volume of HMEs that convey additional deadspace. In the above situations the use of HHs may be recommended. Also, it may be interesting to evaluate HMEs with smaller internal volumes in these situations.

Several investigators have shown that mechanical ventilation with HMEs instead of HHs results in substantial cost savings [7, 13] especially when HMEs are changed every 48 h rather than every 24 h [8, 11, 33], when they are used for up to the first 7 days of mechanical ventilation [14], and in particular when they are changed only once a week [32]. Thus the notable differences in the use of HMEs revealed by this survey either in the number of ICUs that use HMEs or in the duration of HME use that exist between France and Canada further support the notion that the cost of mechanical ventilation may be lower in France than in Canada [21].

This survey builds on our prior work describing ventilator management within and between two countries [21]. In this study we conducted an in-depth evaluation of commonly employed humidification strategies, focusing on the use of HMEs for whom, for how long, why, and according to various decision-makers in the ICU. The survey was rigorously developed and tested, including cross-cultural adaptation for cross-cultural comparisons. Limitations of this work include the universal proviso for all questionnaires, which report stated practice patterns rather than observed practice patterns. We did not directly evaluate knowledge of clinical research evidence about HMEs, which could have contributed to differences between countries. Because many investigations about HMEs have been conducted in France [2, 3, 7, 12], national research expertise may theoretically influence prevailing ICU practices more in France than in Canada. Finally, although having restricted this survey to two

countries and to university-affiliated ICUs may limit the impact of the study, it enabled a consistent and coherent comparison of countries with different health care organizations and also enabled an exceptionally high response rate. In any case, this survey clearly shows important differences in airway humidification strategies between the two countries which may significantly affect the cost of mechanical ventilation [37] and suggests the need for current evidence based practice guidelines on airway heating and humidification.

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