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Evaluation of the user-friendliness of 11 home mechanical ventilators

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Abstract

The home ventilator market has grown in size and complexity.

Question of the study. Are common home ventilators user-friendly for trained ICU physicians ?

Methods. Eleven ventilator models were tested by 13 ICU physicians without practical experience in home mechanical ventilation. Six tests were defined (start up, "unlocking", mode and setting recognition, mode change, pressure setting, alarm). For each test, the physicians were timed and their performance compared to a reference time established by a technician. The physicians also had to rate their global assessment of each machine on a visual analog scale.

Results. The startup test was the only test for which there was no significant difference between the physicians and the technician, except for two ventilators. The physicians were slower than the technician to unlock the ventilator and change the ventilatory mode, with some complete failures during these tests and heterogeneous results between physicians and between ventilators. Mistakes occurred in close to 50% of cases during the ventilatory mode and settings recognition test. The mean time for the most rapid of the physicians for all the tests was 58 ± 53 s, against 15 ± 9 s for the technician.

Answer to the question. Trained ICU physicians perform poorly when confronted with home mechanical ventilators without specific prior training. We hypothesise that the user-friendliness of home ventilators for other categories of users might be questionable.

Key Words

mechanical ventilation ; home care; ventilators; international standardisation office

Introduction

The indications for home mechanical ventilation are numerous in both adults and children (1). Developments in design and technology in the last decade have led to considerable improvements in the mechanical ventilators available to physicians and patients for home use. In the past, the very limited number of models available only permitted controlled ventilation with very few settings possible, and only basic monitoring. We now have over 30 models on the market; each providing several ventilation modes and offering numerous options for settings, but no common nomenclature exists (Table 1). This diversity introduces flexibility and also complexity, thus involving the risk that medical and paramedical personnel responsible for the care of patients using home ventilation may not be able to properly manage the technical aspects. This risk is particularly worrying when urgent or semi-urgent reaction to a situation is required, in the knowledge that the personnel involved is more unlikely than likely to have previous familiarity with home mechanical ventilators. It is probably desirable that any physician dealing with a patient on home mechanical ventilation should be able to easily recognise the ventilation mode administered, understand the source of alarms or malfunctions without alarms, and take simple rapid measures for the patient's safety. This is particularly important in patients who are ventilator dependent or nearly so, a population that is growingly important in the home ventilation setting.

In the present situation, various factors contribute to making such expectations unrealistic. There are very few training programs in home mechanical ventilation for physicians and caregivers (2). Manufacturers of home ventilators are used to technological test-bench assessments (3-5) and cannot easily evaluate the user interface of machines they develop. When they do, they usually turn to physicians experienced in the use of home mechanical ventilators, thus biasing the findings. Paradoxically, there are no marketing regulations for ventilators. This leaves manufacturers free to offer novel control panels and choose the names given to the ventilation modes they provide (to the extent that an identical mode can have several names), and so on. An overview of the home mechanical ventilator market gives the general impression that there is no homogeneity; combinations of buttons

are frequently required to start or stop a function, the labelling of buttons is not very clear, and control screens tend to be too small and difficult to read.

For all that, no published data seem to exist that would convert this impression into findings and thus prompt manufacturers to concentrate their design efforts on sufficiently simple machine-user interfaces to guarantee safe quality care. In this context, the objective of this study was thus to evaluate the user-friendliness of the eleven home mechanical ventilators most frequently used in France for trained ICU physicians.

Material and methods

Ventilators

Eleven ventilator models were tested, in accordance with the following list: Eole 3XLS (Saime, Savigny le Temple, France), Hélia 2 (Saime, Savigny le Temple, France), Onyx plus (Tyco, Saint Louis, Missouri, USA), VPAP III (ResMed, Australia), BiPAP Synchrony (Respironics, Murrysville, Pennsylvania, USA), Smartair PLUS (Airox, Pau, France), VS ultra (Saime, Savigny le Temple, France), Neftis (Taema, Anthony, France), Knightstar (Tyco, Saint Louis, Missouri, USA), PV 403 (Breas Medical, Mölnlyche, Sweden), Légendair (Airox, Pau, France).

While tests were being performed, each ventilator was connected to a 2-litre test bag.

Physicians

Thirteen physicians with sound experience in mechanical ventilation in the context of intensive care, but without practical experience in home mechanical ventilation, participated in the study (5 specialists in respiratory medicine, 5 specialists in intensive care, 2 neurologists, 1 anaesthetist, all qualifying as "senior ICU physicians" although with various degrees of experience due to an age range from 32 to 56). Only one of the 13 ICU physicians had been in contact with the Onyx ventilator before, two had had previous contacts with the Helia 2, three with the VS ultra, one with the Legendair. In all of these cases, the participants did not consider themselves familiar with the ventilators. The situation was slightly different for the Eole 3, that 7 of the participants already knew, with some degree of familiarity.

Tests

Six tests were defined. Each test was explained to the physician; the tester gave the starting signal and timing was stopped as soon as the objective fixed had been achieved, or at the arbitrarily decided limit of 3 minutes. Each physician performed the 6 tests consecutively for the specified ventilator, but the order in which the ventilators were evaluated was randomised. The test list was the following:

1- "start up": with the ventilator completely assembled and connected to the power supply, the physicians had to start the ventilator; the stop signal was given at the first insufflation produced by the ventilator.

2- "unlocking": the ISO standard (6,7) stipulates there must be a safety mechanism to prevent any accidental adjustment of controls on a mechanical ventilator installed at the home of a patient; a physician wanting to change any ventilation setting must first disable this safety mechanism. But the standard does not provide any information on what this safety mechanism should be; home mechanical ventilator manufacturers have adopted very different solutions. Test n°2 required physicians to unlock a previously started ventilator, without consulting the operating manual. The stop signal was given as soon as the physician had actual access to ventilator settings.

3 - "recognition": this test required physicians, with a ventilator that was turned on and supplying a given ventilation mode, to fill in a chart identifying the ventilation mode and the main preset parameters, which were tidal volume (Vt) and breathing frequency (F) in volume-controlled mode, and inspiratory pressure support and positive end-expiratory pressure -PEEP- in pressure-controlled mode. (Ventilator modes: Onyx VSfr; Legendair VPC; Neftis VAC; PV403 AI; Synchrony S/T; Knightstar A/C; Smartair AIfr; VPAPIII S/T; Vs Ultra AI VT; Eole3 VAC; Helia AI Vt, see Table 2). The stop signal was given as soon as the chart was filled in.

4 - "mode change": starting with a ventilator preset to supply pressure support ventilation and unlocked, the physicians had to change to volume-controlled mode and adjust tidal volume and frequency to predefined values. The stop signal was given as soon as the first insufflation was achieved with the required settings. This test only concerned mixed type

ventilators providing the possibility of both pressure-controlled ventilation and volume-controlled ventilation (VS Ultra, Hélia 2, Légendair, Neftis).

5 - "pressure setting": starting with a preset and unlocked ventilator, the physicians had to set a precise level of inspiratory pressure support. The stop signal was given as soon as the first insufflation was achieved with the required settings. This test only concerned ventilators providing pressure-controlled ventilation (Knightstar, VPAP III, Synchrony, Smartair PLUS, Onyx plus).

6 - "alarms": starting with a preset and unlocked ventilator, the physicians had to adjust alarms (high pressure, low pressure and apnoea) to predefined values. The stop signal was given as soon as the alarm values had been adjusted to the required levels. This test naturally only concerned ventilators equipped with alarms (Légendair, Eole and VS Ultra)

Evaluation

For each test, the time taken by the physicians was compared to a "reference time" established by a technician from the Comité d'Assistance Respiratoire à Domicile d'Ile-de-France (CARDIF) (Paris Region Committee for Home Respiratory Assistance) with thorough knowledge of the ventilators tested.

Moreover, once all the tests were completed for a given ventilator, the physicians had to rate their assessment on a visual analog scale along a 10-cm line marked with ("O") on the left for "very difficult to use", and ("10") on the right for "very easy to use".

Statistical analysis

Statistical analysis was performed using Statistix 8.0 software (Statistix, Tallahassee, FL, USA). For each of the six tests performed, variance analysis was carried out using a "physician" factor (including the results of the 13 physicians and those of the technician), and a "ventilator" factor. Comparison of the physician results with those of the technician was performed using a post hoc Dunnett test. Comparison of results between physicians and comparison of ventilators was performed using a Tukey test. For all comparisons, the significance threshold was fixed at the value of p 0.05. The results were expressed in the form of mean values ± standard deviation.

Results

Overall results.

Figure 1 shows the mean results obtained by the physicians (all the tests on all the ventilators) compared to the technician. The mean time for the most rapid of the physicians for was 58 ± 53 s [5-180], against 15 ± 9 s [6-27] for the technician.

Table 2 indicates the scores concerning ventilator user-friendliness given by the physicians after completing the tests. None of the differences reached the statistical significance threshold.

Results by test.

1- "start up" (Fig.2). The ventilators were started in 17 ± 10 s for the most rapid of the physicians, against 13 ± 6 s [6-27] for the technician. There were no significant differences between physicians and the technician or between the physicians. The ventilators were distributed in two groups within which there were no differences, but between which there was a significant difference. In fact, two ventilators, the Neftis (Taema)(61 ± 22 s) [29-135] and the Knightstar (Tyco)(70 ± 61 s)[12-65], required significantly more time to start than the 9 others ($p<0.0001$).

2- "unlocking"(Fig.3). On average, two physicians out of 13 did not take significantly longer than the technician to unlock the 11 ventilators, despite differences that could have a clinical impact (12 s on average for the technician, against 49 and 59 s on average for these two physicians). The 11 other physicians were significantly slower than the technician in the procedure for unlocking ventilator settings. Concerning the ventilators, the Eole® proved to be significantly quicker to unlock than the other models (31 ± 17s) [12-66]. The Synchrony and Knightstar models proved to be significantly longer to unlock that the other machines (173 ± 42 s [32-180] and 170 ± 37 s [73-180] respectively, $p<0.0001$). No physician succeeded in unlocking the VPAP III (Resmed) ventilator in the allotted time limit of three minutes.

3 - "recognition"(Fig.4). Eight physicians out of 13 proved to be significantly slower than the technician in this test. For the 5 others, the difference was not significant, but the physician times were 2 to 3 times that of the technician (24 s on average for the latter, 47 to

71 seconds for the physicians). Moreover, the answers given by the physicians proved to be erroneous on at least one point in 49% of the cases **(Fig. 5)**(wrong mode 13%; wrong frequency 1%; confusion between inspiratory pressure support and intermittent positive airway pressure 21%; confusion between the set value of a given variable and its measured value, 12%; no recognition at all, 2%).

Settings for the Knightstar (Tyco) ventilator took statistically longer to analyse than for the others ($p = 0.01$), which were evenly distributed in two homogeneous groups (51-70 s and 80-110 s).

4 - "mode change"(Fig.6). Seven physicians were significantly slower than the technician for this test, but only one physician was significantly slower than the others (124 ± 70 s [70-180] vs 95 ± 61 [12-480], $p=0.04$). The Helia 2 (Saime) ventilator was markedly different from the others as only one of the physicians succeeded in changing to volume-controlled mode (concealed function).

5 - "pressure setting"(Fig.7). Six out of the 13 physicians were significantly slower than the technician in this test. They were distributed in two homogeneous groups within which there were no differences (a group of 3 physicians timed at 128 to 143 s, and 43 to 124 s for the other group). The test was carried out significantly faster on the Smartair ventilator (mean 56 s) than the other ventilators that underwent this test (84 to 129 s). .

6 - "alarms"(Fig.8). Again, in this test, 6 out of the 13 physicians proved to be significantly slower than the technician. There were no differences between the ventilators.

Discussion

This study, which is apparently one the first of this type, brought out both positive and negative elements. On the positive side, we noted that a variable proportion of physicians participating in the study were able, without previous training, to equal the performance of a technician experienced in the use of home mechanical ventilators. On the negative side, we obviously found the reverse of the previous proposition. It should be emphasised that, even though differences in timing did not reach the statistical significance threshold, the physicians were sometimes very slow in comparison with the reference test. The results of the unlocking test, recognition test (49 % errors, Figure 5), and settings test (mean at 4 times the

"technician" time) are worrying. We also noted some more specific problems, such as the impossibility for all the physicians but one to access the change to "volume" mode on one of the machines tested. All these points result in a quite mediocre overall score (Table 2), granted that the lack of significant differences between ventilators could be due to an insufficient statistical power.

Possible limitations to the study.

Our objective was not to describe the full extent of the difficulties that patients receiving home mechanical ventilation, their families, and their caregivers can be faced with. Rather, from our own experience, we felt that the lack of user-friendliness of home ventilators was so blatant that an alarm had to be rung. For this reason, we restricted our survey to ICU physicians unaware of the specifics of home ventilation but well accustomed to encounter various types of mechanical ventilators and also accustomed to have to manage some ventilators while having little background about their particular type. In this, the study does not tell anything about the ease of use of the ventilators for more "ordinary consumers". Nevertheless, the difficulties encountered by ICU physicians (who should represent the professional category with both the highest and the most homogeneous skills in mechanical ventilation) make the chances slight that other unprepared physicians or caregivers called in to provide care for home ventilated patients will be at ease with the home ventilators. Of note, we deliberately avoided conducting the survey with physicians experienced in home mechanical ventilation. They would have in all likelihood obtained results closer to those of the technician who established the reference times, but it would not have been easy to objectify what their "experience" actually was and thus to constitute an homogeneous group . We also avoided using physicians without any experience of artificial ventilation which would have created the opposite bias. Similar studies involving other professional categories would be interesting.

Some of the participants to the study had some prior knowledge of some of the ventilators tested (see Methods). This did not influence the results, except perhaps for the

Eole 3 ventilator that was the best known of the 13 models tested: this may have contributed to explain why it appeared to be the fastest ventilator to unlock during test 2.

The technician who established the reference times was highly trained, and perhaps these reference times were unreasonably short. Nevertheless, while it is not surprising that unfamiliarised physicians would take longer than a trained technician to perform the tests, some of the recorded differences are huge, and the important variability among physicians must be noted. In addition, the performance of the ICU physicians was poor not only in relation to the reference time, with time-independent recognition errors, and many mere failures to perform some of the tests. Not having given any training to the physicians before the tests could also be criticised, but this appeared to be the best possible standardisation, and does in fact correspond to many real life situations.

Finally on methods, the range of ventilators tested in this study does not represent all the available machines. It does however correspond to the machines most often used in France, and is varied in terms of brands and models. We thus think the study is, from this point of view, representative of possible clinical situations.

Start up and unlock procedures.

Even though all the physicians had taken longer than the reference time to start the ventilators, the results of test n°1 can be considered to be satisfactory. The only two ventilators that proved to be more difficult to start were unlike the others; in one case it was the position of the "on/off" button (on the side of the machine instead of the front panel - Knightsar, Tyco), in the other case it was the type of operation required to activate the button (brief instead of prolonged pressure - Neftis, Taema). Even though it can appear to be a trivial point, this suggests that the ventilator "on/off" button should be systematically placed on the front panel of the machine, and should be operated by pressure sufficiently long to meet the ISO standard safety requirements (these stipulate "*means shall be provided to prevent accidental operation of the on/off switch*", -(6,7)-) but without imposing a time limit.

The ISO standard in force (6,7) recommends the presence of "*a means of protection against inadvertent adjustment of controls that can create a hazardous output (involving risks)*". The standard does not specify whether the aim of these means is to avoid "accidental"

adjustments or to avoid access to adjustments by patients and their families. It is however obvious that the recommendation is directed at the first and not the second case, as the unlocking procedures are in the ventilator operating manual and can be found by trial and error. Patients who want to modify the settings of their ventilators for some reason or other will always find a way. In this context, the results of test n°2 provide a good indication of a real problem; the mean unlocking times greatly exceeded the reference times, and a certain number of failures were recorded (systematically for one of the machines). Two physicians achieved unlocking times that were not statistically different from the reference time, yet the difference (average 49 and 59 s, vs 12s for the technician) might be clinically significant in a crisis situation. The ISO 10654-6:2004 standard (6) states that "*mechanical control techniques such as locks, shielding, friction-loading and detents are considered suitable*". We think that these solutions are preferable to the present ones, especially when the present solutions impose multiple button combinations that are particularly "anti-intuitive". Indeed, we believe that it is important to be able to unlock a ventilator relatively easily, as this is a prerequisite to any intervention if the need for a change in ventilatory mode or ventilatory settings arises. In a caricatural manner, if the concerned patient is ventilator-dependent or nearly so, failure to unlock the ventilator makes a machine switch or manual ventilation the only solutions.

Recognition of settings.

Though the setting recognition charts were completed quite rapidly by the physicians, 49% of the charts were incorrect. The two main sources of error were, on the one hand, the sequential display of the measured values and the set values on the same screen, and on the other hand, the heterogeneous terminology. (Table 2). Theoretically, correcting the first factor would be simple; for manufacturers this would involve allowing for the separate display of measured values and set values. This obviously has a cost, but is unlikely to be weighed against the safety flaw revealed by our results. Concerning the second factor (heterogeneous terminology), it is probably up to the medical profession to take action to establish an international nomenclature for modes of assisted ventilation. In France, Chopin and Chambrin (8) have published a proposition of this type in the journal "Réanimation-

Urgences". Recommendations have also been issued by the french learned society for intensive care (9). To our knowledge, these initiatives have not had much following. Several, not mutually exclusive, explanations can be put forward. Firstly, the journal "Réanimation-Urgences" (now "Réanimation") is not indexed in the Medline database. Secondly, the nomenclature proposed by Chopin and Chambrin (8) is very "physiological" in nature, but a certain degree of pragmatism is probably required, particularly concerning terms that are already accepted through use. Thirdly, awareness of the risks created by the absence of common terminology for modes of assisted ventilation (whether home ventilation or in intensive care) is necessary at medical community level, including learned societies. We hope that this study will contribute towards this.

Mode changes, settings, and alarms.

The results of these three tests appear to be, in a way, less worrying than the preceding tests. It remains however that some ventilators posed problems for certain physicians, including some regarding the particularly important issue of alarms. It should be emphasised that many physicians had inadvertently changed ventilator settings while trying to analyse the preset parameters; this possibility had not been foreseen in the study design but would have warranted specific analysis.

Conclusions

Home mechanical ventilators have benefited from considerable advances in design and technology. They are sophisticated machines whose reliability and performance are validated by detailed technical evaluations (3-5). It is regrettable that this technical excellence is tarnished by inadequate ergonomics; at the most an unjustifiable source of risks for patients, and at the least a cause of suboptimal use by physicians and caregivers. To some extent, this issue also pertains to ICU mechanical ventilators about which some research has already been performed about technological specifities (10) and about user interfaces (11).

The results of the evaluation carried out here should encourage corrective actions, by both the manufacturers and the medical community. These actions require institutional management, through learned society working groups (with a view to drawing up an international nomenclature for example) or statutory measures. It is indeed surprising that

sensitive devices like ventilators are not subject to evaluation regulations similar to those in force for medications. Thus it would not be outrageous to envisage ventilator manufacturers being obliged to conform to a few simple regulations (standardised starting and locking systems, homogeneous nomenclature). In any event, improving home ventilator user-friendliness is important (and would be relatively easy); ventilators will become more numerous with the diversification of indications for this treatment method and increases in the populations concerned.

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Table 1. List of the ventilation modes supplied by the various ventilators tested, using the names devised by the manufacturers.
For each mode, the meaning of the French abbreviation is indicated below the table, followed by a literal English translation (thus not necessarily corresponding to the English term for the ventilation mode).

VAC: Ventilation Assistée Contrôlée/*Assist-Control ventilation*
VC: Ventilation Contrôlée/*Controlled ventilation*
RPrs: Relaxateur de pression*/Pressure relaxation*
AIVT: Aide Inspiratoire avec Volume Assurée*/Inspiratory pressure support with minimal volume*
AI: Aide Inspiratoire avec ou sans fréquence de sécurité*/Inspiratory pressure support (with or without minimal frequency)*
S: Spontanée*/Spontaneous*
ST: Spontanée avec fréquence minimale (VS Ultra)*/Spontanous with minimal frequency*
S/T: Spontané/Temporisé (VPAP III)*/Spontaneous with temporisation*
PAC: Pression Assistée Contrôlée*/Assit-Control pressure support*
VPAC: Ventilation en Pression Assistée Contrôlée*/Assist-control pressure support ventilation*
PPC: Positive Pression Continue*/Continuous positive pressure*
PPC: Pression Constante (Synchrony)*/Constant pressure*
Aifr: Aide Inspiratoire avec fréquence respiratoire de sécurité*/Inspiratory pressure support with security frequency*
VPC: Ventilation en Pression Contrôlée*/Pressure control ventilation*
T: Temporisé (VPAP III)*/Temporized*

Ventilator	Names of modes (French abbreviations)
Eole 3	VAC/VC/RPrs/VACI
Helia 2	VS/AI/VPC/VPAC/RPrs/AI.Vt/VC/VAC
Knightstar	CPAP/IE/AC
Legendair	PPC/AI/AI FR/VPC/VPAC
Neftis	VSAI/VC/VAC/PC/PAC/VACI
Onyx	VSAI/VPAC/VAC
PV 403	AI/VPC/VVC
Smartair	PPC/AI/AI FR/VPC/VPAC
Synchrony	S/ST/T/PPC/AVAPS
VPAPIII	S/ST/T/CP
VS ultra	S/ST/PAC/AI/VPAC/AIVt/VAC

T: 2 niveaux de pression contrôlée (Synchrony)*/Two-level pressure control*
CP: mode de commande de pression*/Pressure command*
AVAPS: fonction d'assistance de pression assure selon un volume moyen (n'est pas un mode ventilatoire en tant que tel)*/Pressure support with minimal mean volume (not a ventilation mode as such)*
CPAP: Pression Constante (Knightstar)*/Constant pressure*
I/E: 2 niveaux de pression (Knightstar)*/ Two pressure levels*
A/C: 2 niveaux de pression avec fréquence minimale (Knightstar)*/Two pressure levels with minimal frequency*

Table 2: Scores given to ventilators by physicians after completing the tests "0 = difficult to use" "10 = easy to use".

Ventilator	Score
Eole 3 XLS	6.2 ±2.3 *[2.5-9]*
Helia 2	4.5 ±2.3 *[0-7.5]*
Knightstar	1.0 ± 1.1 *[0-3]*
Légendair	4.0 ±1.6 *[2-7]*
Neftis	5.5 ± 2.5 *[0-9]*
Onyx	4.8 ± 1.1 *[2.5-6.5]*
PV 403	3.2 ±1.6 *[0-5.5]*
Smartair	3.1 ±1.4 *[0-4.5]*
Synchrony	3.1 ± 1.9 *[0-6]*
VPAPIII	1.4 ±1.7 *[0-5.5]*
VS Ultra	5.4 ±1.7 *[3-8]*

Values in the "score" column are given as mean ± SD with indication of the minimum and maximum (square bracketed range)

Figure captions

Figure 1. Mean time for performing all the tests on all the ventilators by physicians (grey columns) and the technician (white column). There were no significant differences between physicians, but all "physician" times were significantly longer than the "technician" time ($p = 0.001$ or less).

Figure 2. Timing results for test 1 (startup). The x-axis represents the 11 ventilators tested; the y-axis, the time required to successfully perform the test (in seconds); the z-axis, the technician times on the first line and those of the physicians on the following lines. Thus each column corresponds to the time taken by a physician tested on a ventilator.

Figure 3. Timing results for test 2 (unlocking). The x-axis represents the 11 ventilators tested; the y-axis, the time required to successfully perform the test (in seconds); the z-axis, the technician times on the first line and those of the physicians on the following lines. Thus each column corresponds to the time taken by a physician tested on a ventilator.

Figure 4. Timing results for test 3 (recognition). The x-axis represents the 11 ventilators tested; the y-axis, the time required to successfully perform the test (in seconds); the z-axis, the technician times on the first line and those of the physicians on the following lines. Thus each column corresponds to the time taken by a physician tested on a ventilator.

Figure 5. Results of test #3 recognition of modes and settings.

Figure 6. Timing results for test 4 (mode change). The x-axis represents the ventilators tested; the corresponding function are absent in the other ones; the y-axis, the time required to successfully perform the test (in seconds); the z-axis, the technician times on the first line and those of the physicians on the following lines. Thus each column corresponds to the time taken by a physician tested on a ventilator.

Figure 7. Timing results for test 5 (pressure setting). The x-axis represents the ventilators tested; the corresponding function are absent in the other ones; the y-axis, the time required to successfully perform the test (in seconds); the z-axis, the technician times on the first line and those of the physicians on the following lines. Thus each column corresponds to the time taken by a physician tested on a ventilator.

Figure 8. Timing results for test 6 (alarms). The x-axis represents the ventilators tested; the corresponding function are absent in the other ones; the y-axis, the time required to successfully perform the test (in seconds); the z-axis, the technician times on the first line and those of the physicians on the following lines. Thus each column corresponds to the time taken by a physician tested on a ventilator.

Figures

Fig.1

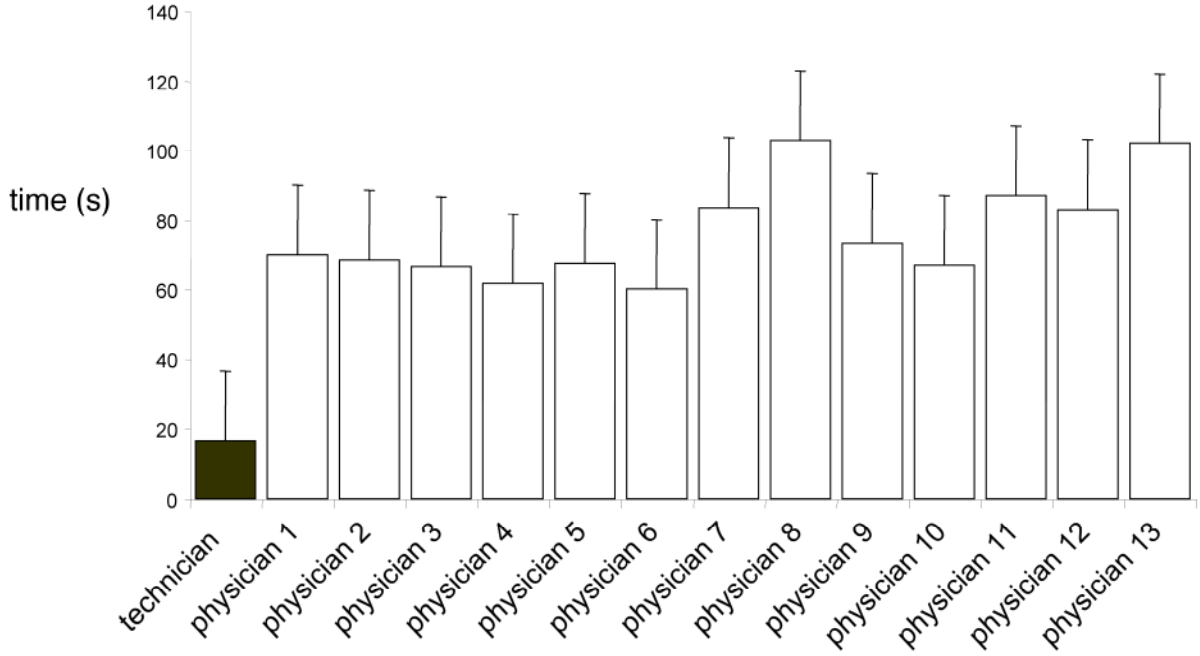


Fig 2

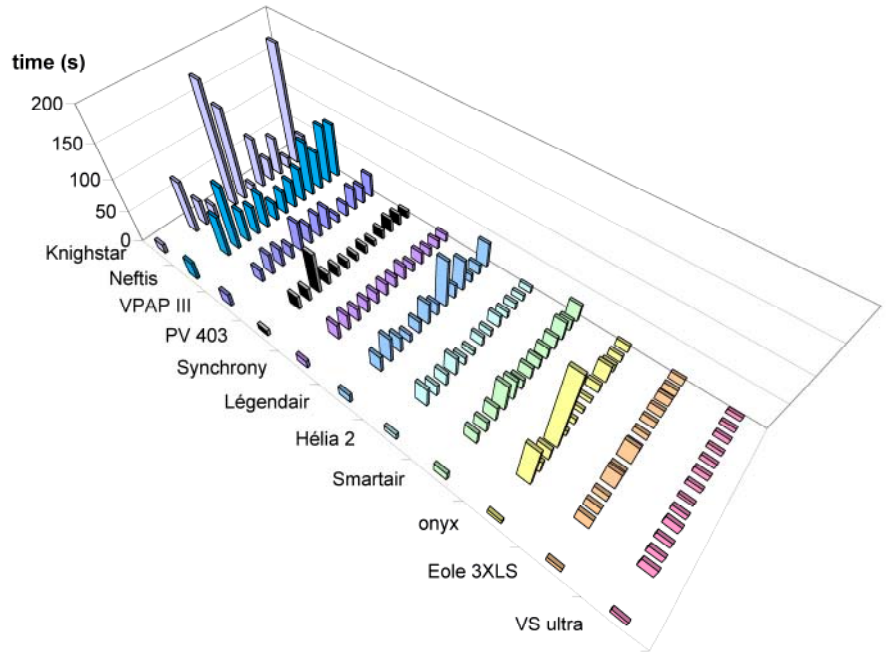
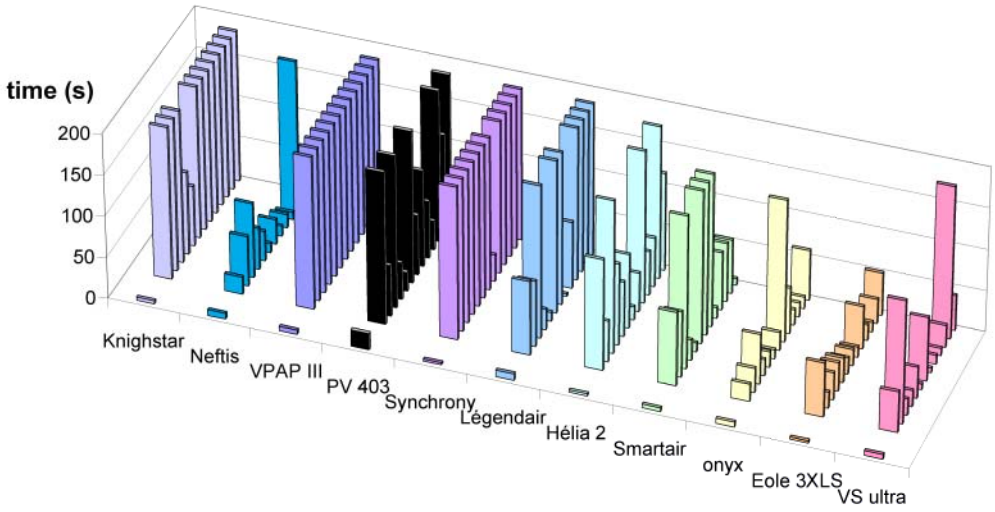


Fig 3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200
150
100
50
0
Knighstar
Neftis
VPAP III
PV 403
Synchrony
Légendair
Hélia 2
Smartair
onyx
Eole 3XLS
VS ultra

Fig 4

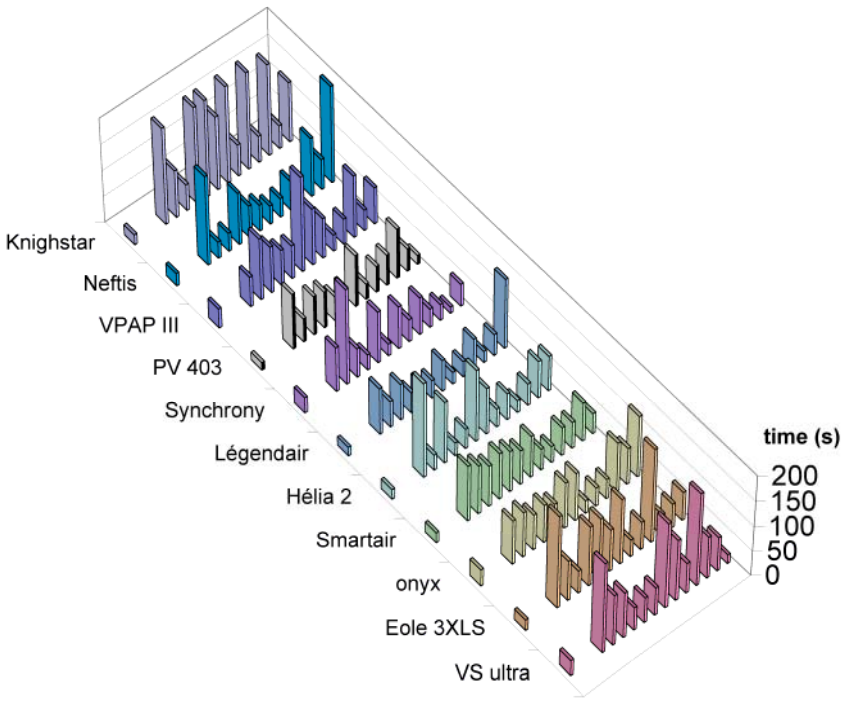

Knighstar
Neftis
VPAP III
PV 403
Synchrony
Légendair
Hélia 2
Smartair
onyx
Eole 3XLS
VS ultra
time (s)
200
150
100
50
0

Fig.3

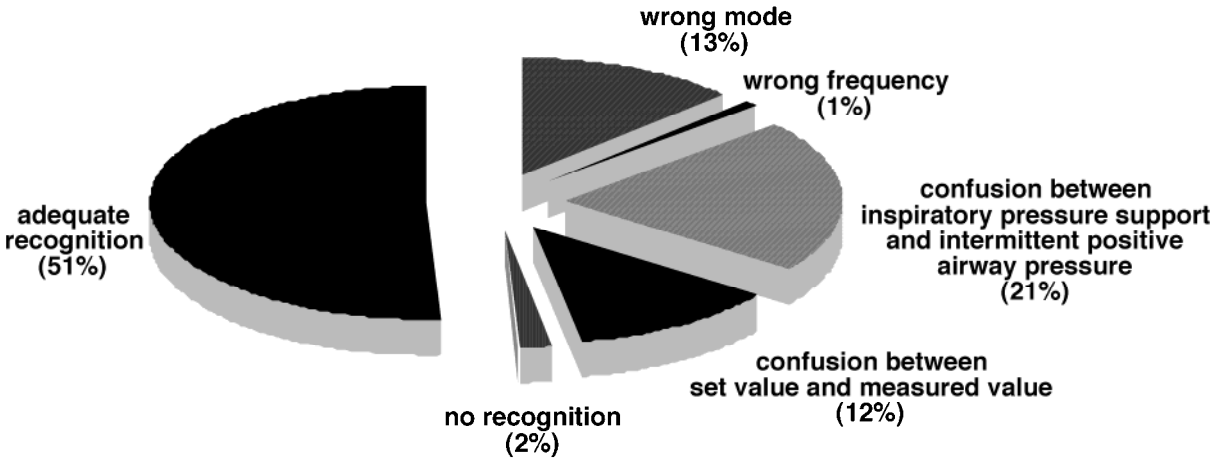

wrong mode
(13%)
wrong frequency
(1%)
confusion between
inspiratory pressure support
and intermittent positive
airway pressure
(21%)
adequate
recognition
(51%)
confusion between
set value and measured value
(12%)
no recognition
(2%)

Fig 6

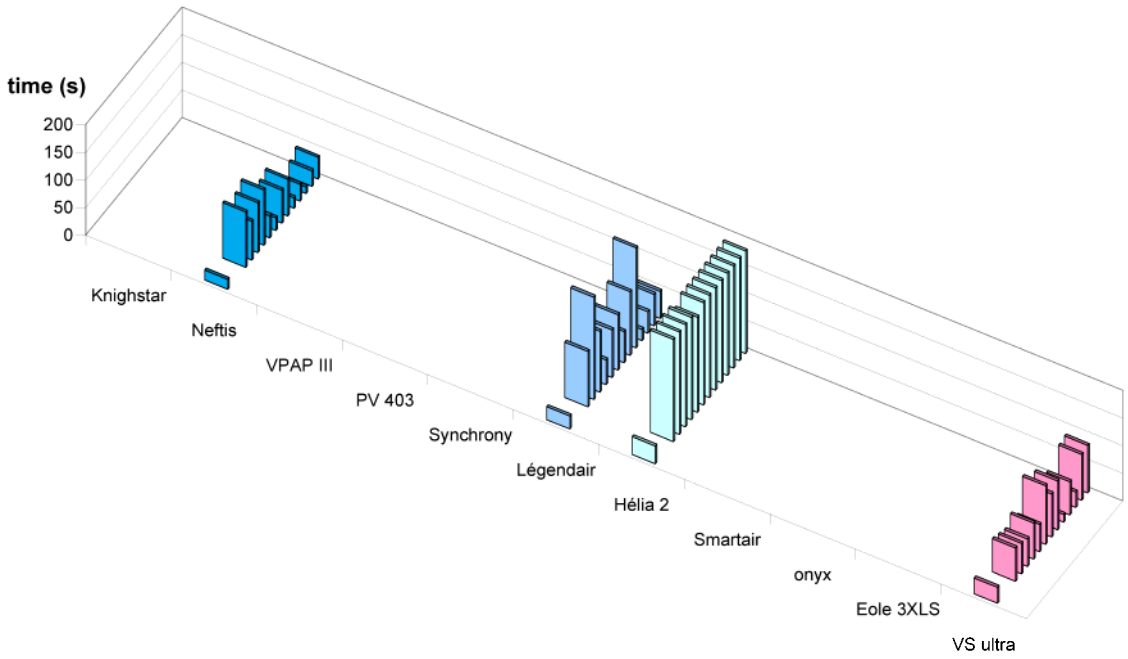
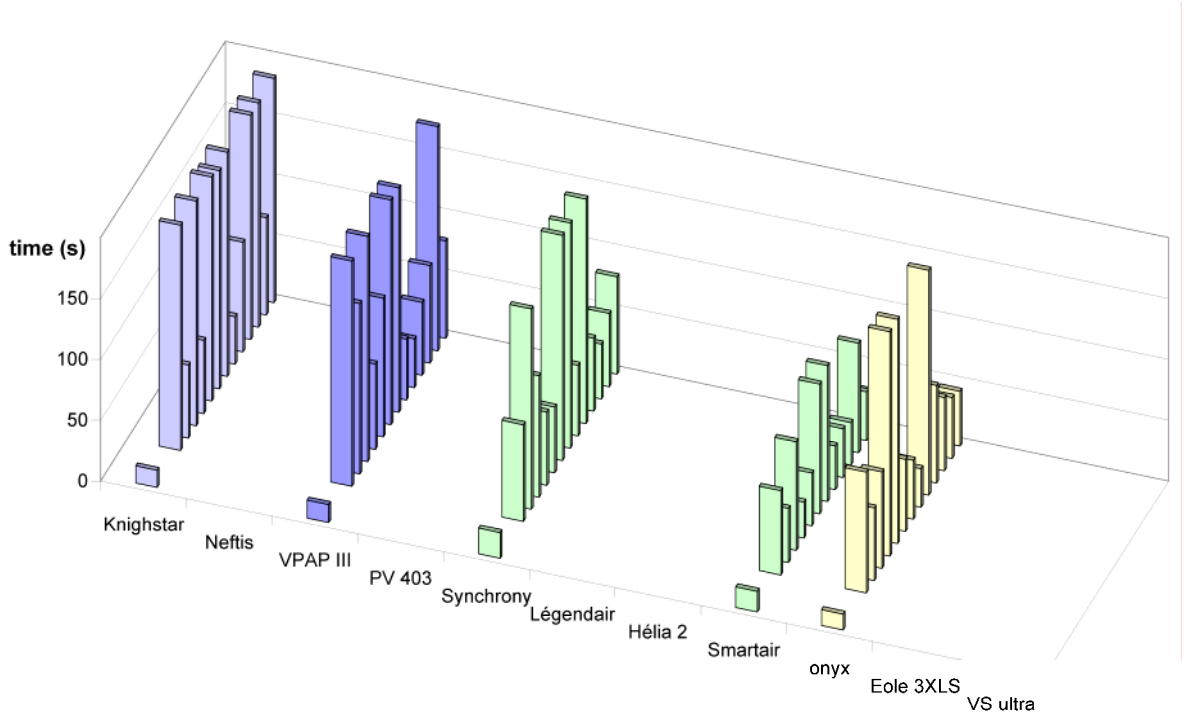

time (s)
200
150
100
50
0
Knighstar
Neftis
VPAP III
PV 403
Synchrony
Légendair
Hélia 2
Smartair
onyx
Eole 3XLS
VS ultra

Fig 7


time (s)
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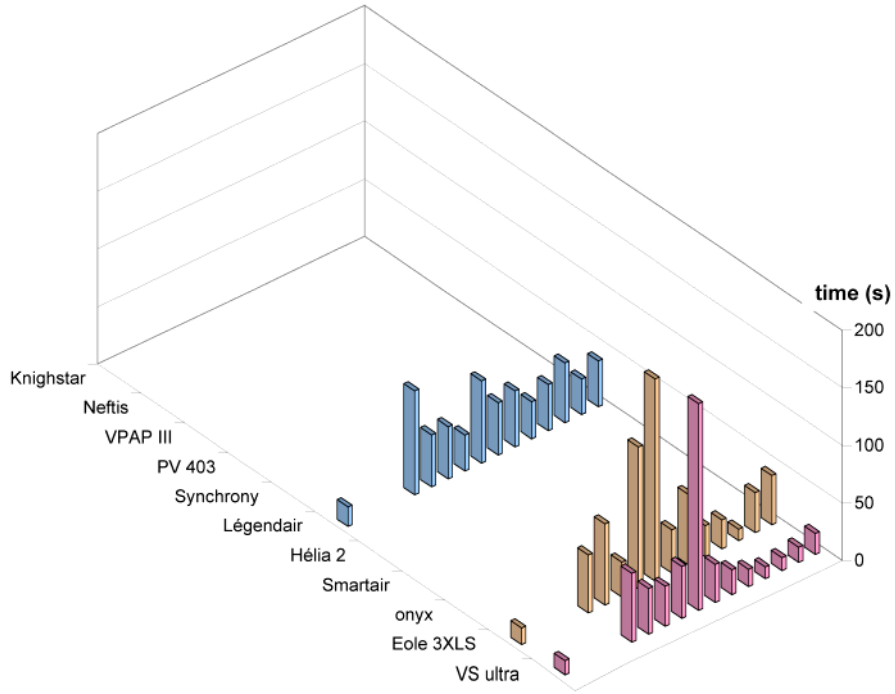
100
50
0
Knighstar
Neftis
VPAP III
PV 403
Synchrony
Légendair
Hélia 2
Smartair
onyx
Eole 3XLS
VS ultra

Fig 8


time (s)
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0
Knighstar
Neftis
VPAP III
PV 403
Synchrony
Légendair
Hélia 2
Smartair
onyx
Eole 3XLS
VS ultra