

A Portable Continuous Positive Airway Pressure Device That Can Perform Optimally under Strenuous Conditions

To the Editor:

Application of continuous positive airway pressure (CPAP) is currently the most widespread and effective therapy for sleep-breathing disorders. Since publication of the seminal paper by Sullivan and colleagues (1), CPAP technology has considerably improved, resulting in devices that incorporate control algorithms to allow the application of stable nasal pressure along the breathing cycle, even in the case of unintended air leaks caused by poor fitting of the mask onto the patient's skin. Moreover, intelligent CPAP devices that are able to detect respiratory events in real time and accordingly adapt the nasal pressure to normalize the patient's breathing have been developed and are now widely used (2). However, a remaining challenge is to improve the relatively low compliance of CPAP therapy (3). To this end, providing patients with more user-friendly devices by reducing the size of the devices and hence improving their usability and portability would be of great interest. Nevertheless, reducing the size of CPAP devices and at the same time ensuring correct performance under the potentially strenuous conditions found in the real-life clinical arena poses a considerable engineering problem.

The main limiting factor in trying to reduce the size of a fixed or auto-setting CPAP device is not its electronic components (flow/pressure transducers and control microprocessor) but rather its blower, which is the core element of the device. Indeed, provided that the control software is well designed, generating a high, stable nasal pressure regardless of the amplitude of the patient's breathing and the magnitude of unintended air leaks requires a blower that is able to generate sufficient airflow (4). Hence, reducing the size of a pressure-generating blower and at the same time maintaining its performance is a difficult design challenge, particularly taking into account that the blower should operate by inducing a reasonably low level of noise for CPAP application during sleep. In this context, we aimed to ascertain whether a CPAP device with considerably reduced size as compared with conventional devices would be able to perform optimally. To that end, a bench test comparing a recently commercialized portable CPAP device (AirMini; ResMed) and a conventional well-performing device (AirSense 10; ResMed) was performed. According to their technical specifications, the weight, volume, and typical power consumption of these devices are 300 g, 0.6 L, 6.3 W, and 1,248 g, 3.9 L, 53 W, respectively.

A previously described realistic patient simulator (5, 6) was used to bench test the performance of these CPAP devices under well-controlled and reproducible conditions. Briefly, a flow generator reproduced respiratory flow patterns of patients with obstructive sleep apnea

(OSA) previously recorded during nocturnal polysomnography. An obstruction valve allowed the simulation of different levels of respiratory resistance in patients with OSA during the different simulated events. A controlled valve allowed the simulation of unintended leaks (whether they are caused by poor mask fitting or by mouth leaks is not relevant with regard to blower performance). Two sensors were placed at the entrance of the simulated patient to record actual breathing flow and nasal pressure. The test was performed under very strenuous operating conditions. First, a patient with OSA presenting with CPAP-set, pressure-dependent breathing events, and requiring application of a considerably high nasal pressure to normalize breathing was mimicked. Indeed, the simulated patient exhibited 1) apneas with airway obstruction for CPAP < 8 cm H₂O; 2) severe hypopneas for CPAP between 8 and 11 cm H₂O; 3) mild hypopneas for CPAP between 11 and 14 cm H₂O; 4) prolonged flow limitation for CPAP between 14 and 18 cm H₂O; and 5) normal breathing for CPAP > 18 cm H₂O. Second, a considerable orifice-like unintended leak (24 L/min at 10 cm H₂O) was imposed. The AirMini CPAP device was connected to the patient simulator by its recommended small-size setting, including a nasal mask with/without a heat and moisture exchanger and 2-m-long tubing (AirFit N20 Mask Kit for AirMini user; ResMed). The AirSense 10 CPAP device (including its humidifier) was connected to the simulated patient by its conventional tubing. Both CPAP devices and accessories were provided by ResMed for this study. Each test started with 15 minutes of normal breathing to simulate the time before sleep onset, followed by 2 hours of simulated OSA, and was performed two times after a general off/on power reset to check reproducibility.

Figure 1 shows the performance of the travel-size CPAP device under the most challenging operating conditions (with heat and moisture exchanger, and unintended air leaks). The device was able to normalize the breathing flow of the simulated patient with severe OSA by applying the required nasal pressure (18 cm H₂O, which is much higher than the typical pressure prescribed to patients with OSA). Table 1 indicates that the response of the small-size CPAP device was virtually identical to that of the conventional device, regardless of the fact that a considerably high unintended leak was present. Remarkably, excellent performance was observed with this CPAP device, which was 4.2-fold lighter and 6.5-fold smaller, and had 8.4-fold lower typical power consumption as compared with the conventional device.

Although the bench test applied here mimicked a specific patient with one of the possible methodological approaches to simulate the upper-airway collapsibility in OSA (7), this report provides a solid proof of concept showing that a CPAP device can be considerably reduced in size, weight, and power consumption with no loss of performance. It is therefore expected that such small-size CPAP devices would perform adequately when further tested in patients experiencing real-life, difficult-to-simulate artifactual events such as sighing, coughing, or deep breathing, or speaking while wearing the mask (8). However, it is important to note that, given that the performance of small-size CPAP devices critically depends on their specific engineering design, the results obtained in this study cannot be extended to other small-size CPAP devices unless their performance is assessed. Finally, it is interesting to note that the observation that small-size CPAP devices can perform well in the presence of considerable leaks at high pressure (18 cm H₂O), which is close to the common inspiratory pressures used in noninvasive ventilation, strongly suggests that the size and hence the battery consumption (9) of this type of assisted ventilation device could be also considerably reduced, thereby opening the window to a new

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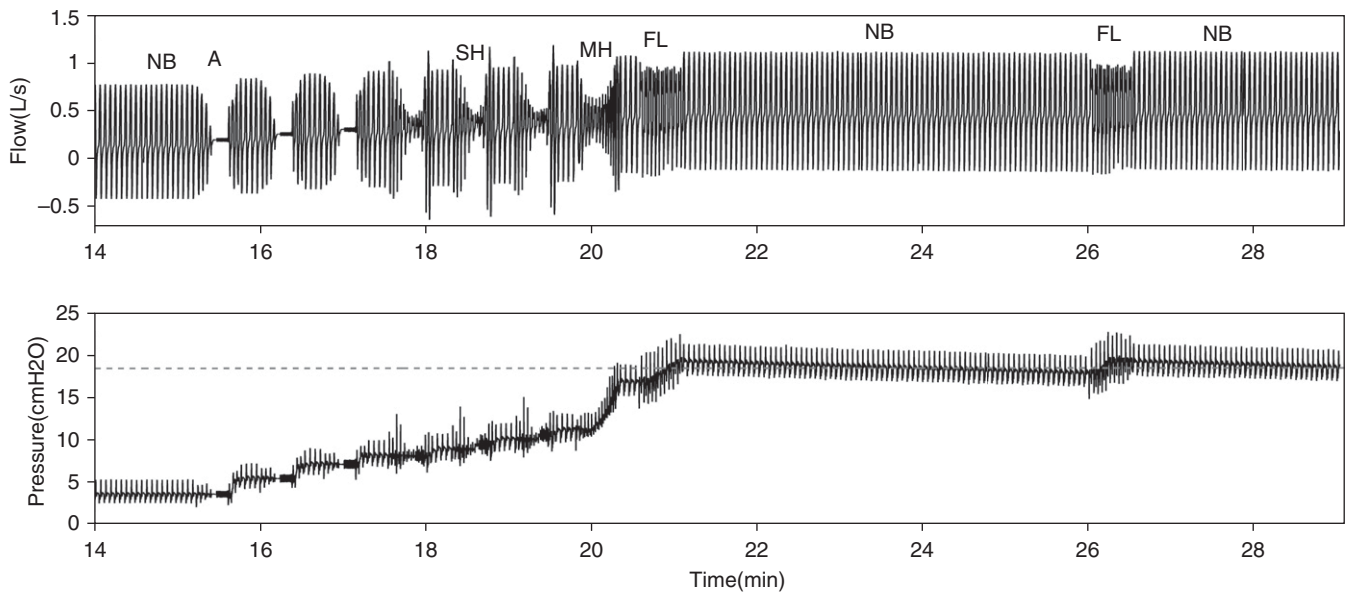


Figure 1. Example of flow and nasal pressure applied by a small-size, automatic continuous positive airway pressure device to a simulated patient with severe obstructive sleep apnea, with simulated unintended air leaks caused by poor mask-to-skin fitting. The flow signal is the breathing flow of the simulated patient plus the flow through the simulated unintended air leak (e.g., 0.40 and 0.52 L/s at 10 and 18 cm H₂O, respectively). Respiratory events started after 15 minutes of normal breathing to simulate the time before sleep onset. The pattern of transition alternating between long periods of normal breathing and short periods of flow limitation shown in the second part of the figure was repeated for the rest of the 2-hour test. The dashed line represents the pressure required to achieve breathing normalization (18 cm H₂O). A = apnea; FL = flow limitation; MH = mild hypopnea; NB = normal breathing; SH = severe hypopnea.

Table 1. Comparison of the Bench-Test Performance of a Reduced-Size and a Conventional Continuous Positive Airway Pressure Device on a Simulated Patient with Obstructive Sleep Apnea Requiring a Nasal Pressure of 18 cm H₂O to Normalize Breathing

Test Configuration	Air Leak	Test #	Overcome Events and Flow Limitation	P _{NORM} (cm H ₂ O)	T-P _{NORM} (min)	P _{MAX} (cm H ₂ O)	T-P _{MAX} (min)	P _{MEAN} (cm H ₂ O)	Residual Events/h
Reduced size	Yes	1	Yes	19.4	5.8	19.4	5.8	18.2	3.5
		2	Yes	19.4	5.4	19.4	5.1	18.2	3.5
AirMini without HME	Yes	1	Yes	20.0	5.4	20.0	5.1	18.5	3.5
		2	Yes	20.0	5.4	20.0	5.0	18.5	3.5
AirSense 10 with humidifier	Yes	1	Yes	18.9	5.0	18.9	5.0	18.0	3
		2	Yes	18.8	5.4	18.9	5.3	18.0	3
Conventional size	No	1	Yes	19.8	4.6	19.8	4.6	18.5	2.5
		2	Yes	19.9	5.4	19.9	5.4	18.5	3
AirMini without HME	No	1	Yes	20.0	5.2	20.0	5.2	18.6	3
		2	Yes	20.0	5.1	20.0	5.1	18.5	3
AirSense 10 with humidifier	No	1	Yes	19.0	4.1	19.0	4.2	18.2	2.5
		2	Yes	19.1	4.1	19.1	4.2	18.2	2.5

Definition of abbreviations: air leak = presence of simulated unintended leak (24 L/min at 10 cm H₂O); HME = heat and moisture exchanger; P_{MAX} = maximum nasal pressure applied; P_{MEAN} = mean pressure applied (excluding the 15 min before sleep onset); P_{NORM} = first peak of pressure delivered by the device that achieved breathing normalization; residual events/h = number of apneas and hypopneas per hour (excluding the 15 min before sleep onset); T-P_{MAX} = time to reach the maximum pressure (excluding the 15 min before sleep onset); T-P_{NORM} = time to reach pressure of breathing normalization (excluding the 15 min before sleep onset).

Tests 1 and 2 correspond to the two independent test runs for each testing condition. Note: As expected, similar good results were obtained when we compared the performance of the small-size and conventional continuous positive airway pressure devices in simulated patients with less severe obstructive sleep apnea requiring 12 and 15 cm H₂O of nasal pressure to normalize breathing (data not shown).

generation of portable and home mechanical ventilators (10) for patients needing assisted ventilatory support. ■

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A Cross-Sectional Assessment of Rhinitis Symptoms and Nasal Patency in Relation to Welding Exposure

To the Editor:

Rhinitis symptoms are often reported by workers exposed to occupational sensitizing agents, and occupational rhinitis due to exposure to welding fumes has been reported (1). A European population-based study also found that the incidence of rhinitis was higher among individuals of both sexes in the welding profession (2).

Between September 2013 and April 2017, we conducted a long-term follow-up assessment of respiratory effects in an inception cohort of apprentices in the welding profession, 7–17 years after they served their apprenticeship (3, 4). Ninety of 330 former apprentices were evaluated after the study was approved by the Hôpital du Sacré-Cœur de Montréal Ethics Committee, in accordance with Canadian ethics rules (CER 2012-801). In this study, we evaluated whether prevalent nasal symptoms and nasal patency were related to current exposure to welding fumes.

Rhinitis was defined as the presence of two or more of the following symptoms at the follow-up visit: sneezing, runny nose, and/or nasal congestion. Nasal patency was measured with a peak nasal inspiratory flow (PNIF) meter. Three PNIF measurements were obtained from each patient and the highest value was retained for analysis. PNIF < 115 L/min was considered low nasal patency (5). Lower-airways function was assessed with spirometry and a methacholine challenge test. Reduced pulmonary function at the time of diagnosis was defined as FEV₁ predicted ≤ 80%.

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