Safety and Efficacy of Bronchoalveolar Lavage Using a Laryngeal Mask Airway in Cases of Acute Hypoxaemic Respiratory Failure with Diffuse Lung Infiltrates

Takafumi Matsumoto, Yoko Sato, Satoshi Fukuda, Shinshu Katayama, Yuya Miyazaki, Makoto Ozaki and Toru Kotani

Abstract

Objective Fibre-optic bronchoscopy with bronchoalveolar lavage (FOB-BAL) is an important tool for diagnosing and selecting treatment for acutely hypoxaemic patients with diffuse lung infiltrates. However, FOB-BAL carries a risk of significant hypoxaemia and subsequent tracheal intubation during and after the procedure. The application of FOB-BAL using a laryngeal mask airway (LMA) in combination with continuous positive airway pressure (CPAP) may minimize the incidence of hypoxaemia; however, the safety and efficacy of this procedure have not been investigated.

Methods A retrospective chart review was performed from April to September 2013. Data regarding the recovered volume of BAL fluid, incidence of tracheal intubation within eight hours after the completion of FOB-BAL, respiratory and haemodynamic parameters and treatment modifications were collected for the evaluation.

Results Ten trials of FOB-BAL using an LMA and CPAP were performed in nine patients with severe acute hypoxaemia associated with diffuse lung infiltrates. The BAL fluid recovery rate was 56%, and the procedure was completed without subsequent complications. In addition, the percutaneous arterial oxygen saturation decreased to $95.7\% \pm 3.8\%$, although it was never lower than 90.0% during the procedure, and no patients required intubation. Furthermore, the arterial blood pressure significantly but transiently decreased due to sedation, and the procedure yielded diagnostic information in all nine patients.

Conclusion FOB-BAL using LMA and CPAP appears to be safe and effective in patients who develop severe acute hypoxaemia.

Key words: bronchoalveolar lavage, continuous positive airway pressure, fibre-optic bronchoscopy, laryngeal mask airway, sedation

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Introduction

In acutely hypoxaemic patients with diffuse pulmonary infiltrates, it is important to establish the specific cause of pulmonary disease so that appropriate therapy may be provided immediately. Fibre-optic bronchoscopy with bronchoalveolar lavage (FOB-BAL) is an important tool for diagnosing diffuse pulmonary infiltrates (1). Although FOB-BAL is generally considered to be safe (2), it is well known

that the arterial blood oxygen saturation usually decreases during and/or after the procedure (3-6). Therefore, FOB-BAL is contraindicated in non-intubated, severely hypoxaemic patients (7). Positive end-expiratory pressure ameliorates hypoxaemia by preventing alveolar collapse, although some type of airway management is necessary for its use. While tracheal intubation is the most reliable airway management technique, certain complications may occur during intubation and/or after extubation (8). Therefore, the development of a strategy other than intubation to prevent hypoxaemic

events during FOB-BAL is required.

The laryngeal mask airway (LMA) is a supraglottic airway device that provides an end-to-end airtight seal around the larynx and maintains effective gas exchange (9, 10). An advantage of LMA is that it can be blindly inserted without laryngoscopy; thus, cardiovascular responses to the introduction of an LMA are less severe than those induced by tracheal intubation (11, 12). The LMA technique for both spontaneous and controlled ventilation is reportedly both safe and effective (13), and a recent study demonstrated that FOB-BAL can be safely and effectively performed with an LMA in immunosuppressed patients with pneumonia and severe hypoxaemia (14).

In our intensive care unit, FOB-BAL is routinely performed using an LMA in combination with continuous positive airway pressure (CPAP) under light sedation in acutely hypoxaemic patients with diffuse lung infiltrates in order to prevent hypoxaemic events during and after the examination. We subsequently conducted a retrospective case-series study of FOB-BAL to demonstrate its safety and efficacy.

Materials and Methods

A retrospective chart review was performed from April to September 2013. Data were collected for patients with diffuse pulmonary infiltrates who exhibited acute hypoxaemic respiratory failure requiring oxygen therapy or non-invasive positive airway pressure ventilation (NPPV) and who underwent FOB-BAL for diagnostic or therapeutic reasons. Data for demographic variables, the ratio of arterial blood oxygen saturation to the fraction of inspired oxygen under CPAP of 5 cm H₂O, Simplified Acute Physiological Score II and underlying diseases were also obtained. NPPV was applied using a ventilator (Respironics V60; Respironics California, Carlsbad, USA) via a full-face mask. Local research ethics committee approval was received for the retrospective review of the patients.

FOB-BAL was performed according to the standard procedures in place at our intensive care unit. Briefly, none of the patients had a contraindication to the insertion of an LMA (15) before undergoing the procedure. One physician was in charge of sedation and haemodynamic management. A flexible fibre-optic bronchoscope (BF-P60; Olympus, Tokyo, Japan), LMA (LMA Supreme; Teleflex Medical, San Diego, USA or i-gel; Intersurgical, Wokingham, Berkshire, UK), topical anaesthetic (4% lidocaine hydrochloride), sedatives (propofol and fentanyl), vasopressor (phenylephrine hydrochloride) and warm sterile 0.9% saline solution for BAL were prepared prior to the examination. A properly sized LMA (size 3 or 4) was chosen for each patient and lubricated with 2% lidocaine gel. The medical team was prepared for tracheal intubation and invasive ventilation while performing the procedure.

An electrocardiogram, non-invasive and/or invasive blood pressure measurements, percutaneous arterial oxygen saturation and respiratory rate were continuously monitored during

the procedure. Initially, CPAP was applied via a full-face mask. The positive end-expiratory pressure was set at 5 cm H₂O or the pre-bronchoscopy level. The fraction of inspired oxygen was increased to 1.0. Topical anaesthesia was applied to the oral cavity and larynx by thoroughly spraying 4% lidocaine hydrochloride. Sedation was initiated by the incremental administration of a combination of 25 µg of fentanyl and 20 to 30 mg of propofol followed by the infusion of 1 to 3 mg/kg/h of propofol to maintain spontaneous breathing. After confirming the patient's unconsciousness, the LMA was inserted and connected to the ventilator via a swivel connector (Sontek Suction-Safe Swivel Y; Sontek Medical, Hingham, USA). Mechanical ventilation was applied in the spontaneous/timed mode in order to maintain the minute volume in case of suppression of spontaneous breathing secondary to sedation. The bronchoscope was introduced through the swivel connector. After examining the tracheobronchial tree and providing topical anaesthesia, the tip of the bronchoscope was wedged into the subsegmental area with the most severe X-ray abnormalities. The bronchus was instilled with sterile saline (five 20-mL aliquots) and gently aspirated. The obtained fluid was pooled, processed and immediately sent to the laboratory for cytologic and microbiological examinations. The LMA was removed when the patient had completely emerged from anaesthesia and was able to obey commands. After removing the LMA, NPPV was continued with a full-face mask. The fraction of inspired oxygen was gradually decreased to the pre-bronchoscopy level. Patients who did not require NPPV before the examination were switched back to conventional oxygen therapy.

The rate of intubation within eight hours after the completion of FOB-BAL and the changes in the respiratory rate, mean arterial pressure and heart rate just before sedation, during FOB-BAL and one hour after FOB-BAL were recorded and compared. The lowest arterial blood oxygen saturation noted during the procedure was recorded, and the volume of BAL aspirated was documented as a percentage of the instilled aliquot. Treatment modifications based on the BAL analysis were also evaluated.

The results are expressed as the mean $\pm$ standard deviation (95% confidence interval). An analysis of variance was used to compare respiratory and haemodynamic parameters obtained just before sedation and during and after the FOB-BAL procedure. A p value of <0.05 was considered to be statistically significant.

Results

Data for 14 cases of FOB were collected during the study period. Ten FOB-BAL procedures using an LMA and CPAP were performed in nine consecutive patients. The characteristics of the patients are shown in Table 1. Eight patients (89%) received immunosuppressive therapy for renal transplantation (n=5), rheumatoid arthritis (n=2) and rapidly progressive glomerulonephritis (n=1). The mean ratio of arterial

Table 1. Patient Characteristics

Demographic data	
No. of patients	9
Age (years)	67.5 ± 12.7 (57.7-77.3)
Gender ratio (F/M)	2/7
BMI (kg/m ²)	21.5 ± 2.5 (19.6-23.5)
Physiological data	
SAPSII	39.9 ± 10.3 (31.9-47.9)
PaO ₂ /FiO ₂	206.7 ± 55.5 (170.0-246.4)
Underlying diseases and comorbidities	
Immunocompromised	
Renal transplantation	5 (55.6%)
Rheumatoid arthritis	2 (22.2%)
Rapidly progressive glomerulonephritis	1 (11.1%)
Haematological malignancy	1 (11.1%)
Use of vasopressor	1 (11.1%)
Use of NPPV prior to FOB-BAL	6 (66.7%)
PEEP (cm H ₂ O)	6.7 ± 1.3 (5.4-8.0)

The data are presented as the mean ± standard deviation (95% confidence interval) or *n* (%).

F: female, M: male, BMI: body mass index, SAPS II: Simplified Acute Physiological Score II, PaO₂/FiO₂: ratio of arterial blood oxygen saturation to fraction of inspired oxygen, NPPV: non-invasive positive airway pressure ventilation, FOB-BAL: fibre-optic bronchoscopy with bronchoalveolar lavage, PEEP: positive end-expiratory pressure

blood oxygen saturation to the fraction of inspired oxygen before FOB-BAL was 206.7±55.5 (170.0-246.4) mmHg. NPPV was performed in six patients (67%) prior to FOB-BAL, with a positive end-expiratory pressure of 6.7±1.3 (5.4-8.0) cm H₂O.

The duration of FOB-BAL was 20.3±3.7 (17.6-30.0) minutes. The total doses of propofol and fentanyl were 129.9±59.6 (93.6-166.1) mg and 102.5±18.4 (89.3-115.7) µg, respectively. The mean positive end-expiratory pressure during the procedure was 6.5±1.4 (5.4-7.5) cm H₂O. The spontaneous/timed mode was temporarily applied with an inspiratory positive airway pressure of 14.0±0.7 (11.7-16.2) cm H₂O in four patients (44.4%). No patients required tracheal intubation within eight hours after FOB-BAL. Only one patient was intubated three days after FOB due to progression of the underlying disease.

The procedure was completed without subsequent complications in all cases. The cardiorespiratory parameters obtained just before sedation, during FOB-BAL and one hour after FOB-BAL are shown in Figure. The changes in the respiratory rate and heart rate induced by the procedure did not reach statistical significance. In contrast, the mean arterial blood pressure during the procedure significantly decreased. However, the haemodynamic changes were modest and transient, with the use of phenylephrine hydrochloride. The mean arterial oxygen saturation was 95.7%±3.8% (93.0%-98.4%), and no patients exhibited an arterial blood oxygen saturation of <90.0% during the procedure. Two patients were switched back to oxygen therapy after the procedure. No other adverse events were noted, such as laryngospasms, coughing, haemorrhage, arrhythmia or pneumothorax.

The results of FOB-BAL are shown in Table 2. The mean percentage volume of recovered BAL fluid was 56.1%±

11.1% (48.1-64.0%). The procedure yielded diagnostic information for nine patients (90%). Pneumocystis pneumonia was diagnosed in eight patients, and acute exacerbation of collagen vascular disease-associated interstitial pneumonia was diagnosed in one case. Treatment was modified in nine procedures based on the results of the BAL analysis (90%).

Discussion

In this study, we found that FOB-BAL using an LMA and CPAP prevented hypoxaemic events and major complications, including tracheal intubation, and contributed to treatment modification, suggesting that this technique is safe and effective in patients with severe acute hypoxaemia and diffuse lung infiltrates. The procedure was well tolerated in all patients. This is the first study to assess the feasibility of FOB-BAL using an LMA in combination with CPAP under light sedation.

The occurrence of hypoxaemia during FOB has been reported in several studies (3, 4, 6). Such hypoxaemia may be caused by partial airway obstruction induced by the bronchoscope, airway suction, anaesthetics or presence of lavage fluid in the alveoli (4, 16). Mechanical ventilation with airway management must be performed in patients undergoing FOB-BAL to ameliorate hypoxaemia and maintain adequate gas exchange during the procedure, and tracheal intubation is the most reliable method for achieving these goals. However, various complications may occur, such as cardiovascular responses to tracheal intubation, with subsequent vocal dysfunction and/or laryngeal disorders after extubation (8, 17, 18). In the current study, the arterial blood oxygen saturation was maintained above 91% in all patients.

NPPV delivers positive pressure without the use of an artificial airway and is a safe and effective method for ameliorating hypoxaemia in patients with acute respiratory failure (19, 20). The feasibility and safety of NPPV using a full-face mask for FOB-BAL has been reported in previous studies (5, 21-28). However, in the majority of these studies, bronchoscopy was performed with only topical anaesthesia (5, 22-24, 26, 27), and essential problems included low tolerance to mask fitting and FOB-BAL in conscious patients. Patient agitation may lead to desaturation and possibly compromise the success of the FOB-BAL procedure (25). One previous study described the difficulties in performing bronchoscopy without sedation, with analgo-sedation used in all patients (14). LMAs provide upper airway patency even in cases of deep sedation or general anaesthesia, which subsequently ensures excellent visualization of the vocal cords, glottis and trachea without decreasing the airway diameter as do tracheal tubes, thus avoiding increases in airway resistance (9, 10, 29-31). In our procedure, the use of appropriate sedation and positive pressure ventilation with an LMA helped to yield diagnostic information by allowing for the recovery of a sufficient volume of bronchoalveolar lavage fluid (BALF).

It is important to minimize the cardiorespiratory response

Figure. Variation in cardiorespiratory parameters. The respiratory rate (*panel A*), heart rate (*panel B*) and mean arterial pressure (*panel B*) were recorded as follows: just before sedation (before), during fibre-optic bronchoscopy with bronchoalveolar lavage (during) and one hour after fibre-optic bronchoscopy with bronchoalveolar lavage (one hour after). The data are expressed as the mean $\pm$ standard deviation. * $p < 0.05$ for comparison with the baseline data (obtained just before sedation). The lowest value of each parameter observed during the procedure was recorded. RR: respiratory rate, HR: heart rate, MAP: mean arterial pressure

Table 2. Characteristics and Results of Fibre-optic Bronchoscopy with Bronchoalveolar Lavage

Duration of FOB-BAL (min)	20.3 $\pm$ 3.7 (17.6-30.0)
No. of FOB-BAL	10 (100%)
BAL	
Volume instilled (mL)	100
Volume recovered (mL)	56.1 $\pm$ 11.1 (48.1-64.0)
Diagnostic yield of FOB-BAL	9 (90%)

The data are presented as the mean $\pm$ standard deviation (95% confidence interval) or n (%).

FOB-BAL: fibre-optic bronchoscopy with bronchoalveolar lavage

during the procedure in severely hypoxaemic patients, and inducing coughing is critical in subjects on long-term steroid therapy. In our strategy, the application of topical anaesthesia to the oral cavity followed by the maintenance of anaesthesia using propofol and fentanyl resulted in better tolerance of FOB. The administration of propofol enables the level of sedation to be adjusted, with rapid elimination of the drug. The majority of previous studies have used this medication to both insert the LMA (15, 32) and perform FOB (9, 14, 21, 25, 33). Fentanyl is a strong analgesic and antitussive that can be employed to reduce the amount of propofol required. In general, the amount of anaesthetics or analgesics needed to establish an LMA is less than that required for tracheal intubation. Recent studies have also demonstrated the occurrence of alveolar hypoventilation, as estimated by an increase in the partial pressure of carbon dioxide, during FOB under sedation (21, 34). In our procedure, mechanical ventilation is immediately applied to maintain the appropriate minute volume if the sedatives suppress the patient's spontaneous breathing. Furthermore, the mean percentage of BALF volume recovered was higher in this report than in previous studies involving the use of NPPV-assisted FOB-BAL (21, 25, 28). Positive pressure ventilation may allow for a sufficient volume of BALF to be recovered,

thus providing diagnostic information.

Our procedure is associated with some limitations. It should be emphasized that well-trained physicians are needed to perform both bronchoscopy and anaesthesia, and the procedure should be carried out in the intensive care unit in order to allow for close monitoring. Therefore, our results may not be generalizable to other settings. In addition, this was a retrospective observational study, and the sample size was small. Although we included patients consecutively during the study period, the background characteristics of the patients were biased. Furthermore, the use of blood gas analyses under CPAP of 5 cm H₂O may reflect a higher ratio of arterial blood oxygen tension to the fraction of inspired oxygen before FOB-BAL compared to that seen in previous studies. A prospective study is therefore warranted to confirm the advantages of LMA over tracheal intubation under the same conditions.

In conclusion, the use of LMA in combination with CPAP under light sedation can be used to provide a safe and effective FOB-BAL procedure in patients with severe acute hypoxaemic respiratory failure.

The authors state that they have no Conflict of Interest (COI).

References

1. Wells AU. The clinical utility of bronchoalveolar lavage in diffuse parenchymal lung disease. *Eur Respir Rev* **19**: 237-241, 2010.
2. Facciolo N, Patelli M, Gasparini S, et al. Incidence of complications in bronchoscopy. Multicentre prospective study of 20,986 bronchoscopies. *Monaldi Arch Chest Dis* **71**: 8-14, 2009.
3. Albertini RE, Harrell JH 2nd, Kurihara N, Moser KM. Arterial hypoxemia induced by fiberoptic bronchoscopy. *JAMA* **230**: 1666-1667, 1974.
4. Matsushima Y, Jones RL, King EG, Moysa G, Alton JD. Alterations in pulmonary mechanics and gas exchange during routine fiberoptic bronchoscopy. *Chest* **86**: 184-188, 1984.

5. Antonelli M, Conti G, Rocco M, et al. Noninvasive positive-pressure ventilation vs. conventional oxygen supplementation in hypoxemic patients undergoing diagnostic bronchoscopy. *Chest* **121**: 1149-1154, 2002.
6. Lindholm CE, Ollman B, Snyder JV, Millen EG, Grenvik A. Cardiorespiratory effects of flexible fiberoptic bronchoscopy in critically ill patients. *Chest* **74**: 362-368, 1978.
7. Goldstein RA, Rohatgi PK, Bergofsky EH, et al. Clinical role of bronchoalveolar lavage in adults with pulmonary disease. *Am Rev Respir Dis* **142**: 481-486, 1990.
8. Pingleton SK. Complications of acute respiratory failure. *Am Rev Respir Dis* **137**: 1463-1493, 1988.
9. Dich-Nielsen JO, Nagel P. Flexible fibreoptic bronchoscopy via the laryngeal mask. *Acta Anaesthesiol Scand* **37**: 17-19, 1993.
10. Fadaizadeh L, Hosseini MS. Laryngeal mask airway in interventional bronchoscopy for tracheal lesions. *Acta Anaesthesiol Taiwan* **51**: 137, 2013.
11. Hickey S, Cameron AE, Asbury AJ. Cardiovascular response to insertion of Brain's laryngeal mask. *Anaesthesia* **45**: 629-633, 1990.
12. Wilson IG, Fell D, Robinson SL, Smith G. Cardiovascular responses to insertion of the laryngeal mask. *Anaesthesia* **47**: 300-302, 1992.
13. Verghese C, Brimacombe JR. Survey of laryngeal mask airway usage in 11,910 patients: safety and efficacy for conventional and nonconventional usage. *Anesth Analg* **82**: 129-133, 1996.
14. Hilbert G, Gruson D, Vargas F, et al. Bronchoscopy with bronchoalveolar lavage via the laryngeal mask airway in high-risk hypoxemic immunosuppressed patients. *Crit Care Med* **29**: 249-255, 2001.
15. Asai T, Morris S. The laryngeal mask airway: its features, effects and role. *Can J Anaesth* **41**: 930-960, 1994.
16. British Thoracic Society Bronchoscopy Guidelines Committee aSoSoCCoBTS. British Thoracic Society guidelines on diagnostic flexible bronchoscopy. *Thorax* **56** (Suppl 1): i1-i21, 2001.
17. Braude N, Clements EA, Hodges UM, Andrews BP. The pressor response and laryngeal mask insertion. A comparison with tracheal intubation. *Anaesthesia* **44**: 551-554, 1989.
18. Zimmert M, Zwirner P, Kruse E, Braun U. Effects on vocal function and incidence of laryngeal disorder when using a laryngeal mask airway in comparison with an endotracheal tube. *Eur J Anaesthesiol* **16**: 511-515, 1999.
19. Brochard L. Noninvasive ventilation for acute respiratory failure. *JAMA* **288**: 932-935, 2002.
20. Nava S, Hill N. Non-invasive ventilation in acute respiratory failure. *Lancet* **374**: 250-259, 2009.
21. Baumann HJ, Klose H, Simon M, et al. Fiber optic bronchoscopy in patients with acute hypoxemic respiratory failure requiring non-invasive ventilation--a feasibility study. *Crit Care* **15**: R179, 2011.
22. Agarwal R, Khan A, Aggarwal AN, Gupta D. Bronchoscopic lung biopsy using noninvasive ventilatory support: case series and review of literature of NIV-assisted bronchoscopy. *Respir Care* **57**: 1927-1936, 2012.
23. Antonelli M, Conti G, Riccioni L, Meduri GU. Noninvasive positive-pressure ventilation via face mask during bronchoscopy with BAL in high-risk hypoxemic patients. *Chest* **110**: 724-728, 1996.
24. Antonelli M, Pennisi MA, Conti G, et al. Fiberoptic bronchoscopy during noninvasive positive pressure ventilation delivered by helmet. *Intensive Care Med* **29**: 126-129, 2003.
25. Clouzeau B, Bui HN, Guilhon E, et al. Fiberoptic bronchoscopy under noninvasive ventilation and propofol target-controlled infusion in hypoxemic patients. *Intensive Care Med* **37**: 1969-1975, 2011.
26. Da Conceicao M, Genco G, Favier JC, Bidallier I, Pitti R. [Fiberoptic bronchoscopy during noninvasive positive-pressure ventilation in patients with chronic obstructive lung disease with hypoxemia and hypercapnia]. *Ann Fr Anesth Reanim* **19**: 231-236, 2000.
27. Heunks LM, de Bruin CJ, van der Hoeven JG, van der Heijden HF. Non-invasive mechanical ventilation for diagnostic bronchoscopy using a new face mask: an observational feasibility study. *Intensive Care Med* **36**: 143-147, 2010.
28. Maitre B, Jaber S, Maggiore SM, et al. Continuous positive airway pressure during fiberoptic bronchoscopy in hypoxemic patients. A randomized double-blind study using a new device. *Am J Respir Crit Care Med* **162**: 1063-1067, 2000.
29. Birmingham B, Mentzer SJ, Body SC. Laryngeal mask airway for therapeutic fiberoptic bronchoscopic procedures. *J Cardiothorac Vasc Anesth* **10**: 519-520, 1996.
30. Brimacombe J. The advantages of the LMA over the tracheal tube or facemask: a meta-analysis. *Can J Anaesth* **42**: 1017-1023, 1995.
31. Brimacombe J, Tucker P, Simons S. The laryngeal mask airway for awake diagnostic bronchoscopy. A retrospective study of 200 consecutive patients. *Eur J Anaesthesiol* **12**: 357-361, 1995.
32. Brown GW, Patel N, Ellis FR. Comparison of propofol and thiopentone for laryngeal mask insertion. *Anaesthesia* **46**: 771-772, 1991.
33. Grendelmeier P, Tamm M, Pflimlin E, Stolz D. Propofol sedation for flexible bronchoscopy: randomized, non-inferiority trial. *Eur Respir J* **43**: 591-601, 2014.
34. Dreher M, Ekkernkamp E, Storre JH, Kabitz HJ, Windisch W. Sedation during flexible bronchoscopy in patients with pre-existing respiratory failure: Midazolam versus Midazolam plus Alfentanil. *Respiration* **79**: 307-314, 2010.