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BRIEF REPORT

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Fiberoptic bronchoscopy during noninvasive positive pressure ventilation delivered by helmet

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Abstract *Objective:* To evaluate the feasibility and safety of fiberoptic bronchoscopy (FOB) with bronchoalveolar lavage (BAL) during noninvasive positive pressure ventilation (NPPV) delivered by helmet in patients with acute respiratory failure (ARF) and suspected pneumonia. *Design and setting:* Prospective, clinical investigation in a general intensive care unit (ICU) of a university hospital. *Patients and participants:* Four adult patients with ARF who underwent NPPV via the helmet and required fiberoptic BAL for suspected pneumonia. *Interventions:* NPPV was delivered through the helmet in the pressure support ventilation mode. The specific seal connector placed in the plastic ring of the helmet allowed the passage of the bronchoscope, maintaining assisted ventilation. Arterial blood gas levels, pH, oxygen saturation, respiratory rate, heart rate, and mean arterial blood pressure were monitored during the study. *Results:* Helmet NPPV avoided gas exchanges deterioration during FOB and BAL, with good tolerance. During the procedure heart rate increased by 5% and mean arterial blood pressure by 7% over baseline; these levels returned to prebronchoscopic values immediately after the withdrawal of the bronchoscope. Endotracheal intubation was never required during the 24 h after the procedure. BAL yielded diagnostic information in three of four patients. *Conclusions:* NPPV through the helmet allows a safe diagnostic FOB with BAL in patients with hypoxemic ARF, avoiding gas exchange deterioration, and endotracheal intubation. *Electronic supplementary material* is available if you access this article at http://dx.doi.org/10.1007/s00134-002-1554-5. On that page (frame on the left side), a link takes you directly to the supplementary materials.

Keywords Noninvasive positive pressure ventilation · Helmet · Pneumonia · Bronchoscopy · Hypoxemia · Acute respiratory failure

Introduction

Fiberoptic bronchoscopy (FOB) and bronchoalveolar lavage (BAL) are major tools for the diagnosis of pneumonia in critically ill patients. The identification of the responsible pathogens is crucial to choice an appropriate antimicrobial regimen and avoiding the empirical administration of unnecessary and often toxic drugs. In nonintubated, spontaneously breathing patients severe hypoxemia (defined as requiring an inspired oxygen concentration greater than 50% to maintain arterial oxygen tension of at least 75 mmHg) is an accepted contraindication to bronchoscopy [1]. In these high-risk patients the traditional options are to avoid FOB and to institute empirical treatment or to intubate and apply mechanical ventilation (MV) to ensure adequate gas exchange during FOB. Endotracheal intubation (ETI) is often associated with discomfort and potential complications and

entails the use of sedative drugs, and paralysis may compromise the process of weaning from mechanical ventilation (MV) [2]. NPPV can be a valid alternative to ETI. NPPV has shown to be as effective as MV in improving gas exchange in patients with hypoxemic acute respiratory failure (ARF) of various causes [3], and in selected immunosuppressed patients with hypoxemic ARF, the early initiation of NPPV has been associated with lower rates of ETI and complications, shortened ICU stay, and reduced crude mortality [4, 5].

Previous studies have applied NPPV through a face mask to ensure adequate gas exchange during FOB in spontaneously breathing, hypoxemic patients, thus avoiding ETI [6, 7, 8, 9, 10]. We recently reported the successful use of NPPV delivered by helmet for a prolonged ventilatory support of hypoxemic patients with ARF [11]. Performing FOB with BAL through the helmet during NPPV has never been investigated. The purpose of this study was to evaluate the feasibility and safety of FOB with BAL during NPPV delivered by helmet in patients with hypoxemic ARF and suspicion of pneumonia.

Materials and methods

Study population

Four adult patients (two receiving immunosuppressive therapy for pulmonary fibrosis) with acute hypoxemic respiratory failure and suspected pneumonia admitted to a 21-bed general intensive care unit (Università Cattolica University Hospital, Rome, Italy) were enrolled in study. Patients' characteristics are presented in Table 1. An ad hoc ethics committee approved the protocol, and all patients gave informed consent. Criteria for hypoxemic ARF included respiratory distress with severe dyspnea at rest, respiratory rate greater than 35 breaths/min, and PaO_2:FIO_2 ratio less than 200 while breathing oxygen through a Venturi mask. Criteria for suspecting pneumonia included body temperature higher than 38°C or lower than 36°C, new and persistent radiological pulmonary infiltrate, purulent secretions, and leukocytosis (white blood cells count >12,000 cells/mm) or leukopenia (white blood cell count <4,000 cells/mm). Exclusion criteria [3, 9] included a requirement for emergent intubation (cardiopulmonary resuscitation, respiratory arrest, severe hemodynamic instability, or encephalopathy), respiratory failure caused by neurological disease, and status asthmaticus.

Severity of illness was assessed by the Simplified Acute Physiology Score II (SAPS II) [12]. All patients were treated with NPPV via the helmet and required fiberoptic BAL for the etiological diagnosis of pneumonia. Technical aspects of NPPV using the helmet (CaStar, Starmed, Italy) have been previously described [11]. The helmet was connected to a Servo 300C ventilator (Siemens-Elema, Solna, Sweden) with 10–20 cmH_2O pressure support, 8–15 cmH_2O positive end-expiratory pressure (PEEP) flow triggering, and the lowest FIO_2 possible to assure a peripheral oxygen saturation equal to or higher than 92%.

Technical aspects

A flexible fiberoptic bronchoscope (BF-20D; Olympus, Tokyo, Japan) was used in all patients. The specific seal connector placed in the plastic ring of the helmet was used to spray local anesthetics into the nostrils and oropharynx of the patient and to allow the passage of the bronchoscope (video clip). The internal adjustable diaphragm of the seal connection prevented loss of the respiratory gases, maintaining ventilation and PEEP throughout FOB. For topical anesthesia of the nostrils and oropharynx five or six sprays of 10% lidocaine were used. Topical anesthesia of the upper airway and tracheobronchial tree was performed with a 2% lidocaine hydrochloride, not exceeding 200 mg. No sedative drug was administered before and during the procedure. As a supplementary distance is added from the body of the bronchoscope and the nose or the mouth, FOB could be more difficult for taller patients. This problem is easily solved reducing this distance by placing patients in the supine position and gently pushing the plastic ring toward the face of the patients.

BAL was performed by wedging the tip of the bronchoscope into a subsegment of the area where the radiological opacities were located. BAL consisted of a sequential instillation and aspiration of four 25-ml aliquots of sterile saline solution. BAL fluid was subjected to microscopic analysis and culturing. The methods and laboratory procedures used to process BAL samples for bacterial, fungal, and viral detection followed consensus guidelines [13]. *Pneumocystis carinii* was sought on BAL fluid by direct immunofluorescence. Bacterial pneumonia was diagnosed when a positive quantitative culture at 10^4 colony forming units or more per milliliter of bacteria in the BAL fluid was detected.

Before starting FOB and during the procedure FIO_2 was set at 0.9 for all patients, and then decreased to 0.7 at the end of FOB and brought to baseline values 30 min after the termination of the procedure. Pressure support and PEEP were not changed during the bronchoscopy. Arterial blood gas analysis and physiological parameters were recorded before the bronchoscopy (during NPPV) (baseline), at the end of the BAL with the bronchoscope still in place and 15 and 60 min after the end of the procedure. Heart rate, respiratory rate,

Table 1 Patients' characteristics and outcome. NPPV duration for the treatment of ARF was 102 h in patient 1, 72 h in patient 2, and 89 h in patient 3; after these periods helmet NPPV was applied intermittently, the patients were successfully weaned from assisted ventilation, and discharged from the ICU. Patient 3 failed NPPV 30 h after the study, was intubated, and died with multiple organ failure 48 h after the study (*SAPS II* Simplified Acute Physiology Score II, *Helmet* duration of helmet noninvasive positive pressure ventilation before fiberoptic bronchoscopy, *PS/PEEP* pressure support/positive end-expiratory pressure, *COPD* chronic obstructive pulmonary disease, *BAL* bronchoalveolar lavage, *ARDS* acute respiratory distress syndrome)

Patient no.	Age (years)	Sex	SAPS II	Helmet (h)	PS/PEEP (cmH_2O)	Underlying diagnosis	Outcome
1	32	F	32	3	12/15	ARDS, orbital mucormycosis, diabetes	Survival
2	75	F	23	4	20/8	COPD, diabetes	Survival
3	64	M	29	3	10/8	ARDS, lung fibrosis, diabetes	Death
4	70	M	30	5	15/10	Pulmonary idiopathic fibrosis, diabetes, renal failure	Survival

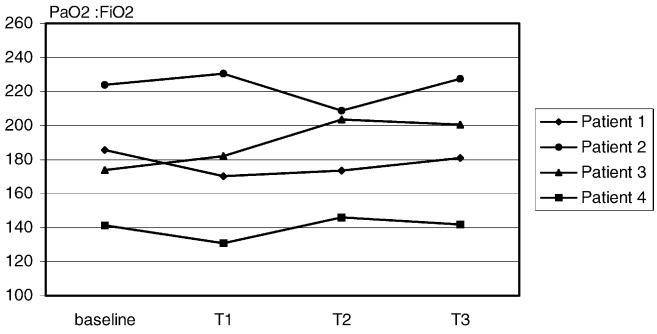

Fig. 1 PaO_2:FIO_2 values over time. Changes during the study were not statistically significant

mean arterial blood pressure (MAP), and oxygen saturation by pulse oximetry were monitored over the study (SC-7000 system, Siemens, Munich, Germany). During the 24 h after FOB the need for ETI and the occurrence of complications such as hemorrhage, arrhythmias, hypoxemia, hypotension, and pneumothorax were recorded.

Statistical analysis

Results are reported as mean ±SD. Physiological characteristics were compared using the *t* test for continuous data (separate estimates of variance were used when variance differed significantly) and Wilcoxon's rank test for evaluation within group. SPSS was used for all analyses.

Results

All patients well tolerated FOB with BAL without requiring sedatives or analgesics. The average duration of the bronchoscopy was 8.0±1.2 min (range 6.5–9.5). A mean of 43±9 ml (range 33–55) of the 100 ml saline solution instilled was retrieved (45% yield). ETI was never required during the 24 h after the procedure. Three patients were never intubated, survived, and were discharged from the ICU. One patient died 48 h after the study, due to his underlying disease.

The PaO_2:FIO_2 ratio did not significantly change throughout the procedure but showed a 2% reduction from 181±34 at baseline to 178±41 at the end of the BAL. Fifteen minutes after the end of the bronchoscopy the ratio was 183±29 (1% increase from the baseline) and 1 h after completing the procedure was 188±36 (4% increase from the baseline). The individual PaO_2:FIO_2 values over time are shown in Fig. 1. Oxygen saturation, $PaCO_2$, respiratory rate, MAP and heart rate are reported in Table 2. Immediately after completing the BAL MAP increased by 5% from the baseline (p=0.03) and heart rate increased by 7% (p=0.03). MAP and heart rate returned to baseline values within 15 min after bronchoscopy. BAL allowed the etiological diagnosis of pneumonia in three cases (one *Pseudomonas aeruginosa*, one methicillin-resistant *Staphylococcus aureus,* and one *Pneumocystis carinii*). In one patient the causative agent remained unknown.

Table 2 Physiological parameters over the study period. Data are presented as mean ±SD. (SaO_2 oxygen saturation by pulse oximetry, *RR* respiratory rate, *MAP* mean arterial blood pressure, *HR* heart rate, Baseline before FOB already with PS ventilation delivered by helmet, t_1 end of the BAL with the bronchoscope still in place, t_2 15 min, t_3 60 min after the end of the procedure

	Baseline	t_1	t_2	t_3
SaO_2 (%)	93.3±1.5	95.3±1.0	94.5±1.3	94.0±1.2
RR (bpm)	15±4.7	15±4.1	15±4.7	15±5.6
$PaCO_2$ (mmHg)	38.9±6.5	39.1±6.7	39±6.6	39.1±6.5
Arterial pH	7.44±0.06	7.42±0.06	7.42±0.05	7.43±0.06
MAP (mmHg)	99±14	104±15*	99±14	98±13
HR (bpm)	96±10.8	102±11.7*	96±11.4	96±11.2

*p<0.05

Discussion

The present study shows that FOB with BAL is feasible and safe in nonintubated hypoxemic ARF patients treated with NPPV via helmet. Helmet NPPV avoided deterioration in gas exchanges and ETI and allowed the maintenance of assisted ventilation. The bronchoscopy was well tolerated by all the patients, without complications. The rationale and effectiveness of using mask NPPV in nonintubated patients during diagnostic FOB has been extensively reported [6, 7, 8, 9, 14]. No data exist on bronchoscopy in association with helmet NPPV.

We observed an increase in heart rate and MAP during the procedure, but these hemodynamic changes were modest and transient, and consistent with the results of other studies [7, 9, 10, 15]. The maintenance of assisted ventilation by helmet avoided the temporary alterations in pulmonary mechanics and gas exchanges during FOB that have been described in several reports [7, 9, 10, 15] and confirms the good results of randomized [8, 9] and nonrandomized studies [6, 7, 10] that used mask NPPV during diagnostic bronchoscopy. Two patients enrolled in this study had immunosuppression. The importance of NPPV in immunodepressed patients to avoid ETI and serious complications was previously described in two randomized trials [4, 5]. The need of invasive diagnostic technique to identify the causative agent of pneumonia may worsen gas exchanges, require ETI, and expose the patients to the risk of complications. The use of helmet NPPV avoids these risks and expands the applicability of NPPV to patients who do not tolerate the mask.

In conclusion, the present study shows that in patients with hypoxemic ARF receiving NPPV through the helmet FOB with BAL is a safe and feasible technique, avoids ETI and discontinuation of assisted ventilation, and thereby limits the patient's discomfort and deterioration in gas exchanges.

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