Indications and Compliance of Home Mechanical Insufflation-Exsufflation in Patients with Neuromuscular Diseases

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ABSTRACT

Introduction: Neuromuscular disease (NMD) patients frequently have impaired cough. Mechanical insufflation-exsufflation (MI-E) has proven efficacy in improving airway clearance, however data related to its long-term home use is lacking. The purpose of this study was to describe indications, safety and compliance of home MI-E in NMD patients.

Methods: Four years observational analysis of 21 NMD patients on home MI-E. Diagnosis included bulbar and non-bulbar Amyotrophic Lateral Sclerosis (ALS) and other NMD. Median age was 58 years. Only cooperative patients with unassisted baseline Peak Cough Flow (PCF) < 270 L/min were included. All patients were under continuous mechanical ventilation (6 by tracheostomy). Pulmonary function before initiation of MI-E (median): FVC = 0.81 L, MIP = 28 cmH2O, MEP = 22 cmH2O and PCF = 60 L/min. MI-E was performed by previously trained non-professional caregivers, with an on-call support of a trained health care professional. Patients had pulse oximetry monitorization and applied MI-E whenever SpO2 < 95 %.

Median follow-up was 12 months (3-41 months).

Results: Ten patients (9 ALS) used MI-E daily. Eleven patients used MI-E intermittently, during exacerbations, and in 8 patients early application of MI-E (guided by oximetry feedback) avoided hospitalization. All tracheostomized patients used MI-E daily and more times a day than patients under NIV. Four patients (3 bulbar ALS), were hospitalized due to secretion encumbrance. MI-E was well-tolerated and there were no complications. In general, caregivers considered MI-E effective. During this period, 4 patients died, related to disease progression.

Conclusions: Home MI-E is well tolerated, effective and safe if used by well trained caregivers. MI-E should be considered as a complement to mechanical ventilation.

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Introduction

Patients with neuromuscular diseases (NMD) frequently have weak respiratory muscles and a deteriorated cough mechanism. Effective coughing depends on the capacity of the inspiratory muscles to achieve an inspiration of about 80% of total pulmonary capacity, followed by closure of the glottis and a pause with an increase in pulmonary volume. After the contraction of the expiratory muscles, intrathoracic pressure increases and, when the glottis opens, air is expelled and secretions are propelled to the central airways. Therefore, deterioration of the cough reflex in patients with NMD is related to weakness of the respiratory muscles, bulbar dysfunction that causes disability to control the glottis or even a deformity of the chest wall due to scoliosis. Deterioration of the cough reflex causes insufficient airway clearance, pneumonia, atelectasis, and respiratory failure related to the accumulation of secretions. Based on basal function, a peak cough flow (PCF) < 160 l/min has been proposed as an indication of an ineffectual cough. However, even a basal PCF < 270 l/min has been associated with pulmonary complications, since, during acute disease, there are additional reductions of the force of the respiratory muscles with an even greater reduction of PCF. As a result, management of airway secretions, especially during intercurrent airway infections, is a significant problem in patients with NMD and is the main cause of morbidity, prolonged hospitalisation, intensive care admissions and mortality. The techniques to improve airway clearance can reduce complications related to the accumulation of secretions and hospitalisation rates to a minimum. However, in patients with chest wall deformity, physiotherapy and manually assisted expectoration techniques can be ineffective. These techniques are also time-consuming and require an appropriately trained carer.

Mechanical Insufflation-exsufflation (MIE) is a mechanically assisted cough technique. It gradually applies positive pressure to the airways, followed by a rapid change due to negative pressure. It can be applied using a face mask or a tracheotomy tube. In 1953, the first device for mechanical assistance of coughing was marketed. Since then, various studies have confirmed its efficacy. MIE is considered more effective than other reference techniques to increase the coughing mechanism.

Material and Methods

Since 1989, the Pneumology Service of the Sant João Hospital has an ambulatory clinic for NMD in collaboration with the Neurology Service. This clinic offers respiratory care to many patients suffering from NMD. IEM devices have been used for home care since February 2005. The device was prescribed for continuous daily rent. These devices are included in the respiratory material offered to patients according to specific clinical indications. This material includes instruments for ventilation, monitoring, and control of secretions and is hired by a home care private company that also provides regular home visits by health professionals. The MIE device and a portable oximeter have a daily rental cost of 10 Euros. All the expenses caused by this home treatment are the responsibility of the Hospital. All the strategies related to clinical assessment of patients, adaptation of devices and programs for carer training are carried out by professionals from the Pneumology Service of the NMD ambulatory clinic. All the patients prescribed home MIE were included in this study. An observational analysis was carried out with a 4 year follow-up. The patients were recruited in the Pneumology Service from those on the multidisciplinary NMD clinic. The protocol was approved by the Investigation Committee of the Hospital and the study was carried out according to the ethical directives for investigation in humans and the principles of the Helsinki Declaration.

Patients

Patients were studied from February 2005 to February 2009. Home MIE was prescribed for 21 NMD patients (15 men) of a median age of 58 years (27-72 years). The diagnosis included bulbar and non-bulbar amyotrophic lateral sclerosis (ALS), Duchenne muscular dystrophy (DMD) and other NMD. The demographic data of the population studied are described at table 1. Inclusion criteria were as follows: diagnosis of NMD, basal assisted < 270 l/min and continuous dependence on mechanical ventilation (24 hours a day). For the prescription of home MIE the decisive criteria was insufficient assisted PCF, after a technique of air entrainment (in patients with non-bulbar ALS) in combination with abdominal thrust. All patients with NMD receiving mechanical ventilation through a tracheotomy were also included.

Patients who could not cooperate or did not receive dedicated care were excluded. All patients depended on continuous home care were excluded. All patients depended on continuous home
Table 1

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Amyotrophic lateral sclerosis</th>
<th>Duchenne muscular dystrophy</th>
<th>Other neuromuscular diseases</th>
<th>Multiple sclerosis</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, number</td>
<td>15</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Age (onset of respiratory deterioration)</td>
<td>62 (46-72)</td>
<td>32 (30-34)</td>
<td>35 (27-36)</td>
<td>68</td>
<td>58</td>
</tr>
<tr>
<td>Duration of symptoms, months</td>
<td>26 (9-90)</td>
<td>83 (27-139)</td>
<td>38 (8-271)</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>FVC (l and predictable %)</td>
<td>0.99 (0.4-1.93)</td>
<td>0.4 (0.26-0.54)</td>
<td>0.6 (0.26-0.84)</td>
<td>0.7</td>
<td>0.81 (0.26-1.93)</td>
</tr>
<tr>
<td>FEV1 (l and predictable %)</td>
<td>32.5 % (15-48%)</td>
<td>9.5 % (7-12%)</td>
<td>14 % (7-20%)</td>
<td>29 %</td>
<td>27.5 % (7-48%)</td>
</tr>
<tr>
<td>FEV1 &lt; 50 %</td>
<td>0.95 (0.3-1.76)</td>
<td>0.37 (0.24-0.49)</td>
<td>0.57 (0.24-0.84)</td>
<td>0.67</td>
<td>0.72 (0.24-1.76)</td>
</tr>
<tr>
<td>MIP (cmH2O)</td>
<td>34 % (7-56%)</td>
<td>10 % (7-13%)</td>
<td>16.5 % (7-23%)</td>
<td>33 %</td>
<td>28 % (7-56%)</td>
</tr>
<tr>
<td>MEP (cmH2O)</td>
<td>31 (0-45)</td>
<td>14 (0-28)</td>
<td>16 (0-28)</td>
<td>ND</td>
<td>28 (0-45)</td>
</tr>
<tr>
<td>Spontaneous PCF (l/min)</td>
<td>27 (0-56)</td>
<td>15 (3-27)</td>
<td>21 (3-27)</td>
<td>ND</td>
<td>22 (0-56)</td>
</tr>
<tr>
<td>Assisted PCF (l/min)</td>
<td>60 (0-250)</td>
<td>90 (80-100)</td>
<td>115 (80-150)</td>
<td>40</td>
<td>60 (0-250)</td>
</tr>
<tr>
<td>NIV, No. of patients</td>
<td>160 (0-260)</td>
<td>170 (160-180)</td>
<td>192.5 (130-250)</td>
<td>80</td>
<td>160 (0-260)</td>
</tr>
<tr>
<td>Tracheotomy, No. of patients</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Time undergoing continuous ventilation support, months</td>
<td>24.5 (9-51)</td>
<td>81.5 (24-139)</td>
<td>37 (7-271)</td>
<td>6</td>
<td>29 (7-271)</td>
</tr>
</tbody>
</table>

FEV1, indicates forced expiratory volume in first second; MEP, maximum expiratory pressure; MIP, maximum inspiratory pressure; NIV, non-invasive ventilation; PCF, peak cough flow.

Determinations

All patients underwent pulmonary function, respiratory muscle force and PCF screening. Pulmonary function was determined by spirometry (Vmax 229, Autobox, Sensormedics), registering the maximum expiratory pressure during the first second of forced expiration (FEV1) and forced vital capacity (FVC). All lung function tests were carried out in a sitting position according to reference procedures defined by the ATS-ERS 2005 work group. The maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) were determined with a portable pressure manometer (Micro RPM, Micromedical Limited) during maximum inspiratory and expiratory manoeuvres through the mouthpiece starting with the residual volume (MIP) and from total lung capacity (MEP). These determinations were performed according to reference procedures defined by the ATS-ERS 2002 work group. The manoeuvres were repeated until three determinations with a variability < 5% were obtained.

The PCF was only determined in non-tracheotomised patients by requesting the patient in a sitting position to cough until a cough manoeuvre and the patient's maximum inspiratory effort. The PCF manoeuvre was repeated until three determinations were obtained with a variability < 5% were obtained.

Since the patients with bulbar dysfunction could not carry out the air entrapment test, assisted PCF was only determined by application of manual abdominal compression.

Protocol for Home MIE

Home MIE was carried out using the Cough-Assist® (Philips, Respironics, Inc) device using an oronasal mask or a non-fenestrated tracheotomy tube with an inflated cuff. Both patients and carers were trained in the use of a portable pulse-oximeter (Nonin 9500 oximeter Minneapolis Plymouth USA) and given information on the use of MIE in their homes, in which a MIE session was applied in each episode of SpO2 < 95%, until a value > 95% was obtained. For better tolerance periods of rest with ventilation between sessions were applied. Before the prescription of home MIE, all the patients and carers in our service were convened to receive specific training on the technique with a specialized respiratory physiotherapist. Training included device management (adjustments and circuit connections) and a practical seminar with clinical simulations, and also detection of clinical signs necessary to determine efficacy. Each session consisted of 6–8 cycles of insufflation-exsufflation with mean pressures of 40 to –40 cmH2O. The duration of each cycle was 3 seconds for insufflation, 2 seconds for exsufflation and 4 seconds for the post-exsufflation pause. During the exsufflation phase, patients were trained to cough, at the same time a carer applied abdominal compression. The adaptation of the technique was gradual, pressure was increased progressively to obtain an adequate chest expansion at a comfortable level to eliminate secretions.

Home MIE was always administered y non-professional trained carers (family members or private assistants) with the support of a health care professional with experience from a home care private company (nurse or respiratory physiotherapist). In case of doubt, the carer called the health professional to resolve the problem or to help carry out the technique in difficult situations. Both patients and carers were trained to detect early signs of respiratory failure or respiratory infections and were instructed to contact service staff (pneumologist or respiratory physiotherapist) on appearance of the first sign. Whenever dyspnoea increased, secretions accumulated or a value of SpO2 < 95% persisted, in spite of continuous use of the ventilator and an aggressive home technique (with the support of expert health carers), the patients were instructed to come in to the emergency service (ES) of the local hospital. The aim of the treatment
was defined as satisfactory control of acute dyspnoea or secretion accumulation, confirmed by pulse-oximetry data (SpO₂ > 95%).

**Variables Analysed**

A descriptive statistical analysis was performed using the SPSS 14.0 database for Windows. Data presented are function on diagnosis, symptom duration, time on mechanical ventilation, spirometry, force of respiratory muscles and assisted and non-assisted PCF. Compliance, tolerance and efficacy were assessed based on daily frequency of MIE use, number of complications, number of visits to the ES due to episodes of secretion accumulation and number of hospitalisations related to airway infections. Clinical files were analysed to assess the number of visits to the ES and the number of hospitalizations prior to the MIE protocol.

Intolerance and adverse effects of the technique were also examined.

**Results**

A total of 21 patients with NMD undergoing continuous mechanical ventilation (6 with tracheotomies) and home MIE treatment were studied. The diagnoses were the following: Amyotrophic lateral sclerosis (ALS) (n = 5), Duchenne muscular dystrophy (DMD) (n = 2), other NMDs (n = 3) and multiple sclerosis (MS) (n = 1) (Table 1). Other NMDs included a heterogeneous group of diseases: Myopathy due to cytoplasmic inclusion bodies, type 2 spinal muscular atrophy and non-classified myopathies. Lung function prior to MIE can be seen at Table 1.

Medium time of onset of respiratory deterioration of the patients was 29 months (7-271 months) and had been using home ventilation support treatment for a median of 29 months (7-271 months) before their inclusion in the protocol (Table 1). As to the ALS patients, at the beginning of the program, there were 6 patients with severe bulbar dysfunction. During follow-up, there was disease progression, so that, at the end of treatment, 10 patients presented severe bulbar dysfunction, 5 of them had undergone tracheotomy (5 rejected it). There was also another patient with non-classified myopathy, ventilated through a tracheotomy, without bulbar dysfunction, that rejected decannulation to VNI.

Compliance with MIE is shown in Table 2. This technique was used daily by 10 patients (7 with bulbar ALS and 1 with non-classified myopathy) (Table 2). The 6 patients with tracheotomy (5 with bulbar ALS and 1 with non-classified myopathy) and 4 patients undergoing VNI (2 with bulbar ALS that rejected tracheotomy and 2 with non-bulbar ALS) used the technique daily. The data related to daily frequency of sessions in the groups of daily users are shown in Table 2. Variability of secretion accumulation, confirmed by pulse-oximetry data (SpO₂ > 95 %).

The technique was used intermittently by 11 patients (Table 2). These patients only used the device during acute exacerbations, such as infection of the airways or during individual episodes of secretion accumulation. When the exacerbation was resolved of the secretions as infection of the airways or during individual episodes of secretion accumulation. When the exacerbation was resolved of the secretions interrupted.

In general, the carers considered the device was effective.

In 8 patients the early application of MIE (guided by oximetry data) prevented visits to the ES due to an accumulation of secretions and the device inverted the episode of desaturations and normalized SpO₂ without the need to administer supplementary oxygen. The 8 patients and their respective carers reported that, if they had not had access to the device, they would have had to come in to the emergency service.

In 4 patients (3 bulbar ALS and 1 non-bulbar ALS), home MIE was not sufficient to normalise oxygen saturation and required hospitalisations to treat accumulated secretions during acute respiratory airway infections (Table 4). Of the 3 bulbar ALS patients, one of them had undergone a tracheotomy and the other 2 had constantly rejected it.

Home MIE was well tolerated and there were no complications related to treatment (Table 4).

During the study period, 4 patients with bulbar ALS died due to disease progression (Table 4).

**Discussion**

The efficacy of MIE to increase PCF and improve the efficacy of cough manoeuvre has already been demonstrated.1-4,7,13,14,21-23 Chatwin et al compared different interventions (cough assisted by physiotherapy, cough assisted by VNI, cough assisted by exsufflation and MIE) with non-assisted cough and showed that MIE was the technique associated with the greatest increase in PCF.2 Oximetry data has shown the usefulness of this technique since it makes it possible to detect a sudden decrease of oxygen saturation as a consequence of a mucous plug.2,3,7,15 In the patients described in this study suffered from severe ventilation failure and continuously depended on mechanical ventilation (24 hours a day). They had all used volume limited time-cycled ventilation for many years before inclusion in the study.

This study was based on the protocol proposed by Bach et al, that consists in home treatment with a VNI support, oximetry monitoring during 24 hours and the use of MIE guided by the data from this (SpO₂ < 95 %).3,7,15,21-24

In this study home MIE was carried out by non-professional carers of the patients with the support of health professionals trained in home care.

Few studies have described home respiratory treatment with MIE in patients with NMD, although many studies describe the efficacy of the combination of cough assistance techniques, manual and mechanical, in acute in-hospital situations.5,9,21 Although MIE carried out by non-professional carers has been considered effective and well tolerated, it causes certain controversy and we still require more data on its home use in the long term.15,21,24

In our strategy, the main condition for effective home care after hospital discharge was the presence of appropriately trained and
motivated carers. This study supports the importance of an appropriate early training phase, administered to both patients and carers in the hospital, as has also been proposed by Tseng et al.\(^{21}\) Furthermore, this study confirmed that carers with appropriate training and motivation can detect respiratory worsening and effectively use a home MIE protocol. Patients with neuromuscular diseases, especially ALS, can suffer progressive disease with early decrease of respiratory muscle force and cough deterioration, both associated with premature death.\(^{3,5,14,21,28}\) The natural course of NMD does not make it possible to clarify the influence of home MIE on visits to the ES/hospitalizations. The number of episodes before and after the home MIE protocol is not comparable. Indeed, before beginning home treatment, the patients’ cough reflex was more powerful and therefore, they suffered fewer episodes of secretion accumulation. In contrast to other NMD, ALS also includes glottis muscle control. In general, patients with non-bulbar NMD non-invasive support treatment may be used and they have a higher survival rate.\(^{3,5,25}\) However, the almost inevitable progression to bulbar dysfunction is one of the more negative characteristics of this disease and the main reason due to which, in contrast to other NMDs, tracheotomy becomes necessary to prolong survival.\(^{1,3,5,7,8,21,24,26}\) In spite of this, we paid special attention to simple but prudent measures to prevent complications: brief episodes of secretion accumulation and made it unnecessary to visit the ES or to require hospitalisation. None of these patients required intubation. Indeed, it would seem that the protocol reduces the problem of secretion accumulation and made it unnecessary to visit ES due to secretion accumulation. Patients stated that, during these episodes, without MIE, they would have had to go to hospital due to their acute respiratory problems. Furthermore, there were very few episodes in which home MIE was not sufficient to resolve the risk of airway infection and prevents both visits to the ES and hospitalizations. Bach et al have reported that patients with NMD incapacable of air entrapment, did not only use MIE as a technique for cough assistance, but also for lung insufflation. According to this study, both patients and carers described greater efficacy in clearance of airway secretions with this home protocol. Its early application, guided by oximetry data with normalisation of oxygen saturation with ambient air, prevented visits to the Emergency Service due to secretion accumulation. Patients stated that, during these episodes, without MIE, they would have had to go to hospital due to their acute respiratory problems. Furthermore, there were very few episodes in which home MIE was not sufficient to resolve the problem of secretion accumulation and made it unnecessary to visit the ES or to require hospitalisation. None of these patients required intubation. Indeed, it would seem that the protocol reduces the risk of airway infection and prevents both visits to the ES and hospitalizations. Bach et al have reported that patients with NMD dependent on VNI that used MIE guided by oximetry data can be treated at home without risk or need of hospitalisation.\(^{3,5,12,15,16}\) This study did not show any complications related to use of the device. Potential complications are very infrequent and include abdominal distension, increase of gastroesophageal reflux, haemoptysis, chest and abdominal discomfort, acute cardiovascular events, barotraumas and pneumothorax.\(^{3}\) Bach et al have not described any complications in more than 500 batches of MIE.\(^{2}\) Some simple but prudent measures to prevent complications are: brief

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**Table 4**

Follow-up and results of mechanical insufflations-exsufflation

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Bulbar amyotrophic lateral sclerosis</th>
<th>Non-bulbar amyotrophic lateral sclerosis</th>
<th>Duchenne muscular dystrophy</th>
<th>Other myopathies</th>
<th>Multiple sclerosis</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, No.</td>
<td>10</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>Time undergoing MIE, months</td>
<td>6.5 (3-41)</td>
<td>19 (12-38)</td>
<td>7.5 (3-12)</td>
<td>16 (6-16)</td>
<td>4</td>
<td>12 (3-41)</td>
</tr>
<tr>
<td>Intolerance MIE</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Complications due to MIE</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Visits to the emergency service (No. of patients/No. of events)</td>
<td>3/5</td>
<td>1/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>4/6</td>
</tr>
<tr>
<td>Hospitalisations (No. of patients/No. of events)</td>
<td>3/3</td>
<td>1/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>4/4</td>
</tr>
<tr>
<td>Deaths, No. of patients</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

MIE indicates mechanical Insufflation-exsufflation.

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In this study, each MIE session consisted of 6-8 cycles of insufflations-exsufflations with mean pressures of 40 to 40 cm H₂O, titrated according to patient tolerance. Chatwin and Sivasothy have considered that lower pressures are more comfortable and involve fewer risks.\(^{4,7}\) However, the adjustments used in this study are widely preferred due to their effects on patient welfare and their efficacy and are also suggested by the manufacturers.\(^{3,8,24,29}\) In general, they are well tolerated and have been considered the most effective means of obtaining higher values of PCF with practically no complications.\(^{3,5,7,8,21,24}\) In spite of this, we paid special attention to careful individual titration of the MIE pressure, to obtain maximum chest expansion, respecting welfare, which can justify the tolerance and absence of complications seen in this study. The application of MIE was adjusted to the needs of each patient in as far as frequency of use, considering daily and intermittent users. With intermittent users it was not possible to register the number of MIE sessions per month or week because compliance was not regular and depended on the number and severity of respiratory exacerbations. In contrast, daily users reported that they used the device every day, independently of exacerbations, both for secretion control and for lung insufflation and to revert episodes of SpO₂ < 95 %. This study also shows that patients who had undergone tracheotomy used MIE daily and more times a day than patients with VNI. This fact may be due to local inflammation and the increase of secretions related to tracheotomy. We also found that some patients with bulbar ALS, incapable of air entrapment, did not only use MIE as a technique for cough assistance, but also for lung insufflation.

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pauses between applications (to avoid hyperventilation), avoiding applications after meals, appropriate treatment of gastroesophageal reflux and reduction of insufflation pressure according to tolerance.\(^5\)

During the study period, 4 patients with bulbar ALS died. The main cause of death was rapid progressive disease with severe bulbar dysfunction. These 4 patients had constantly rejected tracheotomy. The main limitations of this study are the fact that it is observational, the reduced number of patients including the absence of a control group. However, shortly after beginning this protocol, the benefits of the treatment as far as efficacy in management of accumulated secretions, preventing visits to the Emergency Service and improvement of quality of life in these patients became evident. As a result, we consider that it would not be ethical to deprive the patients of a treatment that has been shown to be effective.

**Conclusion**

The most important conclusion of this study is that it is possible to treat patients with severe NMD with sufficient clearance of the secretions of their respiratory airways with home MIE based on careful training of non-professional carers. This is valid for patients with VNI and those with tracheotomies. According to the patients, greater use of MIE during respiratory infections can prevent visiting the emergency service. This technique can be considered a useful complement to ventilation support in these patients.

**References**