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Comparison of nonbronchoscopic bronchoalveolar lavage to open lung biopsy for the bacteriologic diagnosis of pulmonary infections in mechanically ventilated patients

P. Gaussorgues, D. Piperno, P. Bachmann, F. Boyer, G. Jean, M. Gérard, P. Léger and D. Robert

Department of Intensive Care and the Respiratory Intensive Care Unit, Hopital Croix Rousse, Lyon, France

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Abstract. We compared nonbronchoscopic bronchoalveolar lavage (NB-BAL) with open lung biopsy to determine the etiological diagnosis of lung infiltrates in patients requiring mechanical ventilation. NB-BAL was performed via a cuffed reusable 7F catheter generally used for right heart catheterization (BAL-C). In 13 patients, BAL-C and open lung biopsy were performed in the same lobe immediately after death when the ventilator was still functioning. No organism was cultured from BAL-C cultures when histopathologic examination of the lung showed no pneumonia and lung culture isolated no organism. Among the 10 positive BAL-C cultures, lung biopsy showed histologic pneumonia in 9 cases. Among these 9 pneumonia cases, 14 organisms were isolated in lung cultures and BAL-C correctly identified the causative agent in 13 cases. BAL-C appears to be an effective and safe procedure in the diagnosis of pulmonary infections in patients under mechanical ventilation who have previously received antibiotic therapy.

Key words: Bronchoalveolar lavage – Nosocomial infection – Mechanical ventilation

The diagnosis of pulmonary infections in patients requiring mechanical ventilation remains a difficult problem. Open lung biopsy is an accepted bacteriologic reference but cannot be proposed as a first-line diagnostic procedure because of its risks [2, 4]. Several less invasive procedures are now available. Among the multiple procedures recommended for the diagnosis of pulmonary infections, the protected specimen brush described by Wimberley in 1982 [14] has been evaluated by Chastre et al. in mechanically ventilated patients [4]. Endobronchial brushing may however cause bleeding in the presence of coagulation disorders and pneumothorax with a frequency ranging from 1% to 25% in published series [2, 8]. Bronchoalveolar lavage (BAL) is used for the etiological diagnosis of pneumonia in immunocompromised hosts (particularly cytomegalovirus and *Pneumocystis carinii* pneumonia). During fiberoptic bronchoscopy the secretions aspirated through the suction channel are contaminated by the orotracheal flora, thereby limiting their clinical specificity. Quantitative culture of specimens obtained by a protected brush catheter [4] or by BAL [5, 12] has recently been used in an attempt to obviate the problem of contamination. To avoid the deleterious effects of BAL on oxygenation [1, 7] and the contamination of the suction channel by upper airways secretions, nonbronchoscopic bronchoalveolar lavage techniques (NB-BAL) using a control-tipped catheter [3], a double lumen catheter [6] or a cuffed catheter [10] have been proposed.

The aim of this study was to compare NB-BAL, using a cuffed catheter (BAL-C), to open post-mortem lung biopsy for the bacteriologic diagnosis of lung infiltrates in mechanically ventilated patients.

Methods

Patients

Patients who died with pulmonary infiltrates on chest X-ray were included in the study when the BAL-C and the open lung biopsy procedures were available within 1 h after death and when the specimens could be immediately processed by the laboratory.

Between May 1987 and September 1987, 13 patients were included in the study. The clinical diagnoses (Table 1) of the 13 patients (mean age 66±8 years) at time of admission were: 10 cases of acute respiratory failure caused by: *Legionella pneumophila* (2 cases), *Mycoplasma pneumoniae* (1 case), *Streptococ-*

Table 1. Lung cultures, cuffed catheter cultures and histologic examinations in 13 patients

Patients no.	Cuffed catheter cultures	Lung cultures	Histologic examinations
1	*Alpha streptococcus*	*Alpha streptococcus*	Pneumonia
2	*Candida albicans*	*Candida albicans*	Pneumonia
3	*Acinetobacter*	*Acinetobacter*	Pneumonia
4	*Pseudomonas cepacia*	*Pseudomonas cepacia*	Pneumonia
5	*Pseudomonas cepacia*	*Pseudomonas cepacia*	Pneumonia
6	*Streptococcus* D *Cytomegalovirus*	*Streptococcus* D *Cytomegalovirus*	Pneumonia
7	*Pseudomonas aeruginosa* *Pseudomonas cepacia*	*Pseudomonas aeruginosa* *Pseudomonas cepacia*	Pneumonia
8	*Pseudomonas cepacia* *Staphylococcus aureus* *Klebsiella pneumoniae*	*Pseudomonas cepacia* *Staphylococcus aureus* *Klebsiella pneumoniae*	Pneumonia
9	*Pseudomonas aeruginosa* –	*Pseudomonas aeruginosa* *Pseudomonas cepacia*	Pneumonia
10	*Acinetobacter* Rhinovirus	*Acinetobacter* –	Emphysema
11	Sterile	Sterile	Carcinoma
12	Sterile	Sterile	Fibrosis
13	Sterile	Sterile	Emphysema

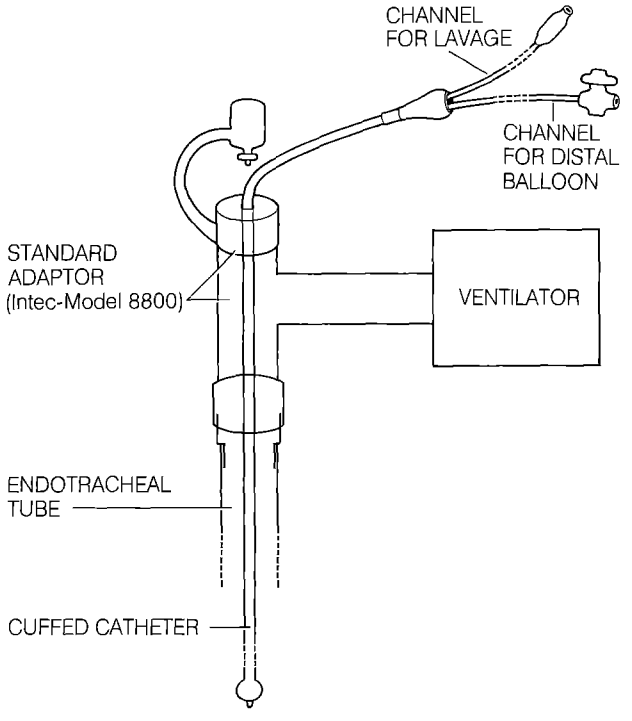

Fig. 1. Cuffed catheter for right heart catheterization (Size 7F USCI – Model 7502). 1 – 2: Standard adaptor (Intec Model 8800). 3: Endotracheal tube; 4: Cuffed catheter; 5: Channel for lavage; 6: Channel for distal balloon; 7: Ventilator

cus pneumoniae (1 case), lung carcinoma (2 cases), lung fibrosis (1 case), cardiac failure (2 cases), unknown pneumonia (1 case), and 3 cases of neurologic disorders caused by cardiac arrest (2 cases) and encephalitis (1 case). All patients required mechanical ventilation and a positive endexpiratory pressure (PEEP) was used in 11 cases.

Death occurred after 21 ± 13 days of mechanical ventilation. At this time all patients had diffuse (9 cases) or lower (4 cases) lobes infiltrates. They were clinically suspected of having nosocomial pneumonia (fever, leucocytosis and purulent sputum) and had received antimicrobial therapy for at least 4 days before death.

BAL-C procedure

Immediately after death, mechanical ventilation was maintained and BAL-C was performed by our bronchoscopy nurses with a cuffed catheter generally used for right heart catheterization (Size 7F-USCI-model 7502) (Fig. 1). The cuffed catheter was blindly guided through the endotracheal tube via a standard adaptor (INTEC-model 8800) into a distal bronchus until it could pass no further (approximately 50 cm). In this presumably wedged position a chest X-ray was performed to assess the distal position of the catheter in the pathological lobe. In this location the cuff was inflated (0.5 cm^3) to occlude the bronchus and BAL was performed. One hundred fifty milliters of saline solution was injected in 50 ml aliquots and aspirated back into a sterile suction trap. Approximately 15 to 20 ml was recovered from each 50 ml aliquot. BAL-C fluid thus collected was distributed into 7 sterile tubes (for viral, fungal, aspergillus, legionnella and bacteriologic cultures, *Pneumocystis carinii* and cytologic examinations). The BAL-C procedure required approximately 10 to 15 min (including chest X-ray).

Open lung biopsy

After the BAL-C procedure, the cuffed catheter remained in place and under surgical conditions, a thoracotomy was performed. Five superficial lung specimens were taken in the same lobe (identified with the palpation of the inflated cuff) and were placed into a sterile tube for: bacteriologic, viral, fungal and legionnella cultures; stain for pneumocystis. One specimen was immersed in Bouin's fixative for pathologic examination. BAL-C fluid and lung specimens were immediately transported to the laboratory. Cultures were examined qualitatively but not quantitatively. Among the 13 patients studied, 12 had blood cultures sampled the day before death.

Reference method

The radiologic infiltrate was considered as pneumonia when pathologic examination showed foci of consolidation with polymorphonuclear leucocyte accumulation.

The bacteriologic diagnosis of this histologic pneumonia was defined by the results of lung culture. Taking the open lung biopsy as reference, the 13 patients were divided into 2 groups: with pneumonia and without pneumonia. This work accorded with the French legislation about taking organs.

Results

Location of the samples

BAL-C and open lung biopsy were performed in the right lower lobe (7 cases), the left lower lobe (4 cases), the right upper lobe (1 case) or the left upper lobe (1 case).

Pathologic examination of lung specimens (Table 1)

In 9 patients, the pathologic examination was consistant with the diagnosis of pneumonia. In 4 patients, pathologic examination showed carcinoma (1 case), fibrosis (1 case) and emphysema (2 cases) but no pneumonia.

Lung cultures (Table 1)

Fifteen microorganisms were isolated from lung cultures in 13 patients. Mean number of organisms found in BPT was 1.15 ± 0.86 (range 0–3). In the 9 patients with pneumonia, lung cultures were positive and yielded mixed infection in 4 cases. The microorganisms isolated were susceptible to the antibiotics used in four of these 9 patients. Among the 4 patients without histologic pneumonia, lung cultures were sterile in 3. In 1 case (emphysema), however, the lung culture was positive with an Acinetobacter.

BAL-C cultures (Table 1)

From BAL-C cultures in 13 patients, 15 microorganisms were isolated. The mean number of organisms found in BAL-C was 1.15 ± 0.86 (range 0–3). In the 9 patients with pneumonia, BAL-C cultures were positive. In 8 cases the same organisms were isolated from BAL-C and lung specimens. In one case BAL-C misdiagnosed the causative agent. In the 4 patients without pneumonia, BAL-C cultures remained sterile in 3 cases. In 1 case (emphysema), cultures were positive for Acinetobacter and Rhinovirus.

Comparison cytologic examination of BAL-C to histologic examination of lung

Squamous epithelial cells, which would predict contamination of the BAL-C sample by orotracheal flora, were not found in any of the 13 specimens. In the 9 patients with histologically proved pneumonia, BAL-C fluid contained $81\% \pm 25\%$ polymorphonuclear cells. Among the 4 patients without histologic pneumonia, 3 had negative BAL-C and lung cultures. These 3 patients had $20\% \pm 18\%$ of neutrophil polymorphonuclear cells in the BAL-C fluid. In the only patient with organisms found both in BAL-C and lung culture but without histologic pneumonia, the differential cells count showed 72% of polymorphonuclear neutrophils.

Operating characteristics of the BAL-C method to identify patients with pneumonia

The 10 positive BAL-C cultures were associated with 9 histologic pneumonia (1 false positive). Therefore, BAL allowed an accurate diagnosis of pneumonia with 1/9 false positive (11%). Among the 4 patients without pneumonia, BAL-C remained sterile in 3 (1 false positive).

Operating characteristics of the BAL-C method to identify microorganism present in the lung of patient with pneumonia

Among the 10 positive BAL-C cultures, BAL identified correctly the germ in 8 cases (1 false negative, 1 false positive).

Results of blood cultures

Before death, the blood cultures remained sterile except for 3 patients. Among them, *Bacillus* and *Pseudomonas aeruginosa* were isolated from blood cultures but *Pseudomonas cepacia* was found in lung culture.

Discussion

Adequate treatment of nosocomial pneumonia in mechanically ventilated patients requires a diagnostic procedure that is simple, minimally invasive, and with good sensitivity and specificity.

Recently, the use of a catheter brush protected by a telescoping double sheath, passed through the suction channel of a bronchoscope has been recommended [14] and validated [4, 13]. This procedure, which includes fiberoptic bronchoscopy, may predispose to alterations in pulmonary mechanics [7] and gas exchange [1]. Some authors [2, 3] also argue that the bronchoscopic-protected catheter brush procedure involves a risk of pulmonary hemorrhage and pneumothorax in critically ill patients.

Flexible fiberoptic bronchoscopy with bronchoalveolar lavage has a high diagnostic yield with minimal risk (in comparison to transbronchial biopsy and brushing) in immunocompromised patients [2, 8]. During bronchoscopic bronchoalveolar lavage, secretions aspirated through the suction channel are however contaminated by orotracheal flora, thereby limiting their clinical specificity. Kahn [5] and Thorpe [12] demonstrated that, even in non-ventilated patients, large numbers of organisms may grow in lavage culture from patients without pneumonia and that a cutoff of 10^5 cfu/ml of lavage fluid on quantitative culture permits colonization and true pneumonia to be distinguished.

Nonbronchoscopic BAL (NB-BAL) using control-tipped reusable catheters originally designed for selective angiography was proposed by Caughey [3]. Mann [6] performed NB-BAL, using a double lumen lavage catheter to diagnose opportunistic infection in patients with AIDS. The authors concluded that NB-BAL was safe and effective.

In our intensive care unit, 435 NB-BAL using a cuffed catheter (BAL-C) have been performed since 1986 to assess the causative organism of pneumonia requiring mechanical ventilation. BAL-C achieved an etiologic diagnosis in 54.8% of cases [10]. Arterial blood gas measurements showed no significant change in PaO_2 before, during, at the end of BAL-C, or 1 h following the procedure [9].

To evaluate the reliability of the BAL-C procedure, we compared this technique with open lung biopsy used as a reference method. Post-mortem bacteriologic study of the lung may however be contaminated during the delay between death and removal, during collection or by bronchial secretions in case of deep sampling. In our study patients remained under mechanical ventilation, lung specimen collection was performed immediately after death, and superficial lung specimens were obtained to avoid contamination by bronchiolar secretions.

The 13 mechanically ventilated patients included in this study had pulmonary infiltrates and had been receiving antibiotic therapy for several days before death. No organism was found in BAL-C cultures when pathologic examination of the lung showed no pneumonia and lung culture isolated no organism. Consequently, a negative BAL-C culture can eliminate the diagnosis of infectious pneumonia. Among the 10 positive BAL-C cultures, lung biopsy showed histologic pneumonia in 9 cases. Consequently, positive BAL-C cultures allowed pneumonia to be diagnosed without false negatives and with a 11% false positive rate.

Among the 9 pneumonia, 14 organisms were isolated in lung cultures and BAL-C correctly identified the causative agent in 13 cases. Thus, BAL-C allowed an accurate diagnosis of the etiologic agent of pneumonia in 93% of cases. However, in one patient without histologic pneumonia, organisms were cultured from lung and BAL-C. In this case, the area sampled by lung biopsy may have been inoculated during the BAL-C procedure. Unfortunately, quantitative cultures were not performed to distinguish between colonization and true pneumonia.

Among the 9 patients with histologic pneumonia, 5 were admitted to the intensive care unit with the clinical diagnosis of pneumonia. In these cases, the value of the pathologic examination to confirm nosocomial pneumonia may be questioned. However, these 5 patients died 3 weeks after hospital admission, and by that time, polymorphonuclear leukocyte accumulation caused by the initial pneumonia had probably disappeared.

BAL-C diagnosed all cases of histologically proved pneumonia (sensitivity = 100%) and correctly identified the pathogen in 8 of 9 patients with pneumonia. With the protected specimen brush (PSB) the rate of false positives was particularly high (58%) in patients who received antimicrobial therapy [4]. With BAL-C the rate of false positives was lower (11%). Seidenfeld [11] comparing bronchoscopic BAL, PSB and lung biopsy found a 27% rate of false positives for PSB and 13% for BAL. The absence of suction during the insertion of the cuffed catheter and the protection of the lavaged area from upper secretion by the inflated cuff might explain why BAL-C appears to be less contaminated than bronchoscopic BAL.

The diagnostic accuracy of BAL-C leads us to propose this technique as a possible alternative to open lung biopsy and to bronchoscopic procedures. BAL-C appears to be an effective technique to diagnose pneumonia and confirm its bacterial etiology in patients requiring mechanical ventilation and receiving antibiotic therapy.

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Dr. P. Gaussorgues
Hopital Croix Rousse
93 grande rue de la Croix Rousse
F-69317 Lyon Cedex 04
France