Evaluation of the Ventilator-User Interface of 2 New Advanced Compact Transport Ventilators

François Templier MD, Patrick Miroux MD, François Dolveck MD, Alexis Descatha MD, Nathalie-Sybille Goddet MD, Charles Jeleff MD, Michel Baer MD, Marcel Chauvin MD PhD, Laurent Brochard MD PhD, and Dominique Fletcher MD PhD

BACKGROUND: Mechanical ventilation during patient transport frequently utilizes compact portable pneumatic ventilators that have limited ventilator-settings options. New advanced transport ventilators should yield quality improvements, but their user-friendliness needs to be tested. OBJECTIVE: To evaluate the ventilator-user interface of 2 new transport ventilators. METHODS: This was a 2-center descriptive study in which the ventilator-user interfaces of the Oxylog 3000 and Elisée 250 were compared by 20 French senior emergency physicians who were initially unfamiliar with these ventilators. Each physician carried out 15 tasks with each ventilator and then assigned each ventilator a satisfaction score. RESULTS: With the Elisée 250 the task success rate was significantly higher (85.6% vs 66.6% with the Oxylog 3000, $p < 0.0001$), and the total number of errors was lower (46 vs 113). The main errors were related to inspiratory flow settings with the Oxylog 3000 (31 errors), inspiratory-expiratory ratio settings with the Elisée 250 (11 errors), ventilation mode choice with the Oxylog 3000 (17 errors), trigger sensitivity setting with the Elisée 250 (16 errors) and the Oxylog 3000 (11 errors), and alarm range setting with the Oxylog 3000 (10 errors). The mean satisfaction score was significantly better with the Elisée 250 (81% ± 7, range 64–92%) than with the Oxylog 3000 (66% ± 10, range 49–87%) ($p < 0.0001$). CONCLUSIONS: The Elisée 250 ventilator-user interface was easier to use than that of the Oxylog 3000. The applicability of these results to other types of users will require further studies, but the types of errors found in our study might help future users. *Key words: ventilator-user interface, evaluation, mechanical ventilation, transport ventilator, ventilator.* [Respir Care 2007;52(12):1701–1709. © 2007 Daedalus Enterprises]

Introduction

Mechanical ventilation is widely used during prehospital care and intrahospital and interhospital transport,[1] but patients who require mechanical ventilation are often unstable, and their transport may be associated with ventilatory function deterioration.[2] Ventilators are recommended that can provide ventilation with the same settings and parameters.[3] Ventilator choices include portable pneumatic ventilators, which are compact and easy

François Templier MD, François Dolveck MD, Alexis Descatha MD, Nathalie-Sybille Goddet MD, Michel Baer MD, Marcel Chauvin MD PhD, and Dominique Fletcher MD PhD are affiliated with the SAMU 92, Département d'Anesthésie Réanimation, Hôpital Raymond Poincaré, Université Paris Ile de France Ouest, Garches, France. Patrick Miroux MD and Charles Jeleff MD are affiliated with the Service d'Accueil des Urgences, Hôpital de Compiègne, Compiègne, France. Laurent Brochard MD PhD is affiliated with Réanimation Médicale, Hôpital Henri Mondor, Université Paris, Créteil, France.

Dr Templier has been a consultant to ResMed, Savigny le Temple, France, which manufactures the Elisée 250, with regard to the user interface of the Elisée 250. Dr Brochard has received research grants from Dräger Medical and Maquet. The authors report no other conflicts of interest related to the content of this paper.

Dr Templier presented a version of this paper at the 47th National Congress of the French Anesthesiology Society, held September 21–24, 2005, in Paris, France.

Correspondence: François Templier MD, SAMU 92, Département d'Anesthésie Réanimation, Hôpital Raymond Poincaré, Assistance Publique Hôpitaux de Paris, 104 Boulevard Raymond Poincaré, 92380 Garches, France. E-mail: francois.templier@rpc.aphp.fr.

Table 1. Comparison of the Main Technical Aspects of the Elisée 250 and Oxylog 3000

	Elisée 250	Oxylog 3000
Motor type	Electrically powered miniaturized turbine	Pneumatically powered (third-generation)
Weight (kg)*	4.5	4.9
Dimensions (cm)*	29 × 25 × 13	28.5 × 18.4 × 17.5
Battery life*	4 h on 1 battery 8 h on 2 batteries	4 h
Ventilation modes (French abbreviation†)	VC-VAC AI VPC-VPAC PEP	VC-VAC-VACI AI BIPAP PEP
I:E setting	Set via inspiratory flow setting	Set directly
Inspiratory flow setting	Set directly	Set via I:E setting ± end-inspiratory pause
Settings after starting ventilator in volume-controlled mode	Respiratory rate 15 breaths/min V_T 500 mL F_{IO_2} 60% PIP 50 cm H_2O Inspiratory flow 50 L/min PEEP 0 cm H_2O Trigger on at sensitivity level 3	Respiratory rate = setting left by previous user V_T setting left by previous user F_{IO_2} setting left by previous user PIP setting left by previous user I:E 0.5 PEEP 4 cm H_2O Trigger off

*According to manufacturer
†For each mode, the meaning of the French abbreviation that appears on the ventilator is indicated below, followed by the English translation:
VC = ventilation contrôlée = CV = controlled ventilation
VAC = ventilation assistée contrôlée = ACV = assist control ventilation
VACI = ventilation assistée contrôlée intermittente = SIMV = synchronized intermittent mandatory ventilation
AI = aide inspiratoire = PSV = pressure support ventilation
VPC = ventilation en pression contrôlée = PCV = pressure control ventilation
VPAC = ventilation en pression assistée contrôlée = PACV = pressure assist control ventilation
BIPAP = Biphasic positive airway pressure (specific mode of Dräger ventilator)
PEP pression expiratoire positive = PEEP = positive end expiratory pressure
I:E = inspiratory-expiratory ratio

to use but have limited settings and/or performance,[4] and intensive-care-unit (ICU) ventilators, many of which are bulky and have less autonomy, notably during interhospital transport.[5] Adverse events during transport may be related to improper ventilator use as well as inadequate user training.[6] Use of ICU advanced ventilators by well-trained physicians may limit the risk of adverse events during transport,[7,8] but not all users have the same expertise in their use.[1,9]

The ideal advanced compact transport ventilator should have the usual capabilities of an ICU ventilator (volume and pressure ventilation modes, positive end-expiratory pressure, alarms, monitoring) and be autonomous and conveniently portable.[10] The ventilator should also be easy to use and allow rapid and error-free regulation of ventilator settings and parameters, as well as correct identification of alarms and monitoring,[10] but without precise recommendations as far as international standards.[11] Very few studies have evaluated the ventilator-user interface,[12–14] and none have involved emergency transport ventilators.

The purpose of the present study was to evaluate the ease of use of 2 newer advanced compact transport ventilators. We also asked the participating physicians to evaluate their level of satisfaction with the 2 ventilators.

Methods

Ventilators

The 2 tested ventilators were the Oxylog 3000 (Dräger, Lübeck, Germany) and the Elisée 250 (ResMed, Savigny le Temple, France). Both ventilators are suitable for use during intrahospital, interhospital, and prehospital patient transport. They have similar features overall, with a few technical differences (Table 1). Their user interfaces, however, are based on 2 different concepts: the Oxylog 3000 has a combination of different types of controls (Fig. 1), whereas the Elisée 250 has a touch-pad (Fig. 2). Compared to most standard transport ventilators,[10] they offer a high performance level and a large choice of settings.

Study Design

We conducted a 2-center descriptive study to compare the use of 2 new advanced compact ventilators suitable for

Fig. 1. The Oxylog 3000 transport ventilator. The user interface facilitates direct and rapid access to the main ventilation parameters via dials similar to those found on simple pneumatic ventilators (eg, tidal volume, respiratory rate, maximum inspiratory pressure, and fraction of inspired oxygen). Advanced setting options can be selected by using the pressure-sensitive keys (for start-up procedure or ventilation mode, for example) and the master click-dial. VC = ventilation contrôlée (controlled ventilation). This also allows access to the assist-control ventilation mode when the inspiratory trigger is activated by the master click-dial. VACI-AI = ventilation assistée contrôlée intermittente - aide inspiratoire (synchronized intermittent mandatory ventilation - pressure-support ventilation). VS PEP-AI = ventilation spontanée avec PEP - aide inspiratoire (spontaneous ventilation with positive end-expiratory pressure - pressure-support ventilation). BIPAP-AI = biphasic positive airway pressure (Dräger-specific ventilation mode) (pressure-support ventilation). The BIPAP-AI mode was not tested in the present study.

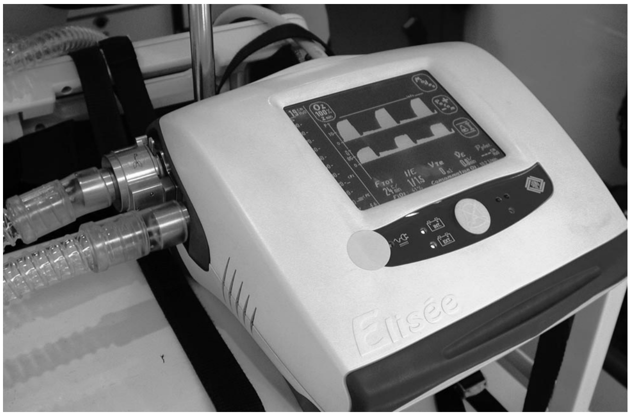

Fig. 2. The Elisée 250 transport ventilator. The ventilator settings are adjusted chiefly via the touch-pad, which has 4 display screens, each dedicated to one function: mode selection, machine parameter settings, alarm settings, patient monitoring (screen shown in this picture). The on/off button is on the side of the ventilator and is not visible in this picture. A lit button under the screen signals alarms visually and allows for the turning off of alarm sounds.

transport: the Oxylog 3000 and the Elisée 250. Three investigators (French senior emergency physicians) collected data from 20 French emergency physicians (10 at each center) who had common training in emergency medicine, but irrespective of their experience or skill with mechanical ventilation or other criteria. Absence of prior experience with the 2 study ventilators was required. The ventilators were tested in random order, using a randomization list and sealed envelopes. Randomization was performed independently at each site. The study data were recorded on a standardized form and then entered into an anonymous computer database created specifically for the study.

Study Procedure

The study involved 4 steps:

Step 1: Emergency Physician Characteristics. Each physician completed a questionnaire about his or her training, ICU experience, and familiarity with the various ventilator types (simple pneumatic ventilators and ICU ventilators).

Step 2: Familiarization With the Study Ventilators. Each emergency physician was initially allowed 15 min with each ventilator. The physicians did not have access to the manuals and were given no explanations. The patient circuit was connected to a balloon. The parameters set on the ventilator after it was turned on in controlled ventilation mode are specified in Table 1. At the beginning of the familiarization period, the physician was instructed to find out how to start and stop the ventilator, how to adjust settings for volumetric modes (inspiratory-expiratory ratio or inspiratory flow), pressure-support ventilation, and positive end-expiratory pressure), what each button on the control panel is for, where the alarm settings are located, and where patient data is displayed.

Step 3: Tasks. In the presence of one of the 3 investigators, the emergency physician tried to perform 15 tasks that correspond to settings and changes frequently encountered during the transport of ventilated patients (Table 2). Each task needed to be completed in less than 120 s (except task 11, for which the time allowance was 180 s). Each task ended when the time allowance was up or when the physician reported that the setting adjustments were confirmed (without noting time). The following were recorded for each individual for each task: task completion without error within the allowed time; task completion with one or more errors within the allowed time; or noncompletion of task. Errors were recorded and categorized as follows. First, by the type of error: A. Failure to find a setting site or display site. B. Confusion with another setting site or display site. C. Setting site identified correctly but inappropriate setting. D. Failure to confirm the settings. Second, the errors were categorized according to their potential risk

Table 2. User Interface Task Results From the Elisée 250 and Oxylog 3000

	Number of Physicians Who Completed the Task Without Error Within the Allowed Time (n)							
	All Physicians (n = 20)		According to Self-Evaluated Expertise With ICU Ventilators					
			Good (n = 5)		Fair (n = 12)		Limited (n = 3)	
	Elisée 250	Oxylog 3000	Elisée 250	Oxylog 3000	Elisée 250	Oxylog 3000	Elisée 250	Oxylog 3000
1. Start CV and set I:E	7	12	3	3	3	8	1	1
2. Set F_{IO_2}	20	19	5	5	12	11	3	3
3. Set inspiratory flow	18	4	4	1	11	3	3	0
4. Identify automatic alarm ranges	18	12	5	4	12	6	1	2
5. Identify control panel set sites	18	10	5	2	10	6	3	2
6. Identify patient parameter display sites	19	16	5	5	11	9	3	2
7. Change alarm ranges	20	19	5	5	12	12	3	2
8. Identify the plateau pressure value	19	18	5	5	11	10	3	3
9. Shut down the ventilator	18	19	5	5	10	11	3	3
10. Start ACV (pediatrics) and set inspiratory flow	11	2	4	1	6	1	1	0
11. Start PSV with PEEP and set apnea ventilation	15	9	4	4	9	5	2	0
12. Identify exhalation values in PSV	20	20	5	5	12	12	3	3
13. Switch from PSV with PEEP to ACV	20	6	5	3	12	3	3	0
14. Rapidly and temporarily set F_{IO_2} to 100%	17	18	5	5	9	11	3	2
15. Determine battery charge level	17	16	5	4	9	10	3	2
Total (n, %) (300 tasks per ventilator)	257 (85.7)*	200 (66.7)	70 (93.3)†	57 (76)	149 (82.7)*	118 (62.2)	38 (84.4)†	25 (55.5)

*Elisée 250 versus Oxylog 3000 $p < 0.001$ via chi-square test
†Elisée 250 versus Oxylog 3000 $p < 0.003$ via chi-square test
CV = controlled ventilation
I:E = inspiratory-expiratory ratio
F_{IO_2} = fraction of inspired oxygen
ACV = assist-control ventilation
PSV = pressure support ventilation
PEEP = positive end expiratory pressure

of immediately adversely affecting oxygenation, ventilation, or the patient work of breathing. The errors that could have a potentially immediate adverse effect were grouped as follows: risk of desaturation (incorrect adjustment of fraction of inspired oxygen [F_{IO_2}] or positive end-expiratory pressure); risk of inadequate alveolar ventilation (error in ventilation mode [type, confirmation]) in one of the mode's parameters (tidal volume or frequency), or the ventilation settings during apnea; risk of provoking patient-ventilator asynchrony (incorrect inspiratory flow, sensitivity of the inspiratory trigger, or the pressurization ramp).

Step 4: Satisfaction Score. After the tasks, each physician scored his/her satisfaction with the ventilator, defined as its perceived ease of use. A specific scale was designed, with a maximum of 88 points (4 groups of 22 items), and the score was converted to a percentage.

Statistical Analysis

We used statistics software (SPSS 11.01, SPSS, Chicago, Illinois) for all the data analysis. The chi-square and paired Wilcoxon tests were selected, based on the type of data. A p value < 0.05 was considered statistically significant.

Results

Participant Characteristics

At each site, the first 10 French emergency physicians invited to participate in the study accepted; none were familiar with the study ventilators. There were no significant differences between the 2 groups of physicians at the 2 study centers. Their profiles were very similar to that found in other evaluations of French emergency physicians.[1] Their self-evaluation of expertise was good with simple pneumatic ventilators and variable with ICU ventilators (3 physicians said their expertise was limited, 12 said theirs was moderate, and 5 said theirs was good).

Overall Ventilator Testing Results

With each ventilator a total of 300 tasks were performed. The percentage of physicians who completed the tasks without any errors was significantly higher with the Elisée 250 (85.6%) than with the Oxylog 3000 (66.6%) ($p < 0.0001$) (see Table 2). The percentage of physicians who completed tasks with errors was smaller with the Elisée 250 (11.6%) than with the Oxylog 3000 (21%) ($p = 0.002$). The percentage of physicians who did not complete tasks was also lower with the Elisée 250 (2.6%) than with the Oxylog 3000 (12.3%) ($p < 0.0001$). The error-free completed-task rate was significantly better with the Elisée 250 than with the Oxylog 3000, at all 3 levels of self-evaluated expertise with ICU ventilators (see Table 2). Several different errors could occur in a single task, and the same type of error could occur in different tasks. In all, the total number of errors was 46 with the Elisée 250 and 113 with the Oxylog 3000 (Table 3).

Types of Errors

Failure to Find a Setting Site or a Display Site. These represented about half of the errors with each ventilator. The main source of error was inspiratory flow adjustment on the Oxylog 3000 ($n = 31$). Inspiratory-expiratory ratio adjustment errors via flow with the Elisée 250 were less common ($n = 11$). There were a substantial number of errors in setting the alarm ranges on the Oxylog 3000 ($n = 10$).

Confusion With Another Setting Site or Display Site. Confusion between assist-control ventilation (these ventilators display the acronym VAC for the French term ventilation assistée contrôlée) and synchronized intermittent mandatory ventilation (SIMV, but the ventilator displays the acronym VACI for the French term ventilation assistée contrôlée intermittente) was common with the Oxylog 3000 ($n = 17$).

Setting Identified Correctly But Inappropriately Adjusted. Errors in adjusting the inspiratory trigger occurred with both ventilators and were more common with the Elisée 250 ($n = 16$) than with the Oxylog 3000 ($n = 11$).

Failure to Confirm the Settings. This error occurred only with the Oxylog 3000 ($n = 3$).

Errors With Potentially Immediate Adverse Effects. Fourteen types of errors were considered as potentially having immediate adverse effects (in Table 3, errors A1–A4, B1, B2, C1–C6, D1, and D2), and of these errors there were a total of 119: 35 with the Elisée 250 (76% of the errors with the Elisée 250) and 84 with the Oxylog 3000 (74.3% of the errors with the Oxylog 3000). Four types of errors represented about three fourths of these 119 errors

Table 3. Errors During User Interface Tasks

Error Categories and Types	Errors (*n*)	
	Elisée 250	Oxylog 3000
A—Failure to find a setting site or display site		
A1 Set I:E*	11	0
A2 Set inspiratory flow*	2	31
A3 Set apnea ventilation*	0	6
A4 Rapid 100% O_2 activation*	3	1
A5 Identify plateau pressure	1	3
A6 Identify and/or set alarm ranges	3	10
A7 Identify exhalation parameters in PSV	0	1
A8 Determine battery charge	2	2
A9 Shut down the ventilator	2	1
Subtotal A (A1–A9)	24	55
B—Confusion with another setting site or display site		
B1 Set SIMV instead of ACV*	0	17
B2 Set PACV instead of ACV*	1	0
B3 Identify setting sites	2	8
B4 Identify patient parameter display sites	1	4
Subtotal B (B1–B4)	4	29
C—Input site identified correctly but inappropriate setting		
C1 Set frequency*	0	3
C2 Set tidal volume*	0	3
C3 Set PEEP*	0	2
C4 Set F_{IO_2}*	0	5
C5 Set inspiratory trigger sensitivity*	16	11
C6 Set the pressurization ramp*	2	2
Subtotal C (C1–C6)	18	26
D—Failure to confirm the setttings		
D1 Controlled ventilation*	0	1
D2 PSV*	0	2
Subtotal D (D1 and D2)	0	3
Total (A + B + C + D)	46	113

*Errors with potential immediate adverse effects
I:E = inspiratory-expiratory ratio
PSV = pressure-support ventilation
SIMV = synchronized intermittent mandatory ventilation (VACI in French)
ACV = assist-control ventilation
PACV = pressure assist control ventilation
PEEP = positive end expiratory pressure
F_{IO_2} = fraction of inspired oxygen

Table 4. Satisfation Scores Given by the 20 Emergency Physicians

Satisfaction Category	Subjective Satisfaction Score* (mean ± SD, range)		p†
	Elisée 250	Oxylog 3000	
S1—General appearance			
Bulk during prehospital transport	3.4 ± 0.5 (3–4)	2.5 ± 0.7 (1–4)	
Bulk during interhospital transport	3.5 ± 0.5 (3–4)	2.9 ± 0.7 (2–4)	
Ease of use during stretcher use	3.4 ± 0.6 (2–4)	2.8 ± 0.7 (1–4)	
Ease in determining battery charge	3.0 ± 1.2 (0–4)	3.4 ± 0.8 (1–4)	
Ease in setting up the circuit	3.4 ± 0.6 (2–4)	3.1 ± 0.9 (1–4)	
Perceived fragility during prehospital transport	2.6 ± 0.6 (1–3)	2.9 ± 0.8 (1–4)	
Perceived fragility during interhospital transport	2.9 ± 0.6 (2–4)	3.1 ± 0.8 (1–4)	
Sub-score (highest possible score 28)	22.0 ± 2.0 (19–25)	20.5 ± 3.2 (14–25)	0.02
S2—Starting up and adjusting the settings			
Ease in distinguishing between adult/pediatric and volume/pressure/PSV	3.9 ± 0.3 (3–4)	2.3 ± 1.1 (0–4)	
Ease in setting the volume modes	3.8 ± 0.6 (2–4)	2.9 ± 0.8 (1–4)	
Ease in identifying inspiratory trigger sensitivity	3.3 ± 1.1 (1–4)	2.7 ± 0.9 (1–4)	
Ease in setting inspiratory flow	3.3 ± 0.7 (2–4)	1.9 ± 1.0 (0–3)	
Ease in setting the PSV with PEEP mode and apnea ventilation	3.2 ± 0.7 (2–4)	2.6 ± 0.8 (1–4)	
Ease in switching from PSV with PEEP in volume mode (CV or ACV)	3.5 ± 0.5 (3–4)	2.6 ± 1.0 (0–4)	
Sub-score (highest possible score 24)	20.8 ± 2.4 (15–24)	14.9 ± 3.4 (9–22)	$p < 0.0001$
S3—Alarms			
Ease in identifying preset alarm ranges	3.3 ± 0.6 (2–4)	2.6 ± 0.6 (2–4)	
Ease in modifying an alarm range	3.6 ± 0.6 (2–4)	2.7 ± 0.7 (2–4)	
Ease in identifying the type of alarm	3.2 ± 0.9 0–4)	2.6 ± 0.7 (2–4)	
Usefulness and ease of automatic alarms	3.1 ± 0.7 (2–4)	2.6 ± 0.7 (2–4)	
Sub-score (highest possible score 16)	13.0 ± 2.0 (9–16)	10.5 ± 2.2 (8–16)	0.005
S4—Interface			
Overall ease of use	3.2 ± 0.8 (1–4)	2.5 ± 0.6 (1–3)	
Display legibility	3.4 ± 0.7 (2–4)	2.3 ± 0.9 (0–4)	
Usefulness of plots	2.9 ± 0.7 (2–4)	2.8 ± 0.7 (2–4)	
Ease in identifying patient parameters	3.1 ± 1.0 (2–4)	2.3 ± 0.7 (0–3)	
Ease in learning without the manual	2.8 ± 1.0 (2–4)	2.3 ± 0.7 (1–3)	
Sub-score (highest possible score 20)	15.4 ± 3.3 (7–20)	11.9 ± 2.3 (8–16)	0.002
Total score (maximum possible 88 points)	71.1 ± 6.4 (56–81)	57.7 ± 8.5 (43–77)	< 0.0001
Total score (converted to a percentage	80.8 ± 7.3 (64–92)	65.6 ± 9.6 (49–87)	< 0.0001

*The score indicates the physician's subjective assessment of ease of use of the user interface. The maximum number of points was 88 (22 items, each scores 0 to 4, where 0 = very poor, 1 = poor, 2 = fair, 3 = good, and 4 = excellent).
†p calculated via the paired Wilcoxon test (difference significant if $p < 0.05$)
PSV = pressure support ventilation
PEEP = positive end expiratory pressure
CV = controlled ventilation
ACV = assist-control ventilation

(A1, A2, B1, and C5), which were twice as common with the Oxylog 3000 ($n = 59$) as with the Elisée 250 ($n = 29$).

Satisfaction Score

The satisfaction score was significantly better with the Elisée 250, both overall and for each group of items (Table 4). About three fourths of the physicians said they would be willing to use both ventilators immediately or after receiving specific hands-on training, but the willingness to use the ventilator without training was more common with the Elisée 250. One physician was unwilling to use the Oxylog 3000. We did not research the correlation between the satisfaction score and the percentage of task successes.

Discussion

Our study shows that for this group of French emergency physicians, who participated and in the absence of specific training, the Elisée 250 proved significantly easier to use, with fewer errors than the Oxylog 3000.

Several studies have compared the technical performance of ventilators, but data on the ventilator-user interface are scarce and available only for ICU and home ventilators[12,13] or for a single element of the interface.[10] To our knowledge, the present study is the first to study advanced compact transport ventilators. The importance of a user-friendly interface in ensuring easy and safe ventilator use was recently underscored, and interface evaluations are recommended in addition to performance evaluations.[15]

Limitations

The present study has several possible limitations. First, though the profile of the participants was representative of all French emergency physicians,[1] we cannot directly apply these results to other categories of users (eg, ICU physicians, emergency physicians in countries other then France, respiratory therapists, or emergency nurses). The difference between the ease of use of the 2 ventilators, however, was also found in the present study among the physicians familiar with ICU ventilators.

Second, testing only 2 ventilators may seem like too few, compared to other studies.[12,13] We had very strict criteria in choosing a ventilator, and they were representative of practical needs: compact, advanced, and with good performance, as defined in the study methods. Ventilators that did not match our criteria were not considered,[4,16,17] and we also eliminated ventilators not available in France. The 2 ventilators we did test are available almost worldwide. The LTV 1000 (Pulmonetic Systems, Colton, California) could have been included, given our criteria, but we did not test it because many emergency physicians here are familiar with it.

Third, there is no standard methodology for this type of study, which required us to choose our methods. We followed general recommendations, observing the users, evaluating task success rate, and categorizing errors according to potential consequences.[15,18] The tasks chosen were representative of practical requirements (adjustments, monitoring) and of recommendations for patient transport.[5,7,17] The small number of ventilators tested allowed us to test 15 tasks per ventilator, whereas other studies have looked at only 6 or 7 tasks.[12,13]

Fourth, the physicians did not have access to the ventilator manuals and received no explanations about the ventilators. In theory, physicians should receive training before using a new ventilator. In practice, however, training may be cursory, and we sought to replicate this situation. In addition, some physicians have few opportunities to use ventilators and may therefore forget some of their initial training.

Analysis of Overall Results

In the conditions of our study, the Elisée 250 was significantly easier to use than the Oxylog 3000. This is probably due to the difference in concept between the 2 interfaces (a touch-pad vs a combination of various types of controls). The small size of these ventilators may complicate the search for ideal ergonomics as well. The touch-pad of the Elisée 250 allows for placement of different categories of parameters on different distinct screens. The letters can be larger, which facilitates recognition. Adjusting a setting is simpler because the user does not have to manipulate multiple controls of different types. The Oxylog 3000 allows direct access to basic adjustments, similar to those on simple pneumatic ventilators (tidal volume, respiratory rate, maximum inspiratory pressure, and F_{IO_2}), which could be advantageous in emergencies. Yet the physician errors in making these basic settings (frequency, tidal volume) were more frequent than with the Elisée 250. For advanced parameters, manipulating different types of controls is often necessary to visualize or confirm a given parameter. This undoubtedly represents a potential source of confusion and error for the new or occasional user.

Analysis of Errors According to Different Types

Failure to Find a Setting Site or Display Site. This error type constituted half of all the errors. The indirect adjustment of a requested setting appears to be one source of difficulty. One example is the high error rate in adjusting the inspiratory flow on the Oxylog 3000. One must adjust the inspiratory-expiratory ratio and, often, also the end-inspiratory pause.

Confusion With Another Setting Site or Display Site. The most common error was choosing SIMV (French acronym VACI) mode rather than assist-control ventilation (French acronym VAC) on the Oxylog 3000, which resulted in ventilation with an inappropriately increased inspiratory-expiratory ratio (inspiratory time lengthened by default in VACI). The absence of the acronym ACV (for assist-control ventilation) next to the label for assist-control ventilation on the access button for this mode might explain this, especially since the French acronyms VAC and VACI are so similar. Identifying this type of user-interface defect would allow the manufacturer to make simple, rapid, and efficient corrections.

Setting Identified Correctly But Inappropriately Adjusted. Inappropriate setting of inspiratory trigger sensitivity was fairly common. On the Elisée 250, the technology of the trigger does not depend on detection of the flow or pressure, but on the gradient of the pressure drop. Therefore, no units are marked, which might contribute to errors. Clear indication on the controls of the trigger sensitivity (eg, from "very sensitive" to "least sensitive") might reduce this type of error.

Analysis of Errors With Potentially Immediate Adverse Effects. To our knowledge, the distinction between errors that might or probably would not have immediate adverse effects has not previously been used in this type of study. Nevertheless, many clinical studies have stated the importance of the correct adjustment of these parameters for optimal mechanical ventilation.[19–23] In the present study these errors were frequent (3 out of 4) and they happened twice as often with the Oxylog 3000 (see Table 3). The reasons for these errors are probably the same as those previously noted, including the advantage of directly adjusting the essential parameters, advantage of grouping the same functions on one screen, and the advantage of not having many different types of control buttons. Therefore, in the context of our study, the risk of an error that might have an adverse clinical effect appeared to be higher with the Oxylog 3000. We did not consider error A8 (determination of battery charge) as potentially having immediate adverse effect, because both ventilators have a low-battery sound alarm that gives the user time to react appropriately.

Analysis of Satisfaction Scores

Both the overall satisfaction score and the subscores were significantly better with the Elisée 250. Nearly all the participating physicians said they would be willing to use either ventilator, although the demand for additional training was greater with the Oxylog 3000. We did not study the possible influence that previous experience with other ventilators might have had on the score. Since touch-pad technology is a relatively recent development, one could postulate that the physicians were less accustomed to it. This would not have given it any score advantage. The relationship between the satisfaction score and the success rate in the tasks was not studied, but this might be interesting to include in future similar studies.

Conclusions

This limited study of 20 volunteer emergency physicians in France found that the Elisée 250 user interface was easier to use, and therefore more reliable than the Oxylog 3000 user interface. These results cannot be directly applicable to other types of users without further studies. Studies of the ease and dependability of use of different types of ventilators with different types of users should be done more often, to improve the ergonomics of the user interface, with special attention to the types of errors that occurred in our study, especially those with immediate adverse effects.

ACKNOWLEDGMENTS

We thank Barbara Hanke MD, Emergency Department, American Hospital of Paris, Paris, France, for her help in translating this manuscript.

REFERENCES

1. Templier F, Thys F, Durand JS, Jardel B. Oxygen therapy and ventilatory support. In: Actualités en Réanimation préhospitalière: Dyspnée aiguë - Journées Scientifiques de Samu de France 2004. Paris: 2005:87–158 (*in French*).
2. Waydhas C, Schneck G, Duswald KH. Deterioration of respiratory function after intra-hospital transport of critically ill surgical patients. Intensive Care Med 1995;21(10):784–789.
3. Warren J, Fromm RE, Orr RA, Rotello LC, Horst M. Guidelines for the inter- and intrahospital transport of critically ill patients. Crit Care Med 2004;32(1):256–262.
4. Zanetta G, Robert D, Guérin C. Evaluation of ventilators used during transport of ICU patients: A bench study. Intensive Care Med 2002; 28(4):443–451.
5. Douge G, Allaire H, Leroux C, Baer M, Chauvin M, Fletcher D, Templier F. Ventilatory support equipment used by mobile intensive care units in France: a nationwide survey. Rev SAMU 2003;351–355 (*article in French*).
6. Beckmann U, Gillies DM, Berenholtz SM, Wu AW, Pronovost P. Incidents relating to the intra-hospital transfer of critically ill patients. Intensive Care Med 2004;30(8):1579–1585.
7. Waydhas C. Intrahospital transport of critically ill patients. Crit Care 1999;3(5):R83–R89.
8. Nakamura T, Fujino Y, Uchiyama A, Mashimo T, Nishimura M. Intrahospital transport of critically ill patients using ventilator with patient-triggering function. Chest 2003;123(1):159–164.
9. Cox CE, Carson SS, Ely EW, Govert JA, Garret JM, Brower RG, et al. Effectiveness of medical resident education in mechanical ventilation. Am J Respir Crit Care Med 2003;167(1):32–38.
10. Austin PN, Campbell RS, Johannigman JA, Branson RD. Transport ventilators. Respir Care Clin N Am 2002;8(1):119–150.
11. International organization for standardization (ISO). Lung ventilators for medical use. Part 3: Particular requirement for emergency and transport ventilators. 1st ed. Geneva: ISO; 1997:10651–10653.
12. Gonzalez-Bermejo J, Laplanche V, Husseini FE, Duguet A, Derenne JP, Similowski T. Evaluation of the user-friendliness of 11 home mechanical ventilators. Eur Respir J 2006;27(6):1236–1243.
13. Fartoukh M, Richard JC, Maggiore SM, Lellouche F, Lemaire F, Brochard L. Evaluation of intensive care ventilator-user interface. Am J Respir Crit Care Med 2001;163:A128 (abstract).
14. Liu Y, Osvalder AL. Usability evaluation of a GUI prototype for a ventilator machine. J Clin Monit 2004;18(5–6):365–372.
15. Lellouche F, Taillé S, Fartoukh M, Brochard L. Convenience of new ventilators. ITBM-RBM 2005;26:92–95 (in French).
16. Austin PN, Campbell RS, Johannigman JA, Branson RD. Work of breathing characteristics of seven portable ventilators. Resuscitation 2001;49(2):159–167.
17. Dureuil B, Roupie E. Specific aspects of alarm setting and monitoring for patients receiving ventilation during intrahospital or interhospital transport. Réanim Urgences 2000;9:477–480 (*in French*).
18. Chatburn RL. Computer control of mechanical ventilation. Respir Care 2004;49(5):507–517.
19. Laghi F. Effect of inspiratory time and flow settings during assist-control ventilation. Curr Opin Crit Care 2003;9(1):39–44.
20. Corne S, Gillespie D, Roberts D, Younes M. Effect of inspiratory flow rate on respiratory rate in intubated ventilated patients. Am J Crit Care Med 1997;156(1):304–308.

21. Laghi F, Segal J, Choe WK, Tobin MJ. Effect of imposed inflation time on respiratory frequency and hyperinflation in patients with chronic obstructive pulmonary disease. Am J Crit Care Med 2001; 163(6):1365–1370.
22. Aslanian P, Brochard L. Work of breathing during assisted modes of ventilation. Curr Opin Crit Care 1997;3:38–42.
23. Ranieri VM, Puntillo F, Giuliani R. Patient-ventilator interactions in the critically ill. Curr Opin Crit Care 1997;3:16–21.

Preparing soldiers for medical air evacuation
U. S. Army Air Force photo
December 29, 1942
Courtesy National Library of Medicine