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Noninvasive ventilation and obstructive lung diseases

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ABSTRACT: The key role of noninvasive positive pressure ventilation (NPPV) is well documented in chronic obstructive pulmonary disease (COPD) patients with acute respiratory failure (ARF) since it may avoid endotracheal intubation in >50% of cases when used as the initial treatment. However, currently only minimal data is available to assess usefulness of NPPV in COPD patients on a long-term basis. Even if such studies are difficult to manage, there is clearly a need for prospective studies comparing long-term oxygen therapy (LTOT) and NPPV in the most severe COPD in a large amount of patients and on a real long-term basis of several years. Two randomized prospective studies are being completed in Europe and the first preliminary results show that NPPV is associated with a reduction of hospitalization for chronic respiratory failure decompensation.

The main beneficial effect of long-term mechanical ventilation in COPD patients with chronic respiratory failure implies a correction of nocturnal hypoventilation that could persist beyond the ventilation period because of a temporary improvement in carbon dioxide sensitivity that is often blunted in these patients.

A synthesis from the literature suggest to consider NPPV for severe COPD patients who present with chronic hypoxia and hypercapnia and develop an unstable respiratory condition. Instability may be appreciated on a clinical basis and confirmed by a progressive worsening of arterial blood gas tensions, leading to frequent cardiorespiratory decompensations with ominous ARF episodes. NPPV should also be considered after an ARF episode successfully treated by noninvasive ventilation but with the impossibility to wean the patient from the ventilator.

Thus, noninvasive positive pressure ventilation could be proposed as a preventive treatment in severe chronic obstructive pulmonary disease patients with unstable respiratory condition associated with fluctuating hypercapnia before, during and after an acute respiratory failure episode, avoiding the need for a tracheotomy. Adjunction of noninvasive ventilation to exercise rehabilitation is under evaluation.

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Optimal management of severe chronic obstructive pulmonary disease (COPD) patients includes long-term oxygen therapy (LTOT), respiratory stimulant drugs, lung volume reduction surgery and mechanically assisted ventilation. Only a small proportion of patients with COPD will need ventilatory assistance either in an acute care setting or on a long-term basis.

However, COPD patients have ~4 exacerbation episodes per year and the main costs related to COPD are related to inpatient hospital care. Because acute respiratory failure (ARF) episodes are recurrent in this population, noninvasive positive pressure ventilation (NPPV) has gained wide acceptance since it does not use the endotracheal way [1] and is therefore associated with less morbidity and less duration in

hospital stay as compared with invasive mechanical ventilation.

Long-term home mechanical ventilation (LTHMV) is generally considered in patients with COPD and chronic respiratory failure (CRF) and with progressive worsening of the general and respiratory status, associated with frequent episodes of ARF, when LTOT fails. Home mechanical ventilation represents the discharge to home from acute (or chronic) care hospital of ventilator-assisted patients who require long-term use of their ventilator (≥ 3 h·day⁻¹) intermittently or continuously, either with a tracheostomy, mouthpiece, facial or nasal mask, or an external device [2, 3]. However, LTHMV in severe COPD patients is still controversial since only limited data have been published today in this population. This

review will highlight the present data from the literature concerning NPPV in acute and chronic care management of COPD patients and will suggest an algorithm for selecting the subpopulation of patients who will benefit from NPPV on a long-term basis.

History

LTHMV with intermittent positive pressure ventilation (IPPV) was introduced in clinical practice after the iron lung era during the 1950s. LTHMV development was favoured by a rapid progress in ventilator technology and a net survival improvement of patients treated by tracheotomy-mediated ventilation, as later reported by ROBERT *et al.* [4] in a retrospective study including various aetiologies of CRF. After the poliomyelitis epidemics, LTHMV was further indicated in patients with chronic respiratory insufficiency secondary to many restrictive disorders like muscular dystrophies and tuberculosis sequelae but also to obstructive diseases such as COPD. At the beginning of the 1960s, the French precursor P. Sadoul, satisfactorily documented arterial blood gas controls by using volumetric ventilators and facial masks in COPD patients with ARF [5]. However, that technique was abandoned because of the large extent of ventilation with tracheostomy at that period, and because convenient masks were not available.

The relative interest of IPPV through mouthpiece or tracheotomy *versus* LTOT for COPD patients was discussed as soon as the early 1970s [6]. At the end of the 1970s, the multicentre study of the British Medical Research Council (BMRC) [7] confirmed the first results from the Denver group [8] and showed a significant improvement of survival among COPD patients receiving LTOT *versus* a control group without LTOT. The simultaneous publication of the American Nocturnal Oxygen Therapy Trial (NOTT) study also demonstrated benefits in the group receiving continuous LTOT *versus* a control group in which only nocturnal oxygen therapy had been given [9]. Oxygen therapy seemed to put an end to the cumbersome and constraining long-term mechanical ventilation techniques for which indications had never been clearly documented in COPD patients. However, within the present decade, general advances in respiratory care and rehabilitation, better home-care services and new generations of compact, portable ventilators have prompted renewed interest in long-term mechanical ventilation [10]. Improvement of interfaces such as nasal masks [11, 12] or external prostheses occurred in the 1980s due to new interest in noninvasive mechanical ventilation when improved types of interfaces became available. Thus, many thousands of patients, mainly with a restrictive ventilatory defect, are currently treated by LTHMV all over the world [13, 14]. According to the French National Association for Home Respiratory Care (ANTADIR), at the end of 2000 5,000 individuals were estimated to have been treated in France by long-term IPPV. However, NPPV is not new, if the

important results obtained in polio patients in the 1950s with perithoracic ventilation are considered.

In the late 1980s, the publications from MEDURI *et al.* [15] about facial mask ventilation in COPD patients with ARF were confirmed in a controlled fashion successively by BROCHARD *et al.* [16], KRAMER *et al.* [17] and BOTT *et al.* [18]. Such data favoured numerous publications, proving benefits of this technique in the acute care setting but also in the long-term, as similarly reported in neuromuscular patients by BACH and ALBA [19] in USA and by RIDEAU [20] in France for patients with muscular dystrophy. As a result, NPPV was reconsidered for patients with severe hypoxic and hypercapnic COPD whose condition was unstable and who had poor responsiveness to LTOT [21].

NPPV may be delivered with various kinds of ventilatory methods, which are generally divided in two concepts, internal methods using intermittent positive pressure ventilation, and external methods with mainly negative pressure ventilation using perithoracic prostheses.

Negative pressure ventilation

Use of negative intermittent pressure ventilation was reconsidered at the beginning of the 1980s in COPD patients [22] due to the existence of new devices which performed better than the classic iron lung. These devices, such as cuirass, external shells and jackets (poncho or wrap), are applied to the thorax and/or the abdomen. Several trials have been conducted to determine whether respiratory muscles can be rested by negative pressure ventilation and if this is beneficial on a long-term basis. Preliminary results showed that there was a real effect on the dyspnoea level, on the capture of diaphragmatic activity and on the respiratory muscle strength [23]. In terms of dyspnoea levels, negative intermittent pressure ventilation seems better tolerated by "type B" COPD patients (*i.e.* hypercapnic) than "type A" (*i.e.* eucapnic) emphysematous patients. However, randomized trials failed to prove efficiency of this treatment and compliance was poor [24, 25]. A previous controlled, randomized study [26] showed no beneficial effects on arterial blood gases, walking tests, level of dyspnoea, and quality of life in 184 COPD patients treated during 12 weeks with effective negative intermittent pressure ventilation by poncho, as compared to a sham ventilation with poncho. Compliance was poor within the 63 patients not using the poncho or who stopped using it before the end of the study. These poor results and a low compliance with such a cumbersome technique explain that negative pressure ventilation was supplanted by the rapidly growing nasal ventilation.

Intermittent positive pressure ventilation

NPPV may be applied to the nose *via* a mask or pillows and to the mouth *via* a mask or a mouthpiece [27]. Survival rates for home intermittent positive

pressure ventilation are much lower for patients with chronic airflow obstruction, with a 10-yr survival of ~10% [28–30], decreased hospitalization and some improvement in right heart failure and arterial gases, than for those with restrictive chest wall or neuromuscular disease.

Mouth positive pressure ventilation

Intermittent oral positive pressure generally refers to "intermittent positive pressure breathing (IPPB)" when used for short time-periods with pressure-cycled ventilators and to "mouth intermittent positive pressure ventilation (MIPPV)" when used for a longer period of time with a volume-cycled ventilator [27]. MIPPV was very popular in Europe during the 1970s but was rapidly found to be nonbeneficial for patients because of its constraints and the impossibility to provide long-term periods of mechanical ventilation [28–30]. Consequently, compliance and efficiency of the technique were poor. It is more than likely that a number of patients treated by MIPPV during the 1970s for a moderate hypercapnia would have been offered simple LTOT in the 1980s. It differed from the IPPB programmes studied in the USA during the same period because IPPB does not provide a real respiratory assistance [31, 32]. A prospective study [33] has shown no benefit from IPPB as compared to simple nebulizations in a group of less severe COPD patients.

From home mechanical ventilation with tracheostomy to nasal noninvasive positive pressure ventilation

The major potential benefit from mechanical ventilation by tracheostomy is the potential of longer periods of efficient mechanical ventilation sessions, especially during the night. Evaluation of long-term results of home mechanical ventilation with tracheostomy (HMVT) in COPD patients is impaired because of a lack of controlled studies. Different studies [28, 30] have reported the prognosis of COPD with HMVT, which appeared less favourable as compared to patients with restrictive chest wall or neuromuscular disorders. In the study of ROBERT *et al.* [4], the 5-yr survival is 30% and the 10-yr survival is 8%, with stabilization after the 10th year for a population of 112 COPD patients using HMVT (fig. 1). However, these results must be considered as an attempt at improving patient comfort by reducing the frequency of hospitalizations for ARF [10, 34, 35].

This led the authors to conduct a similar multicentre retrospective study in a larger population of 259 COPD patients treated by HMVT with the help of ANTADIR [36]. Survival curves (fig. 2) were drawn between the study of ROBERT *et al.* [4] and the previous reports of LTOT alone in the BMRC [6] and NOTT [8] trials. The latter report recruited patients with less severe COPD: 42% with 5-yr survival and 22% with 8-yr survival. However, survival in the ANTADIR study is better than the survival of treated patients from the BMRC trial until the fourth year of

Fig. 1. – Survival of patients treated at home by long-term mechanical ventilation with tracheostomy according to the aetiology of the chronic respiratory failure. —: post-polio syndrome;: myopathies; — — —: kyphoscoliosis; - - - - -: damaging sequelae of tuberculosis; — · — · —: chronic obstructive pulmonary disease; — · — —: bronchiectasis. Reproduced with permission from [4].

follow-up, where survival curves become identical. In spite of the difficulty to extrapolate from one study to another, comparison of the survival curves from the ANTADIR group to those of the BMRC study seems to favour a more interventional approach for these patients including a trial of mechanical ventilation. Indeed, the BMRC study showed that early deaths were recruited in the most hypercapnic and the most polyglobulic patients *i.e.* with the most severe chronic respiratory failure. Logically, mechanical ventilation should have been beneficial to those patients since LTOT appeared to provide no benefit during the first 500 days after initiation.

Fig. 2. – Actuarial survival curve of chronic obstructive pulmonary disease (COPD) patients treated by home mechanical ventilation with tracheostomy as compared with long-term oxygen therapy. In this figure are presented the results implying tracheotomized patients from the studies of ROBERT *et al.* [4] (— (n=50)) and of CUEVIER and MUIR [37], (— (n=259)). Survival curves are compared with patients treated by oxygen therapy alone from the American Nocturnal Oxygen Therapy Trial (NOTT) [8] (12 h group: — (n=101)); 24 h group: (n=101)) and the British Medical Research Council (BMRC) [6] (15 h group: — (n=42); control group: — — — (n=45)) studies. Study/NOTT O₂ 12 h group, $p < 0.05$ and study/BMRC control group $p < 0.05$. Reproduced with permission from [37].

Nasal noninvasive positive pressure ventilation

IPPV can be applied to the airways with a nasal mask [12], a facial mask, or with nasal pillows as initially proposed by Rideau [20] for LTHMV in patients with muscular dystrophy. Since the early 1980s, nasal intermittent positive pressure ventilation has been extensively studied in patients with restrictive chronic respiratory insufficiency as well as in those with acute [14, 38, 39–43] and chronic conditions [44, 45]. After 1 or 2 months of nasal IPPV at night, transcutaneous arterial carbon dioxide tension (P_{a,CO_2}) and arterial oxygen saturation (S_{a,O_2}) improved.

Important results were obtained in COPD patients with ARF [15, 38, 39–43] whereby nasal NPPV may avoid endotracheal intubation in >50% of patients when used as the initial treatment [42]. It was then attractive to perform NPPV on a long-term basis in COPD patients with CRF, but this subject remains controversial [39]. In the first uncontrolled studies with COPD patients treated with NPPV for 3–9 months, a significant improvement occurred in the diurnal arterial blood gases with an improvement of sleep quality [12, 13, 40], the best results being obtained in the more hypercapnic patients [44, 45] with nevertheless a less satisfactory compliance than in restrictive patients.

However, currently there is only minimal data to

assess usefulness of NPPV in COPD patients on a long-term basis [43–45]. In 12 patients, ELLIOTT *et al.* [41] reported an interesting compliance to the nasal ventilation with an improvement of arterial blood gases at the 12th month (fig. 3), with an improvement of sleep quality and of quality of life. In a collective of 276 patients under NPPV (among which 50 COPD were included), LEGER *et al.* [46] reported an improvement of arterial oxygen tension (P_{a,O_2}) and P_{a,O_2} after 1 and 2 yrs. After 1 yr, the authors showed a marked reduction in the numbers of days in hospital for ARF, the probability to pursue NPPV being 55% at the 36th month of treatment (fig. 4). A UK retrospective study in 33 COPD patients followed during 5 yrs [47], showed that the probability of continuing ventilation was lower (~43%) but this study concerned patients at the end stage of their disease (fig. 5). In 14 patients with hypercapnic COPD followed during 6 months, PERRIN *et al.* [48] showed that daytime arterial blood gases were improved with NPPV and that the total St. George Respiratory Questionnaire (SGRQ) and the impact components of this score were improved (fig. 6).

Some controlled studies are available but remain controversial: STRUMPF *et al.* [49] using NPPV in a randomized crossover study within 23 patients with COPD, failed to note a clear improvement with mechanical ventilation. No modifications were assessed

Fig. 3. – Arterial blood gas tensions a and b) arterial oxygen tension (P_{a,O_2}) and c and d) arterial carbon dioxide tension (P_{a,CO_2}) during spontaneous breathing and after 6 months and 1 yr in patients submitted to nasal positive pressure ventilation (NPPV): seven patients still using NPPV at home and one who discontinued ventilation after 9 months. Three patients who discontinued home mechanical ventilation before 6 months. Reproduced with permission from [41].

Fig. 4. – Probability to continue nasal intermittent positive pressure ventilation in various aetiologies of chronic respiratory failure. ●: kyphoscoliosis; □: tuberculosis; ○: chronic obstructive pulmonary disease; ▲: bronchiectasis; ■: duchenne. Reproduced with permission from [46].

concerning dyspnoea, pulmonary function tests, respiratory muscle strength, arterial blood gases, exercise tests and sleep parameters. The only benefits were noticed on the neuropsychological function. However, only seven patients completed the study, such a poor compliance being linked to the nasal mask interface. Moreover, the authors used bilevel positive pressure ventilation (BiPAP) [49, 50] and the patients, in spite of a frank obstructive defect, had only a moderate alteration of arterial blood gases, some of them being even normocapnic at stable state. In a more recent randomized crossover study, MEECHAM-JONES *et al.* [51] compared the benefit of NPPV plus oxygen therapy *versus* LTOT alone in 18 patients followed during two successive periods of 3 months with each treatment. Significant improvements in daytime arterial blood gases were assessed with a mean P_{a,O_2} increase and a mean P_{a,O_2} reduction under NPPV (fig. 7) associated with an improvement of

Fig. 5. – Probability of continuing nasal intermittent positive pressure ventilation (NIPPV) in UK according to different diagnostic groups. —: poliomyelitis; ---: tuberculosis;: neuromuscular; ---: kyphoscoliosis; —: chronic obstructive pulmonary disease; —: bronchiectasis. Reproduced with permission from [47].

Fig. 6. – Evolution of the St. George's Respiratory Questionnaire (SGRQ) scores after 6 months of nasal intermittent positive pressure ventilation. *: $p < 0.05$. Reproduced with permission from [48].

nocturnal P_{a,O_2} and sleep parameters. This study also showed that the improvement of daytime arterial blood gases was correlated with the change in overnight P_{a,O_2} . Compliance was satisfactory, 14 out of the 18 patients completed the study. This was attributed to the fact that the included patients were

Fig. 7. – Individual (---) and mean (—) values of daytime arterial oxygen tension (P_{a,O_2}) and arterial carbon dioxide tension (P_{a,CO_2}) at run-in and after 3 months of oxygen alone and 3 months of oxygen and nasal pressure support (NPSV) in 14 chronic obstructive pulmonary disease (COPD) patients. Reproduced with permission from [51].

inpatients with better education to NPPV and also more severe patients with more severe hypercapnia. Because quality of life scores (symptom, impact, and total quality of life scores) were also improved, the authors suggested that such a benefit could be associated to the improvement of arterial blood gases and to the improvement of sleep quality. LIN [52] prospectively compared the benefits of 2-week treatment periods by LTOT alone, NPPV alone and NPPV in COPD patients. No difference was found for pulmonary function tests, arterial blood gases, index of respiratory muscle strength or ventilatory drive. Sleep quality was worse under NPPV. This negative study was flawed by the low level of inspiratory positive airway pressure (IPAP) used (8–15 mmHg) which did not allow control of nocturnal hypoventilation, and also by the short duration of each treatment period in order to achieve a satisfactory adaptation to treatment. In the same direction, GAY *et al.* [53] studied 35 severe hypercapnic COPD patients randomized for a 3-month period of either NPPV with BiPAP at 10 cmH₂O IPAP, or sham NPPV with IPAP at 0 cmH₂O. Only four of the seven patients from the NPPV group but all six patients from the sham NPPV group completed the study. Only one patient had a substantial reduction of P_{a,O_2} under NPPV. Indeed, no significant change and no difference were observed between both arms of the study considering P_{a,O_2} decrease, modification of lung function, nocturnal O_2 saturation and sleep efficiency. Again, this study included only a small group of patients for rather short periods of NPPV.

In a very recent paper, CASANOVA *et al.* [54] studied 52 patients with severe COPD receiving in a randomized order either NPPV + standard care or standard care alone (93% with LTOT) during 1 yr. Survival was identical at 1 yr (78%) as well as the number of acute exacerbations. The number of hospital admissions fell significantly at 3 months in the NPPV group (5 *versus* 15%) but remained unchanged after the third month. The only benefits observed in the NPPV arms were a reduction of dyspnoea and an improvement of one of the neuropsychological tests (psychomotor coordination) at 6 months. Again it was concluded towards a marginal benefit of NPPV in severe COPD patients, but on a limited population and during a too short period of 1 yr.

Evaluation of NPPV in diffuse bronchiectasis and cystic fibrosis (CF) bring also arguments to the contention that patients with severe airway obstruction and hypercapnia may respond favourably to NPPV. A recent publication in bronchiectasis patients [55] showed a P_{a,O_2} decrease and less frequent hospitalizations during the year after NPPV initiation (as compared with the previous year). Other series have reported stabilization of severe hypercapnic patients with CF under NPPV while they awaited lung transplantation [56–58].

Even if such studies are difficult to manage, there is clearly a need for prospective studies comparing LTOT and NPPV in the most severe obstructive pulmonary diseases, in a large amount of patients and on a real long-term basis of several years. Two randomized prospective studies are being completed

in Europe to assess the real role of NPPV in severe hypercapnic patients either under mechanical ventilation with volume preset machines or with pressure preset respirators [59, 60]. The first preliminary results show that NPPV is well accepted by severe disabled patients with chronic hypercapnia and is associated with a reduction of hospitalization for CRF decompensation [59]. Incidence of NPPV on life quality and survival is being analysed, some subgroups of patients being more sensitive to nocturnal NPPV.

Rationale for chronic mechanical ventilation in chronic obstructive pulmonary disease

CRF secondary to COPD is a complex situation associating a parenchymal impairment with reduced efficiency of its gas exchange function. Hypoxia is a marker of ventilation/perfusion abnormalities and hypercapnia a marker of chronic pump failure and alveolar hypoventilation. As low flow oxygen therapy is commonly able to compensate hypoxia in COPD patients, external mechanical ventilation will compensate for hypoventilation. Thus, improvement of arterial blood gases is one of the main objectives that determines ventilator adjustments.

Several hypothesis have been suggested to explain the beneficial effects of long-term mechanical ventilation in patients with COPD and CRF. NPPV is preferentially indicated during sleep periods, in order to achieve longer duration of ventilation; this is probably necessary to compensate nocturnal hypoventilation and episodes of arterial oxygen desaturation which occur predominantly during rapid eye movement sleep when breathing room air [61]. Indeed, the main beneficial effect of NPPV implies a correction of nocturnal hypoventilation and P_{a,O_2} reduction is the hallmark of improvement in alveolar ventilation under all types of mechanical ventilation. Such an improvement could persist after interruption of the ventilation period because of a temporary improvement in CO_2 sensitivity of the respiratory centres, that is often blunted in COPD patients [62]. However, the same results might be obtained when using NPPV 8 h during the daytime [63].

The improvement of nocturnal P_{a,O_2} could also lead to an improvement of the diurnal P_{a,O_2} [31, 64], an effect that can be related to the correction of the alveolar-arterial gradient under NPPV and to the increase in spontaneous breathing pattern following mechanical ventilation. This is the consequence of an improved compliance of the chest wall and the lungs [65], an improved respiratory muscle function, an increased respiratory drive [62] and a lowering oxygen consumption secondary to a decrease in work of breathing or an increase in efficiency of the respiratory muscle function or perhaps a reduction of chronic respiratory muscle fatigue [66–68]. The relief of chronic respiratory muscle fatigue remains controversial, as well as the concept of chronic respiratory muscle fatigue. Indeed, it is difficult to assess if the modifications of respiratory muscle strength are a cause or a consequence of the arterial blood gases improvement under NPPV [26, 69–71]. Respiratory

muscle fatigue is probably not an important contributing factor when evaluating patients during periods of clinical stability. Thus, patients with severe CO₂ retention, particularly those with nocturnal oxygen desaturation, appear to be the best candidates to get a favourable response to nocturnal NPPV.

Selection of chronic obstructive pulmonary disease patients to noninvasive positive pressure ventilation

In a recent Consensus Conference [58], it has been proposed to indicate NPPV in COPD patients presenting with the characteristics detailed in the table 1. However, those recommendations do not perfectly apply to patients with COPD [72]. Symptoms of chronic nocturnal hypoventilation are difficult to screen in patients with poor quality of sleep, frequent morning headaches and chronic fatigue linked to their poor general and respiratory condition. Although the Consensus consider as mandatory the presence of hypercapnia, the presence of chronic hypercapnia by itself is not an indication of NPPV if stable and well tolerated. The presence of nocturnal oxygen desaturation is common in such patients and not always corrected by nocturnal oxygen therapy, as formerly shown by DOUGLAS *et al.* [61]. Conversely, the notion of frequent episodes of decompensation leading to repeated hospitalizations is a good criteria if the associated LTOT and medical management are optimal.

To indicate NPPV in a patient with COPD and CRF, the presence of a progressive deterioration of respiratory status based on clinical and biological

criteria should be considered. Thus, in spite of the controversial results previously reported, it is suggested that NPPV is used for patients with severe hypoxic and hypercapnic COPD in some practical situations. COPD patients who present with blue and bloated type associated with chronic hypoxia and hypercapnia and develop an unstable respiratory condition. This may be appreciated on a clinical basis with chronic dependent oedemas and deterioration of respiratory and clinical status in spite of a well prescribed and well followed medical treatment, associating physiotherapy and LTOT. Instability may be confirmed by a progressive worsening of arterial blood gas tensions, leading to frequent cardio-respiratory decompensations with ominous ARF episodes [21, 72]. NPPV is a preventive treatment of future dangerous episodes of ARF. Associated obesity is a further argument of indicating NPPV even in the presence of an overlap syndrome; in such a case, the setting of expiratory positive airway pressure (EPAP) will be adapted during polysomnographic recordings which are mandatory when obesity is present [73]. NPPV should also be considered after an ARF episode successfully treated by noninvasive ventilation [74, 75] but with the impossibility to wean the patient from the ventilator or even patients receiving NPPV to be successfully weaned from endotracheal mechanical ventilation [27]. In such acute conditions, NPPV will be maintained beyond the ARF episode and re-evaluated on a long-term basis a few weeks or months later. Consequently, tracheotomy-mediated ventilation has nowadays restricting indications, such as failure of NPPV, often after a further episode of ARF, and weaning failure from endotracheal ventilation.

Table 1.—Clinical indicators for institution of nasal positive pressure ventilation in patients with chronic obstructive pulmonary disease (COPD)

Disease documentation	
Establish and document an appropriate diagnosis	History Physical examination Results of diagnostic tests
The most common obstructive lung diseases would include	Chronic bronchitis Emphysema Bronchiectasis Cystic fibrosis
Assure optimal management of COPD	Bronchodilators Oxygen therapy when indicated
Optimal management of other underlying disorders	Multichannel sleep study to exclude associated OSAS if clinically indicated
Indications for usage	
Symptoms	Fatigue Dyspnoea Morning headache, <i>etc</i>
Physiological criteria (one of the following)	$P_{a,CO_2} \geq 55$ mmHg P_{a,CO_2} between 50 and 54 mmHg with nocturnal desaturation (S_{a,O_2} by pulse oximetry $\leq 88\%$ for 5 continuous min while receiving oxygen therapy ≥ 2 L·min ⁻¹) P_{a,CO_2} between 50 and 54 mmHg with hospitalizations related to recurrent episodes of hypercapnic respiratory failure (≥ 2 in a 12-month period)

OSAS: obstructive sleep apnoea syndrome; P_{a,CO_2} : arterial carbon dioxide tension; S_{a,O_2} : arterial oxygen saturation; Adapted from ref [58].

Fig. 8. – Algorithm for indicating long-term oxygen therapy (LTOT) and nasal intermittent positive pressure ventilation (NIPPV) in patients with obstructive chronic respiratory insufficiency (OCRI). TTO: trans-tracheal oxygen therapy, HMVVT: home mechanical ventilation *via* tracheotomy. Reproduced with permission from [27].

Thus, NPPV could be proposed as a preventive treatment in severe COPD patients with unstable respiratory condition associated with fluctuating hypercapnia before, during and after an ARF episode, avoiding the need for a tracheotomy. An algorithm can be suggested to designate indications for HMVVT (table 1), LTOT and IPPV by the nasal route in patients with severe COPD (fig. 8) [27].

Ventilators and interfaces

In spite of the controversial results previously shown in the different studies, NPPV is better tolerated than the negative pressure techniques. Its portability and ease of administration also explain its popularity and its use as a first choice in COPD as well as in most other aetiologies of CRF.

Ventilators for use in NPPV devoted to patients with COPD are generally used for long periods of time, and generally at least overnight. Therefore, ventilators should be simple, reliable and easy to use which is allowed by regular technological improvements. As COPD patients necessitating NPPV are generally partially dependent upon their machine, the presence of a battery-operated ventilator is only mandatory if patients need to ventilate more than 12 h per day. Ventilators must also be light and portable. Both high- and low-pressure alarms are required to indicate airflow obstruction, disconnection or failure of the ventilator and have to be set according to a leaky ventilation. At the present time, available studies are in favour of clinical equivalence of flow-cycled (volumetric) and pressure-cycled (barometric) ventilation modes [76–78]. However, the actual trend is to use pressure-cycled ventilators on a

first-line basis, especially with pressure support mode that is easier to adjust and to synchronize with the patient. Secondly, in case of failure, poor tolerance or inefficiency of pressure-cycled ventilation, flow-cycled ventilators may be proposed, as patients may appear to be a responder or not to either volumetric or barometric ventilation [79]. The recent release of dual portable ventilators providing either pressure support ventilation or volume-cycled ventilation (Neftis, (Taema, France), LTV 100 (Pulmonetics, USA), Achieva PS (Mallinckrodt, USA), PV403 (Breas Medical, Sweden)) could be a flexible way for managing the most difficult patients. The concept of prophylactic intermittent NPPV (*i.e.* given only one or two nights per week) in difficult patients might be developed in a cost-effective prospective.

When pressure support ventilation is used [16, 49, 50, 72, 80] the level of inspiratory aid is raised from 10–20 cmH₂O according to the patient tolerance. A back-up frequency is usually set at 12 breaths·min⁻¹ and the inspiratory duration as short as possible. The comfort of the patient remains crucial and conditions the long-term compliance. A recent paper by VITTACA *et al.* [81] confirmed that ventilatory settings established according to patient tolerance, patient comfort and arterial blood gases controls were as satisfactory as ventilatory settings established more rigorously upon more conventional criteria, mechanics and respiratory muscle function assessments.

With flow-cycled ventilation, simple patterns of ventilation are used, with assist-control mode. Settings are similar to those of mechanical ventilation in COPD with ARF (tidal volume 10–20 mL·kg⁻¹ with nasal mask ventilation; inspiratory:expiratory is 1:2 to 1:3; respiratory rate 12–14 breaths·min⁻¹; inspiratory oxygen fraction (*F*_{I,O₂}): <35%). Oxygen delivery can be achieved conventionally by cylinders, liquid oxygen or a concentrator.

Nasal masks commonly in use are similar to the devices used to treat sleep apnoea syndrome. Nasal pillows are sometimes preferred for local skin tolerance and/or particular anatomical configuration.

Noninvasive positive pressure ventilation initiation and follow-up in chronic obstructive pulmonary disease patients

Initiating noninvasive ventilation (NIV) is a very important phase conditioning the future compliance to the treatment. The best way is to initiate the ventilatory trial during a hospital stay of 1 week in order to familiarize the patient and their family to a treatment which is a part of the rehabilitation programme. Apart from the ventilatory treatment itself, the patient must learn how to use nasal connections, which is also crucial to the compliance. Nocturnal assessment with clinical scores, monitoring of arterial oxygen saturation and transcutaneous *P*_{a,O₂} are useful as well as serial arterial blood gases controls. The suspicion of an overlap syndrome always implies a polysomnographic recording. Long-term follow-up implies regular visits at the hospital every 3–6 months. Close technical supervision is achieved by

home respiratory care organizations of various compositions and structures according to the different countries and social organizations.

Noninvasive positive pressure ventilation and rehabilitation

Despite medication and respiratory assistance, many patients with severe COPD suffer from dyspnoea resulting in limitation of physical capacity and even in their activities of daily living. Thus, methods to improve the ability of patients with severe COPD to function in the home and work environment with reduced symptoms (the goals of rehabilitation) have become accepted forms of therapy [82]. That approach, called "pulmonary rehabilitation", has been defined as "an art of medical practice wherein an individually tailored, multidisciplinary programme is formulated, which, through accurate diagnosis, therapy, emotional support, and education, stabilizes or reverses both the physio- and psychopathology of pulmonary diseases and attempts to return the patient to the highest possible functional capacity allowed by their pulmonary handicap and overall life situation" [83]. Adjunction of NPPV to exercise rehabilitation is under evaluation [84]. Thus, the key elements which will return the patient back to home with their ventilator are education about their disease and the management of their own therapy (*i.e.* NPPV), including physical therapy, exercise conditioning (adapted to those severely disabled patients), breathing retraining, psychosocial counselling and vocational training.

Conclusion

In conclusion, long-term noninvasive positive pressure ventilation in chronic obstructive pulmonary disease should be considered as a preventive treatment in severe patients with unstable respiratory condition associated with fluctuating hypercapnia before, during and after an acute respiratory failure episode. Instability may be appreciated on a clinical basis and confirmed by a progressive worsening of arterial blood gas tensions, leading to frequent cardiorespiratory decompensations with ominous acute respiratory failure episodes. In this setting, the association of noninvasive positive pressure ventilation with pulmonary rehabilitation programmes should be promising.

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