Noninvasive High-Frequency Percussive Ventilation in the Prone Position after Lung Transplantation

P. Feltracco, E. Serra, S. Barbieri, M. Milevoj, E. Michieletto, C. Carollo, F. Rea, G. Zanus, R. Boetto, and C. Ori

ABSTRACT

Noninvasive positive-pressure ventilation (NIV), which represents a consolidated treatment of both acute and chronic respiratory failure, is increasingly being used to maintain spontaneous ventilation in lung transplant patients with impending pulmonary complications. Adding a noninvasive inspiratory support plus positive end-expiratory pressure (PEEP) has proven to be useful in preventing endotracheal mechanical ventilation, airway injury, and infections. Lung recipients with closure of the small airways in the dependent regions may also benefit from the prone position, which is helpful to promote recruitment of nonaerated alveoli and faster healing of consolidated atelectatic areas. In patients with localized or diffuse lung infiltrates, high-frequency percussive ventilation (HFPV), by either an invasive airway or a facial mask, has been adopted as an alternative ventilatory mode to enhance airway opening, limit potential respirator-associated lung injury, and improve mucus clearance. In nonintubated lung recipients at risk for volubarotrauma with conventional mechanical ventilation, it allows oxygen diffusion into the distal airways at lower mean airway pressures while avoiding repetitive cyclical opening and closing of the terminal airways. We summarize the clinical course of 3 patients with post–lung transplantation respiratory complications who were noninvasively ventilated with HFPV in the prone position. Major advantages of this treatment included gradual improvement of spontaneous clearance of bronchial secretions, significant attenuation of graft infiltrates and consolidations, a reduction in the number of bronchoscopies required, a decrease in spontaneous respiratory rate and work of breathing, and a significant improvement in gas exchange. The patients found HFPV with either standard facial mask or total mask interface to be comfortable or only mildly uncomfortable, and after the sessions they felt more restored. HFPV by facial mask in the prone position may be an interesting and attractive alternative to standard NIV, one that is more useful when implemented before full-blown respiratory failure is established.

Graft- and patient-related respiratory insufficiency requiring assisted ventilation is a common feature in the postoperative period of lung transplantation (LT). Modifications of lung function, including pulmonary infiltrates, pulmonary volume decrease, and atelectasis, associated with a restrictive syndrome and diaphragm dysfunction may occur early or late after surgery and may be responsible for variable degrees of acute respiratory failure (ARF).

Ineffective airway clearance and breathing pattern due to denervation of the transplanted lung lead to impaired cough and slowing of mucociliary clearance, infection, and/or altered chest wall musculoskeletal function. Increased severity of these conditions can affect both the "pump" function (respiratory muscles) as well as the "exchange" function of the lungs.

From the Departments of Pharmacology and Anesthesiology (P.F., E.S., S.B., M.M., E.M., C.C., C.O.), Cardiothoracic Surgery (F.R.), and Hepatobiliary Surgery and Liver Transplant Center (G.Z., R.B.), University Hospital of Padua, Padua, Italy.

Address reprint requests to Paolo Feltracco, Dipartimento di Farmacologia e Anestesiologia, Policlinico di Padova, Via Cesare Battisti 267, 35100 Padova, Italy. E-mail: paolofeltracco@inwind.it

0041-1345/12/$–see front matter
http://dx.doi.org/10.1016/j.transproceed.2012.05.062

Maintenance of spontaneous ventilation in an LT patient with impending pulmonary complications is of major importance, because invasive endotracheal mechanical ventilation has been shown to be associated with many adverse effects, including a higher rate of mortality.[1]

Noninvasive positive-pressure ventilation (NIV), which represents a consolidated treatment of both acute and chronic respiratory failure, is increasingly used to prevent or treat ARF in LT recipients. Adding a noninvasive inspiratory support plus positive end-expiratory pressure (PEEP) has proven to be helpful in preventing airway injury and infections.[2]

In LT recipients, complete closure of small airways in the dependent areas may develop because of insufficient lung inflation; in spontaneously breathing patients, recruitment maneuvers are inadequate and a sustained impairment of gas exchange may ensue. The prone position may be adopted in these circumstances to promote some recruitment of nonaerated alveoli and a faster healing of consolidated atelectatic areas. A significant and persistent improvement in the PaO_2/FiO_2 ratio with prone positioning compared with supine position has been reported in patients with localized or diffuse lung infiltrates predominantly distributed along the dorsal areas of the lung.[3]

Long experience with NIV and prone positioning has encouraged us to combine them contemporarily in an effort to avoid a more invasive approach.[4]

Early positioning of the noninvasively ventilated patient in the prone position may decrease the incidence of tracheal intubation and ventilator-associated pneumonia by reducing respiratory workload, promoting better clearance of dorsobasal bronchial secretions, and improving gas exchange.

High-frequency percussive ventilation (HFPV), by either an invasive airway or a facial mask, has been revived in recent years as an effective ventilatory mode to enhance ventilation, unload fatigued ventilatory muscles, and limit potential respirator-associated lung parenchyma injury.[5] HFPV is a flow-regulated pressure-limited ventilation delivered by a time-cycled ventilator that conveys a series of high-frequency (200–900 cycles/min) small volumes in a successive stepwise stacking pattern, resulting in the formation of low-frequency convective pressure-limited breathing cycles. The subtidal volumes at high frequencies provide a more uniform intrapulmonary gas exchange with improved distal ventilation. Oxygenation is controlled by manipulating the fraction of inspired oxygen (FiO_2), continuous positive airway pressure, peak inspiratory pressure, PEEP, inspiratory time, and frequency. Ventilation is governed by the relationship between inspiratory time and expiratory time, peak inspiratory pressure, and frequency. At high percussion frequencies (300–600 cycles/min), oxygenation is enhanced, whereas low percussion frequencies (180–240 cycles/min) favour CO_2 elimination.[6] In hypoxic patients at risk for volubarotrauma with conventional mechanical ventilation, HFPV allows oxygen diffusion into the distal airways at lower mean airway pressures while avoiding repetitive cyclic opening and closing of terminal airways. The HFPV technique is usually associated with nebulization of inspiratory gas and has the ability to improve the secretion clearance.[7] In nonintubated patients, HFPV has been used as a therapeutic option in exacerbations of chronic obstructive pulmonary disease,[8] and in stable cystic fibrosis patients it has been proven to be an efficient tool in promoting the removal of thick bronchial secretions.[9] In the present article we summarize the clinical course of 3 patients with post-LT respiratory complications who were noninvasively ventilated with HFPV in the prone position.

CASE 1

A 27-year-old woman affected by end-stage respiratory failure associated with lymphangioleiomyomatosis underwent bilateral sequential single LT (BSSLT). Owing to the poor postoperative function of the "marginal" grafts after the transplant she could not be weaned from mechanical ventilation (VAM) until the 5th postoperative day. After tracheal extubation she was assisted with intermittent (mainly nocturnal) application of NIV with helmet with satisfactory results regarding oxygenation and respiratory fatigue relief. In the following days, hypersecretion of mucus, changes in mucus viscoelasticity, and retained airway secretions associated with mild fever suggested the development of bronchopneumonia, which was confirmed by the appearance of bilateral lower lobe consolidations on chest x-ray. NIV assistance by helmet at this stage could only relieve the deterioration of gas exchange and alleviate the increased respiratory workload due to an increase in airway resistance, but it could hardly help with the increase in sputum volume and viscous mucus occluding the small airways. Coughing and vigorous physiotherapy were ineffective in mobilizing and completely removing the copious bronchial secretions. In addition, the repeated bronchoscopies performed to guarantee the tracheobronchial toilette first showed ischemic damage on the right bronchial suture and, in the following days, evident bronchomalacia with tendency to airway obstruction.

HFPV with "standard" facial mask was then applied (delivered by a volumetric diffusive respirator: VDR-4 Percussionator; Bird Technologies, Sandpoint, Idaho); the first sessions in the semirecumbent position under light sedation with propofol lasted 1–3 hours, 5–6 times per day. The frequency of the percussions was initially set at 350–400/min, the peak pressure at 18 cm H_2O, PEEP 8 cm H_2O. The inspiration-to-expiration ratio (I:E) was adjusted to 1:2.5. Nebulization was provided and oxygen fed into the mask to maintain oxygen saturation >92%. Between periods of HFPV, the patient breathed oxygen spontaneously. This mode of ventilation partially improved the spontaneous clearance of respiratory secretions, but even though it decreased the respiratory rate it did not improve the oxygenation index nor the x-ray images. After 2 days of intermittent HFPV, the patient was asked to try the HFPV sessions with facial mask in the prone position. HFPV mode