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Continuous Monitoring of Arterial Blood Gas during Bronchopulmonary Lavage for Pulmonary Alveolar Proteinosis

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Abstract

Pulmonary proteinosis is a rare lung disorder in which an amorphous proteinaceous material is deposited in alveoli and bronchioli. Bronchopulmonary lavage (BPL) is the only successful treatment. We had a case with pulmonary proteinosis scheduled for BPL under general anesthesia.

Anesthesia was induced with fentanyl and thiamylal. The trachea was intubated with a double lumen tube following vecuronium. Anesthesia was maintained with sevoflurane in oxygen. An arterial cannula with a sensor tip, a pulmonary artery catheter and a pulse oximeter were placed to monitor arterial blood pH, Pa_{O_2}, Pa_{CO_2}, mixed venous oxygen saturation ($S\bar{v}_{O_2}$), pulse oxymetry (S_{PO_2}), arterial blood pressure, pulmonary and central venous pressure and cardiac index continuously. Physiological saline was infused into the washing lung by a pressure of 30 cmH_2O and drained by -60 cmH_2O. After BPL, mechanical ventilation was continued for 18 hours. Right and left ventricular stroke work indices (RVSWI and LVSWI), systemic and pulmonary vascular resistance indices (SVRI, PVRI), oxygen delivery index ($D_{O_2}I$), oxygen consumption ($\dot{V}_{O_2}$), alveolar to arterial oxygen tension difference (DAa_{O_2}), alveolar to arterial blood oxygen tension difference (Cav_{O_2}) and intrapulmonary shunt (Qs/Qt) were calculated.

PAP, CVP, Pa_{O_2}, S_{PO_2}, and $S\bar{v}_{O_2}$ increased by the instillation of fluid while they were vice versa by the drainage. During the instillation, the increased intra-alveolar pressure caused the diversion of pulmonary blood flow to the ventilated lung. Drainage reversed these changes. Pa_{O_2}, S_{PO_2} and $S\bar{v}_{O_2}$ indicate blood oxygenation. The change of Pa_{O_2} is the quickest and most among them. Because arterial oxygenation changes quickly during BPL, the placement of an arterial cannula with a continuous blood gas analysis sensor is useful.

Key words : Continuous arterial blood gas analysis, Bronchopulmonary lavage, Unilateral whole lung lavage, Pulmonary proteinosis.

Introduction

Pulmonary alveolar proteinosis, which is characterized by the progessive accumulation of lipid, protein, and cellular debris in alveolar spaces, could show the symptom of impaired gas exchange[1]. This is dependent on the deficiency in cleaning of cellular debris and the byproducts of alveolar metabolism and secondary infection[2~4]. If the patients with pulmonary alveolar proteinosis failed to respond to inhalational aerosol such as trypsin, bronchopulmonary lavage

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(BPL) that could remove alveolar materials in a part or entire lung is the choice of treatment[2, 5~10].

BPL procedure requires general anesthesia and one lung ventilation to separate the washed and non-washed lung. The infusion of large amount of saline can be associated with siginificant changes of hemodynamics and arterial oxygenation. During BPL, hemodynamics has been assessed by continuous monitoring of central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP), and cardiac output (CO) but arterial oxygenation has been evaluated by intermittent analysis of arterial blood gas and continuous noninvasive measurement of arterial oxygen saturation using pulse oxymetry. Hypoxia is the most serious complication associated with BPL[11].

Continuous intra-arterial blood gas monitroring could have potencial advantages in clinical situation over intermittent measurements during anesthesia and in the Intensive Care Unit (ICU)[12~15]. Availability of continuous data could offer useful information for an immediate therapeutic decision that is necessary in critical situation such as BPL procedure in the patients with pulmonary alveolar proteinosis[15]. In this study, we evaluated the usefulness of continuous intra-arterial blood gas monitoring compared to arterial oxygen saturation using pulse oxymetry in BPL procedure for pulmonary alveolar proreinosis.

Case Report

A 40-year old male chiefly complained of dry cough and became progessively short of breath for these two months. He has been medicated chlorpromazine 500 mg, haloperidol 20 mg, fluphenazine 20 mg, perphenazine 15 mg, sulpiride 1200 mg, sultopride 1800 mg, timiperone 12 mg, biperiden 6 mg, trihexyphenidyl 6 mg, levomepromazine 50 mg, nitrazepam 10 mg, estazolam 5 mg, sennosides 24 mg and pantethine 600 mg for schiz-ophrenia for recent 12 years. After establishing the diagnosis of pulmonary alveolar proteinosis by transpulmonary lung biopsy, four unilateral whole-lung lavages under general anesthesia at a week interval were scheduled. On the preoperative evaluation, he clearly recognized his present condition and agreed to undergo BPL procedure to improve his symptoms. Chest examination revealed normal diaphragmatic excursion but slight fine rales at basilar and axillary region. Reduction of% vital capacity (75%) and the first second forced expiratry volume (77.2%) might reflect the decrease of Pa_{O_2} (61.9 mmHg) at room air. There was a remarkable reduction in the diffusing capacity.

Anesthesia course

Premedication consisted of brotizolam 0.25 mg and ranitidine 150 mg orally 90 min before induction of anesthsia. General anesthsia was induced with intravenous (i.v.) thiamylal 4 $mg \cdot kg^{-1}$ and i.v. fentanyl 100 μg. After i.v. vecuronium 1.2 $mg \cdot kg^{-1}$, his trachea was intubated with a 39F left-sided double lumen endobronchial tube (Broncho-Cath ®, Mallinckrodt Anesthesia Products, St. Louis, MO). The correct position of the tube was confirmed by fiberoptic bronchoscopy. Anesthesia was maintained with isoflurane 1 MAC combined with supplementary i.v. fentanyl. We placed a thin fiberoptic sensor tip (FOxS®, Puritan-Bennett Corp., Carlsbad, CA, USA) through the radial artery for continuous monitoring of arterial blood pressure and arterial gas (PB3300 IABG monitor®, Puritann-Bennett Corp., Carlsbad, CA, USA). Then a pulmonary artrey catheter (Edwards Swan-Ganz CCO/$S\bar{v}O_2$ thermodilution catheter®, Baxter Health Care Corp., Irvine, CA, USA) was placed through the right internal jugular vein to monitor central venous pressure (CVP), pulmonary artery pressure (PAP), mixed venous oxygen saturation ($S\bar{v}O_2$) and cardiac output (CO) continuously (Vigilance®, Baxter Health Care Corp., Irvine, CA, USA)[16]. Cardiac index (CI), right and left ventricular stroke work indices (RVSWI and LVSWI), systemic and pulmonary vascular resistance indices (SVRI, PVRI), oxygen delivery index ($D_{O_2}I$), oxygen consumption ($\dot{V}_{O_2}$), alveolar to arterial oxygen tension difference (DAa_{O_2}), alveolar to arterial blood oxygen tension difference (Cav_{O_2}) and intrapulmonary shunt (Qs/Qt) were calculated by a built-in computor.

After mechanical ventilation under F_{IO_2} 1.0 and a fresh gas flow of 4 $l \cdot min^{-1}$ for 15 min to wash out nitrogen in lungs, the orifice of the double lumen tube

to the lavage-side was clamped[6,17]. During one lung ventilation, we kept the airway pressure less than 30 mmHg adjusting tidal volume, ventilation frequency and inspiratory-expiratory phase time ratio to avoid barotrauma. After confirming the lavage-side lung to be collapsed by chest X-ray, one lung was filled up with maximum of 1.8 liters of normal saline, which was infused by gravity from the position 30 cm above the patient's midaxillary line. When no fluid flowed into the lung, the lung was drained by gravity to 60cm below the midaxillary line[5~7,17]. Mechanical percussion was applied during filling and drainage phases. This process was repeated 7 to 18 times in the right and 5 to 7 times in the left lung, respectively. About 94% of the total infused fluid was drained.

After completion of the procedure, both lungs were re-expanded[5~7,17]. The patient was transfered to the ICU with a single lumen endtracheal tube in place and ventilated with PEEP[5]. The patient's trachea was extubated after 18 hours in the ICU. Continuous arterial blood gas monitoring was continued till extubation.

The changes of Pa_{O_2}, Pa_{CO_2}, S_{PO_2}, $S\bar{v}_{O_2}$, Cav_{O_2}, $\dot{V}_{O_2}$ and DAa_{O_2} during BPL were shown in table 1. The changes of HR, mAP, mPAP, CVP, CI, LVSWI, RVSWI, SVRI, and PVRI during BPL were shown in table 2. Typical respiratory and hemodynamical changes during the left lung lavage were shown in figures 1-4.

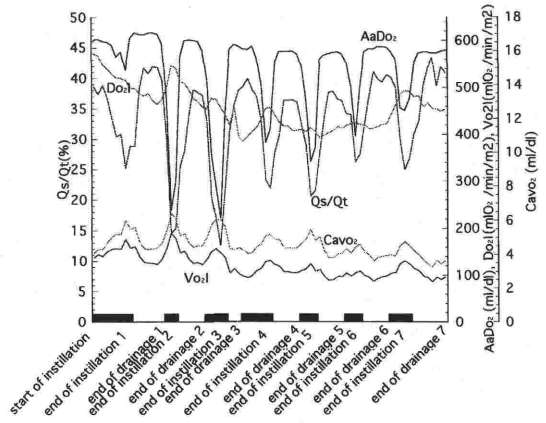

Fig. 2 Typical changes of respiratory function during bronchopulmonary lavage.

Qs/Qt = intrapulmonary shunt, DAa_{O_2} = alveolar to arterial oxygen tension difference, Do_2I = oxygen delivery index, Vo_2I = oxygen consumption index, Cav_{O_2} = arterial to mixed venous oxygen content difference

■= instillation phase.

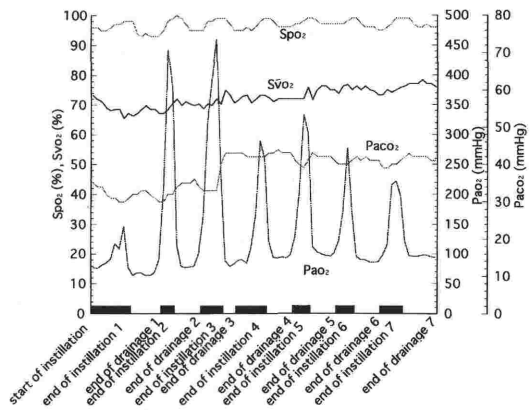

Fig. 1 Typical changes of blood gas analysis during bronchopulmonary lavage.

Pa_{O_2}=arterial oxygen tension, Pa_{CO_2}=arterial carbon dioxide tension, S_{PO_2}=pulse oxymetry, $S\bar{v}_{O_2}$=mixed venous oxygen saturation

■= instillation phase.

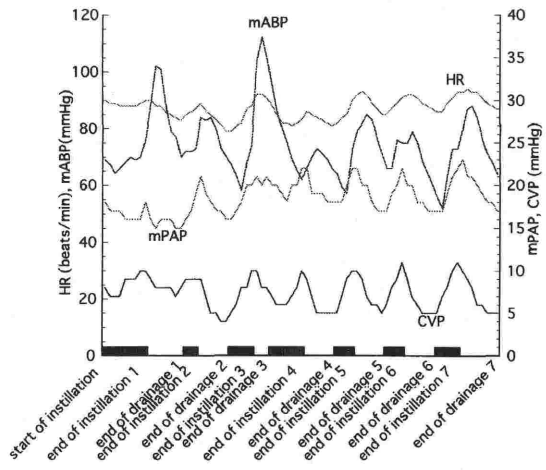

Fig. 3 Typical changes of hemodynamics during bronchopulmonary lavage.

HR = heart rate, mABP = mean arterial blood pressure, mPAP = mean pulmonary arterial blood pressure, CVP = central venous pressure

■= instillation phase.

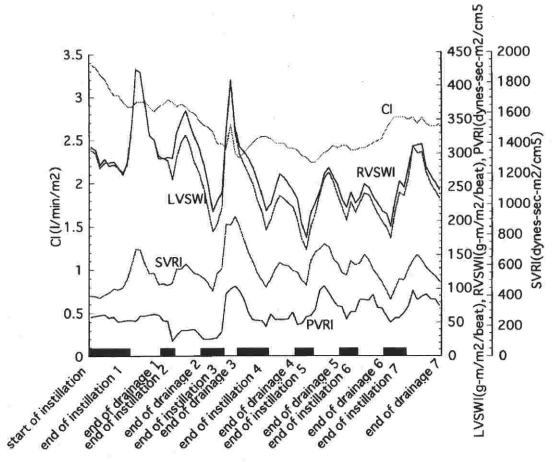

Fig. 4 Typical changes of cardiac function during bronchopulmonary lavage.

CI = cardiac index, LVSWI = left ventricular stroke work index, RVSWI = right ventricular stroke work index, PVRI = pulmonary vascular resistance index, SVRI = systemic vascular resistance index

■= instillation phase.

Discussion

Intermittent cardiovascular and respiratory monitoring associated with BPL were well documented[5,8,18~19]. The repeated changes in BPL are that Pa_{O_2} increases during the infusion phase and abruptly decreases during the drainage phase. These changes were clearly and continuously observed in our case.

These changes are resulted from the change of intrathoracic pressure. The fluid instillation results in not only the alveolar expansion but also the collapse of pulmonary arteries and capillaries in the washing lung. The collapse of pulmonary arteries and capillaries causes the increase of PAP. The alveolar expansion induces the mediastinal shift from fluid-filled lung[6,7]. The squeezed blood from the washing lung initially increases venous return. Then PAP increases as the instillation fluid fills the washing lung. Finally, the squeezed vessels and mediastinal shift provoke the reduction of RVSWI and LVSWI[5~7,20]. This situation frequently accompnied with the reduction of mABP and HR. More blood flows into the ventilated lung because of the collapsed pulmonary blood vessels in the washing lungs. This moves the ventilation-perfusion ratio toward 1.0 and results in reduction of Qs/Qt and increases in Pa_{O_2} and Sp_{O_2}[5,7]. The elevation of Pa_{O_2} may increase Cav_{O_2} followed by increased $\dot{V}_{O_2}$ because the patient is metabolically stable under general anesthesia[5]. The drainage phase shows a reverse effect. As fluid drained, mPAP and CVP decrease. The blood perfuses dilated capillary bed in the washing lung[7]. This could decreases venous return, PAP, CVP, RVSWI, and LVSWI and Qs/Qt increases[6]. The reduction of CI and the ventilation-perfusion ratio results in decreases of Pa_{O_2}, Sp_{O_2}, Cav_{O_2} and $\dot{V}_{O_2}$. The changes of mPAP and CVP produce the same directional changes of SVRI and PVRI. But these changes of mPAP and CVP are mainly affected by the intrathoracic pressure with filling and emptying lungs with fluid instead of air. They are not reflecting ventricular volume and these SVRI and PVRI may not indicate vascular resistance[21~23].

All the changes in respiration and hemodynamics depend on how much instilled saline is in the washing lung and it means they depend on the intra-alveolar pressure. One liter of instilled fluid is almost the half of full dose of it and the values of mABP, mPAP, CVP, CI, Pa_{O_2}, $S\bar{v}_{O_2}$ and Qs/Qt at 1 liter instillation are about the median of the values between at the end of drainage and at the end of instillation. This may suggest that the relationship between Pa_{O_2}, $S\bar{v}_{O_2}$, Qs/Qt and intra-alveolar pressure is linear.

$S\bar{v}_{O_2}$ monitoring requires the placement of a pulmonary artery catheter. The pulmonary artery catheter gives pulmonary hemodynamic data other than $S\bar{v}_{O_2}$ but they are not essential during BPL. Although Sp_{O_2} is non-invasive, Sp_{O_2} can not detect a sudden Pa_{O_2} decrease accurately and promptly because of the sigmoid shape of oxygen-dissociation curve. Our results indicate that Pa_{O_2} changed quicker and more than Sp_{O_2} and $S\bar{v}_{O_2}$. An early detection of hypoxemia and its treatment are important for prevention of hypoxemic damages to vital organs during BPL. Although continuous monitoring of Pa_{O_2} is invasive, the catheter is worth placing in the radial artery during BPL.

In conclusion, we evaluated the usefulness of continuous arterial blood gas monitoring during bronc-

hopulmonary lavage in a patient with pulmonary alveolar proteinosis. We also examined cardiovascular changes associated with this procedure. Respiratory and hemodynamic changes depend on the quantity of lavage fluid in the washing lung. And continuous blood gas monitoring is the quick and accurate way to know arterial oxygenation of the patient during BPL.

References

1) Rosen SH, Castleman B, Liebow AA, et al : Pulmonary alveolar proteinosis. N Eng J Med 258 : 1123-1142, 1958
2) Wasserman K, Blank N, Fletcher G : Lung lavage (alveolar washing) in alveolar proteinosis. Am J Med 44 : 611-617, 1968
3) Ramirez RJ : Bronchopulmonary lavage, new techniques and observations. Dis Chest 50 : 581-588, 1966
4) Kawakami M : Pulmonary alveolar proteinosis, clinical features and some findings relating to sex differences. Hai to Shin 39 : 68-74 (abstract in English)
5) Blenkarn GD, Lanning CF, Kylstra JA : Anesthetic management of volume controlled unilateral lung lavage. Canad Anaesth Soc J 22 : 154-163, 1975
6) Lippmann M, Mok MS : Anesthetic Management of pulmonary lavage in adults. Anesth Analg 56 : 661-668, 1977
7) Smith JD, Millen JE, Safar P, et al : Intrathoracic pressure, pulmonary vascular pressures and gas exchange during pulmonary lavage. Anesthesiology 33 : 401-405, 1970
8) Rogers RM, Levin DC, Gray BA, et al : Physiologic effects of bronchopulmonary lavage in alveolar proteinosis. Am Rev Respir Dis 118 : 255-264, 1978
9) Selecky PA, Wasserman K, Benfield JR, et al : The clinical physiological effect of whole-lung lavage in pulmonary alveolar proteinosis: a ten-year experience. Ann Thorac Surg 24 : 451-461, 1977
10) Kao D, Wasserman K, Costley D, et al : Advances in the treatment of pulmonary alveolar proteinosis. Am Rev Respir Dis 111 : 361-363, 1975
11) Benumof JL, Alfery DD : Anesthesia for thoracic surgery, anesthesia 4th edition. edited by Miller RD, New York, Churchill Livingstone, 1986, pp.1380-1419
12) Wahr JA, Tremper KK : Continuous intravascular blood gas monitoring. J Cardiothorac Vasc Anesth : 342-353, 1994
13) Venkatesh B, Hendry SP : Continuous intra-arterial blood gas monitoring. Intensive Care Med 22 : 818-828, 1996
14) Roupie EE, Brochard L, Lemaire FJ : Clinical evaluation of a continuous inra-arterial blood gas system in critically ill patients. Intensive Care Med 22 : 1162-1168, 1996
15) Bohrer H, Schmidt H, Amann R, et al : Superiority of continuous intra-arterial blood gas monitoring over pulse oxymetry with acute respiratory failure. Anaesthesia 496 : 551, 1994
16) Okada K, Kinoshita Y, Iwasaki H, et al : Evaluation of monitoring during lung lavage. Jpn J Anesthesiol 37 : 727-730, 1988 (abstract in English)
17) Ramirez RJ: Alveolar Proteinosis : Importance of pulmonary lavage. Amer Rev Resp Dis 103 : 666-678, 1971
18) Kobayashi T, Nakanishi T, Kishizuchi S, Murakami S : A case of alveolar proteinosis change in blood gases by pulmonary lavage. Jpn J Anesthesiol 27 : 43-47, 1978 (abstract in English)
19) Goto Y, Akashi M, Ishikawa K, et al : Clinical studies on the classification of techniques and efficiency of whole-lung lavage. Jpn J Anesthesiol 31 : 19-28, 1982 (abstract in English)
20) Busque : Pulmonary lavage in the treatment of alveolar proteinosis. Can Anaesth Soc J 42 : 380-389, 1977
21) Swenson JD, Astle KL, Bailey PL : Reduction in left ventricular filling during bronchopulmonary lavage demonstrated by transesophageal echocardiography. Anesth Analg 81 : 634-637, 1995
22) Hansen RM, Viquerat CE, Mathay MA, et al : Poor correlation between pulmonary arterial wedge pressure and left ventricular end-diastolic volume after coronary artery bypass graft surgery. Anesthesiology 64 : 764-770, 1986
23) O'Quin R, Marini JJ : Pulmonary artery occlusion pressure:clinical physiology, measurement and interpretation. Am Rev Respir Dis 128 : 319-326, 1983

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