Noninvasive Positive-Pressure Ventilation Via Face Mask During Bronchoscopy With BAL in High-Risk Hypoxemic Patients*

Massimo Antonelli, MD; Giorgio Conti, MD; Luigi Riccioni, MD; and Gianfranco Umberto Meduri, MD, FCCP

**Study objective:** The aim of this study was to assess the feasibility and safety of noninvasive positive-pressure ventilation (NPPV) via a face mask to aid in performing fiberoptic bronchoscopy (FOB) with BAL in immunosuppressed patients with gas exchange abnormalities that contraindicate using conventional unassisted FOB.

**Study population:** Eight consecutive immunosuppressed patients (40±14 years old) with suspected pneumonia entered the study. Entrance criteria included the following: (1) PaO2/fraction of inspired oxygen (FiO2) of 100 or less; pH of 7.35 or more; and (3) improvement in O2 saturation during NPPV before initiating FOB.

**Intervention:** Patients had routine application of topical anesthesia to the nasopharynx. A full face mask was connected to a ventilator (Servo 900C; Sola, Sweden) set to deliver continuous positive airway pressure (CPAP) of 4 cm H2O, pressure support ventilation of 17 cm H2O, and 1.0 FiO2. The mask was secured to the patient with head straps. NPPV began 10 min before starting FOB and continued for 90 min or more after the procedure was completed. The bronchoscope was passed through a T-adapter and advanced through the nose. BAL was obtained by sequential instillation and aspiration of 5 to 25 mL aliquots of sterile saline solution through a bronchoscope wedged in a radiographically involved subsegment. Oxygen saturation, heart rate, respiratory rate, and arterial blood gases were monitored during the study.

**Results:** NPPV significantly improved PaO2/FiO2 and O2 saturation. FOB with NPPV was well tolerated, and no patient required endotracheal intubation. A causative pathogen was identified by BAL in all patients. Six patients responded to treatment and survived hospital admission. Two patients died 5 to 7 days after FOB from unrelated complications of the underlying illness.

**Conclusions:** NPPV should be considered during bronchoscopy of immunosuppressed patients with severe hypoxemia.

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**Key words:** bronchoalveolar lavage; fiberoptic bronchoscopy; hypoxemia; noninvasive positive pressure ventilation

**Abbreviations:** CMV=cytomegalovirus; CPAP=continuous positive airway pressure; FiO2=fraction of inspired oxygen; FOB=fiberoptic bronchoscopy; NPPV=noninvasive positive-pressure ventilation; PSV=pressure support ventilation

The most frequent indication for fiberoptic bronchoscopy (FOB) in an immunosuppressed host is the need to determine the cause of diffuse infiltrates that often occur in association with fever and new onset of respiratory symptoms.1 Pulmonary disease in the immunosuppressed patient can progress rapidly and has a high associated mortality, often exceeding 50%.1

Early and accurate diagnosis simplifies management and may improve outcome. In nonintubated patients, severe hypoxemia (defined as requiring of continuous positive airway pressure [CPAP] or an inspired oxygen concentration greater than 50% to maintain an arterial oxygen tension of at least 75 mm Hg) is an accepted contraindication to bronchoscopy.1 Because the arterial oxygen tension routinely decreases by 10 to 20 mm Hg after uncomplicated bronchoscopy, these patients are at high risk for developing respiratory failure or serious cardiac arrhythmias.1,2 In these high-risk patients, the caring physician has two options: intubate with mechanical ventilation to ensure adequate gas exchange during FOB or avoid FOB and institute empirical treatment.

A large body of literature indicates that noninvasive
ventilation with either face mask CPAP or intermittent positive pressure is a safe and effective means of recruiting alveoli and augmenting ventilation in many patients with acute respiratory failure. We have found noninvasive positive-pressure ventilation (NPPV) via face mask to be highly effective in correcting gas exchange, well tolerated, and associated with a low rate of complications. As an extension of this experience, we prospectively evaluated NPPV via face mask as a ventilatory aid to performing FOB with BAL in immunosuppressed patients with suspected pneumonia and severe hypoxemia (PaO₂/fraction of inspired oxygen [FIo₂] ≤ 100). We utilized the combination of CPAP (4 cm H₂O) to recruit alveoli, and pressure support ventilation (PSV) to augment ventilation and to increase mean airway pressure, while FIo₂ was kept at 1.0. PSV was set a level of 17 cm H₂O, previously shown to be effective in patients with restrictive lung disease.

**Materials and Methods**

The study was approved by the institutional review boards, and all patients gave informed consent. Immunosuppressed patients (including those receiving long-term corticosteroid therapy) with clinical manifestations of pneumonia were considered eligible for NPPV-supported FOB if they met the following criteria: (1) PaO₂/FIo₂ of 100 or less; (2) pH greater than 7.35; and (3) ability to increase O₂ saturation with NPPV. From May to November 1994, eight patients (six male and two female) were prospectively evaluated and entered into the study. Their mean (±SD) age was 40±14 years.

Clinical manifestations of pneumonia were modified from a prior study and included all of the following: (1) core temperature greater than 38.3°C; (2) purulent tracheobronchial secretions; (3) worsening pulmonary gas exchange; and (4) persistent radiographic pulmonary density (>24 h). Leukocytosis (WBC count > 10,000 cells per cubic millimeter) was not required, because most (7/8) patients were leukopenic. Bacterial pneumonia was diagnosed by recovering 10³ colony-forming units/mL or more of at least 1 pathogen in quantitative bacterial cultures of BAL.

**Methodology of NPPV and FOB**

Patients received continuous ECG and oximetric monitoring (Ohmeda; Maurepas, France). BP was measured at frequent intervals. Topical anesthesia of the nose and posterior pharynx was obtained by spraying a 10% lidocaine solution, while the patients received 0.5 FIo₂ by Venturi face mask (DAR, Mirandola, Italy). A full face mask was connected to a ventilator (Servo 900C) and secured to the patient’s face with elastic straps (Fig 1). Ventilator parameters were set at CPAP of 4 cm H₂O, PSV of 17 cm H₂O, and trigger of –1 cm H₂O. The FIo₂ was kept at 0.7 while the patients adjusted to the system (at least 15 min). Before bronchoscopy, FIo₂ was increased to 1.0 and kept at this concentration during the procedure. A T-adapter was attached to the facial mask for inserting of the FOB (Olympus IT20) through the nose (Fig 1). Topical anesthesia of the larynx and vocal cords was performed (2% lidocaine hydrochloride, not exceeding 200 mg) before advancing the FOB into the tracheobronchial tree. The tip of the FOB was then wedged into the orifice of the bronchial subsegment with increased densities on chest radiograph. BAL was performed by sequential instillation and aspiration of 5 aliquots of 25 mL of nonbacteriostatic saline solution. The retrieved effluent was immediately sent to the microbiology laboratory for microscopic analysis and cultures.

After bronchoscopy, the FIo₂ was decreased to 0.7, and NPPV was continued for at least 90 min. During NPPV, serial arterial blood gas values were obtained every 10 min, and then every 15 min.
Table 1—Demographics, Underlying Disease, Cause of Pneumonia, and Outcome*

<table>
<thead>
<tr>
<th>Patient/Age, yr/Sex</th>
<th>Disease</th>
<th>Agent</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/35/M</td>
<td>AML</td>
<td>CMV</td>
<td>S</td>
</tr>
<tr>
<td>2/28/M</td>
<td>AML</td>
<td>P. carinii</td>
<td>S</td>
</tr>
<tr>
<td>3/30/F</td>
<td>ANLL</td>
<td>P. carinii</td>
<td>S</td>
</tr>
<tr>
<td>4/7/1/F</td>
<td>COPD, diabetes</td>
<td>Legionella</td>
<td>S</td>
</tr>
<tr>
<td>5/4/4/M</td>
<td>Hodgkin’s</td>
<td>Mycobacterium tuberculosis</td>
<td>D</td>
</tr>
<tr>
<td>6/28/M</td>
<td>ALL</td>
<td>Pseudomonas</td>
<td>D</td>
</tr>
<tr>
<td>7/36/M</td>
<td>AML</td>
<td>CMV</td>
<td>S</td>
</tr>
<tr>
<td>8/4/9/F</td>
<td>Kidney transplant</td>
<td>CMV</td>
<td>S</td>
</tr>
</tbody>
</table>

*AML = acute myeloid leukemia; ANLL = acute nonlymphoid leukemia; ALL = acute lymphoid leukemia; S = survivor; D = dead.

In two patients (patients 7 and 8), a flow transducer was placed in line with the ventilator circuit for evaluating airway pressure and flow (Bicore CP 100; Irvine, Calif.). NPPV was discontinued if patients maintained arterial oxygen saturation greater than 94% and had no respiratory difficulties.

Methods for BAL quantitative bacterial cultures and for identifying cytomegalovirus (CMV) and Pneumocystis carinii are described elsewhere. Gram’s and Ziehl-Neelsen stains and direct immunofluorescence against Legionella pneumophila were performed using undiluted samples. CMV pneumonia was diagnosed by cytolologic study, the presence of CMV nucleic acid sequences, or detection of CMV antigens.

Statistical Analysis

Results are expressed as mean±SD. The arterial blood gas values at baseline and during NPPV treatment were compared by Wilcoxon sign rank test, a nonparametric test for paired samples.

RESULTS

Patients’ demographics, underlying illness, etiology of pneumonia, and outcomes are shown in Table 1. All but one patient were immunosuppressed and leukopenic (WBC count <1,000/mm³). Two patients had thrombocytopenia (platelet count <20,000/mm³) and required platelet transfusion before the procedure. All patients tolerated bronchoscopy with NPPV support. The entire procedure never exceeded 10 min in duration (average time, 7 min.). No patient required endotracheal intubation or reinstitution of NPPV during the 96 h following the procedure.

A causative agent of pneumonia was identified in all patients; five of eight were opportunistic pathogens. None of the patients received antibiotics for the suspected pneumonia prior to diagnostic bronchoscopy, while one patient (patient 5) was receiving Pneumocystis prophylaxis with trimethoprim-sulfamethoxazole. Treatment was directed by the findings of BAL. Six patients survived and were discharged from the hospital. Two patients died due to complications from their underlying disease 5 and 7 days after bronchoscopy.

Application of NPPV was associated with a significant increase in PaO₂/FIO₂ and oxygen saturation (Fig 2). This increment was maintained over the study period. PaCO₂ never increased over the study period (Fig 3). Heart rate and respiratory rate decreased immediately after initiating NPPV but increased slightly during bronchoscopy. After bronchoscopy, both parameters returned to values recorded immediately after application of NPPV (data not shown).

Analysis of the airflow and airway pressures (patients 7 and 8) demonstrated an increase in the inspiratory time when the bronchoscope was wedged into a segment or subsegment of the bronchial tree (Fig 4). This flow limitation gradually disappeared after withdrawal of the instrument. All patients tolerated the procedure well without requiring sedatives or analgesics.
DISCUSSION

Bronchoscopy is associated with temporary alterations in lung mechanics and gas exchange.\(^6,11\) In a nonintubated patient, the bronchoscope occupies about 10% of the total cross-sectional area of the trachea, thereby decreasing delivered tidal volume.\(^9,12\) Furthermore, when suction is applied during FOB, end-expiratory volume and positive end-expiratory pressure are reduced, facilitating alveolar closure and venous admixture.\(^9,11\) These changes slowly subside following bronchoscopy. Time to normalization of gas exchange varies from about 15 min for normal lungs to several hours in lungs with severe parenchymal disease.\(^11\) In one study,\(^13\) on the cardiopulmonary risk of FOB in 107 ventilated patients, significant hypoxemia (PaO\(_2\) ≤ 60 mm Hg on FiO\(_2\) of 0.8) was seen in 13% and was linked to severity of pulmonary dysfunction and decreased alveolar ventilation. The mean drop in PaO\(_2\) was 26%, which persisted for as long as 2 h. The American Thoracic Society recommends avoiding BAL in patients spontaneously breathing with hypercapnia and/or hypoxemia and who cannot be corrected to at least PaO\(_2\) of 75 mm Hg or to oxygen saturation more than 90% with supplemental oxygen.\(^2\) In our institution, we avoid FOB in patients with PaO\(_2\) less than 50 mm Hg, FiO\(_2\) more than 0.6, and FEV\(_1\) less than 1 L.\(^14\)

Immunosuppressed patients with suspected lung infection benefit from early and accurate diagnosis of pneumonia.\(^1\) When high-risk patients are intubated, they are exposed to additional risk for complications. These considerations induced us to test a possible conservative approach: applying NPPV to severely hypoxemic patients during a diagnostic bronchoscopic procedure. As previously demonstrated for patients with COPD with acute exacerbation and for patients with other forms of respiratory failure,\(^3,4\) NPPV can be an effective way to correct gas exchange abnormalities. In the current study, PaO\(_2\)/FiO\(_2\) significantly increased soon after initiating of NPPV, and this improvement was maintained during and after bronchoscopy.\(^13\) Moreover, as the presence of the bronchoscope within the trachea reduces its caliber and increases airway resistance and the work of breathing, application of NPPV may compensate for this extra work, thereby improving the tolerability and safety of the bronchoscopic procedure. In this study, the accurate isolation of the agent responsible for the respiratory failure avoided the empirical administration of unnecessary and often toxic drugs and allowed the successful hospital discharge of 6 (75%) patients.

Applying NPPV for bronchoscopic procedures and BAL offers evident advantages, but some limitations need to be outlined: (1) the patient’s cooperation is essential; (2) the entire procedure must be performed while closely monitoring vital signs and oxygen satura-

![Figure 4](link)

**Figure 4.** Breathing pattern of patient 7: airway pressure and flow recordings obtained by a probe placed between the respiratory circuit and the catheter mount and connected to a system (Bicore CP 100). A: airway pressure and flow with NPPV, before FOB. B: recording during the passage through the vocal cords. C: airway pressure and flow during FOB with the bronchoscope in the wedge position. D: respiratory pattern after the withdrawal of the bronchoscope. Panel C demonstrates the increase of the inspiratory time when the bronchoscope was wedged into a segment or subsegment of the bronchial tree. This flow limitation gradually disappeared after the withdrawal of the instrument (D).

**REFERENCES**

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