Pulmonary Perfusion Using Intrabronchial Capnography in Pulmonary Artery Stenosis

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Established Facts

- In patients with severe bronchial stenosis, impaired gas exchange can occur due to a ventilation-perfusion mismatch.

Novel Insights

- Intrabronchial capnography can predict whether stent implantation will improve the perfusion-ventilation status in patients with bilateral bronchial stenosis.
- This case demonstrates both clinically and physiologically the importance of intrabronchial capnography for assessing the outcome of stenting.

Keywords

Bronchial stenosis · Dead-space ventilation · End-tidal carbon dioxide concentration · Regional perfusion status · Ventilation-perfusion mismatch

Abstract

Stenting at the flow-limiting segment can improve the ventilation-perfusion ratio in patients with central airway stenosis. However, there is no quantitative examination for assessing the perfusion status during interventional bronchoscopy. Intrabronchial capnography can estimate regional gas exchange by measuring carbon dioxide concentration. We herein report a case of bilateral bronchial stenosis where

stenting was able to improve ventilation-perfusion ratio using intrabronchial capnography. A 44-year-old man was admitted to our institution with orthopnea. Chest computed tomography showed an extrinsic compression at the bilateral main bronchus and right pulmonary artery due to a mediastinal mass. After introduction of general anesthesia, arterial oxygen tension suddenly decreased in the supine position. After initial stenting, an increase was seen in ventilation at the right lung; however, a ventilation-perfusion mismatch occurred due to an increase in dead-space ventilation at the right pulmonary artery stenosis. Intrabronchial capnography was an effective modality to confirm the regional perfusion status during interventional bronchoscopy in real time.

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Introduction

In patients with severe malignant airway stenosis, interventional bronchoscopy is considered as a method of maintaining airway patency [1]. The positioning of the stent at the flow-limiting segment provides the greatest functional benefit to patients with central airway stenosis [2–4], due to an improvement in the ventilation-perfusion ratio. However, an increase in ventilation within an obstructed lung can fail to result in any improvements in gas exchange if recanalization is not accompanied by an increase in arterial pulmonary blood flow, such as pulmonary artery stenosis and pulmonary thromboembolism.

In patients with severe bronchial stenosis, impaired gas exchange can occur due to a ventilation-perfusion mismatch. The assessment of perfusion status is able to assist in selecting the site for stenting. We herein report a case of bilateral bronchial stenosis where oxygenation was not relieved after initial stenting because of a pulmonary artery stenosis.

Case Report

A 44-year-old man without any notable past or familial history, presenting with epigastralgia and backache was admitted to a previous hospital. The patient was referred to our institution due to the presence of a bilateral main stem bronchial stenosis. Vital signs were considered normal on admission, but his condition devolved into orthopnea. Auscultation of the chest demonstrated an absence of respiratory sounds at the left lung. Chest computed tomography (CT) scan visualized an extrinsic compression at the bilateral main bronchus and right side pulmonary artery due to a mediastinal mass (Fig. 1a). On admission, emergency interventional bronchoscopy was conducted. After administration of general anesthesia, percutaneous arterial oxygen saturation by pulse oximetry (SpO_2) decreased from 96 to 60% in the supine position. He was ventilated manually with bag-valve-mask ventilation, but oxygenation was unsuccessful. After intubation, a spiral Z stent (Medico's Hirata Inc., Osaka, Japan; length 40 mm, diameter 12 mm) was immediately inserted into the right main stem bronchus, but oxygenation did not improve. A second stent (Medico's Hirata Inc., Osaka, Japan; length 80 mm, diameter 18/12 mm) was added from the trachea to the left main stem bronchus and SpO_2 increased to 100%. Bronchial patency was maintained after the procedure. We sub-

Fig. 1. **a** Chest CT before interventional bronchoscopy shows an extrinsic compression of the pulmonary artery due to a mediastinal mass. **b** Contrast CT scan shows thrombi at the right pulmonary arteries 1 day after interventional bronchoscopy (arrows).

Fig. 2. Intrabronchial capnography after stenting. The end-tidal carbon dioxide concentration (EtCO_2) was lower on the right side (**a**) than the left (**b**). The ripple shape during the expiratory phase shows cardiogenic oscillations.

sequently measured carbon dioxide (CO₂) concentration at the right and left main bronchus using intrabronchial capnography. The CO₂ sampling tube was advanced through the working channel of the bronchoscope into each main bronchus collecting inspired and expired gas continuously. The CO₂ concentration curve was recorded during spontaneous breathing. The end-tidal carbon dioxide concentration (EtCO₂) was lower at the right-side lung (Fig. 2a, b). Due to unstable hemodynamic status, he was put on a respirator. Although his D-dimer level was negative before the procedure, this level increased to 20.1 µg/mL 1 day after the procedure, and a subsequent contrast CT scan showed thrombi in the right pulmonary arteries (Fig 1b). Further, the right-side pulmonary perfusion decreased on perfusion scintigraphy. The patient was diagnosed with pulmonary thromboembolism and was administered a continuous infusion of heparin. After 7 days, the patients' oxygenation improved, and a second contrast CT scan showed an absence of thrombus in the right pulmonary arteries. Extubation was successfully performed and he was diagnosed with stage IV lung squamous cell carcinoma (T4N3M1b). Docetaxel plus carboplatin chemotherapy was selected as a first-line therapy. The patient was treated with radiotherapy at a dose of 66.6 Gy.

Discussion

To our knowledge, this is the first case to assess the changes in ventilation and perfusion status by intrabronchial capnography during stenting. For most cases, stent implantation leads to a substantial improvement of the bronchial stenosis and an immediate relief of dyspnea. In this case, initial stenting at the right main stem bronchus did not result in an increase in arterial oxygen tension. We considered that an increase in ventilation for the right lung results in a failure to improve the ventilation-perfusion ratio because of an increase in dead-space ventilation due to right pulmonary artery stenosis. Intrabronchial capnography is able to predict whether stent implantation can improve the perfusion-ventilation status in patients with bilateral bronchial stenosis.

The physiological assessment of the flow-limiting segment is an important indicator to estimate the outcome [2–4]. To date, however, there is no quantitative examination for assessing the perfusion status during interventional bronchoscopy. Hauck et al. [5] investigated whether an improvement in ventilatory status was paralleled by an increase in blood flow and gas exchange. They reported that stenting leads to an increase in bronchial patency and in the distribution of both ventilation and perfusion status at the affected lung in patients with bronchial obstruction. However, ventilation-perfusion scintigraphy cannot be performed during interventional bronchoscopy.

In this case, we were unable to perform perfusion scintigraphy before stenting because of orthopnea. D-dimer levels in the blood were negative and a contrast-enhanced CT revealed no thrombus in either right or left pulmonary arteries at admission. Therefore, we considered that the right pulmonary artery stenosis led to a decrease in blood flow and a decrease in EtCO₂ at the right side after stenting. The main mechanism of hypoxemia in pulmonary artery obstruction is V/Q mismatch, as well as pulmonary embolism [6]. V/Q mismatch occurs due to redistribution of blood from occluded pulmonary arteries to the non-occluded vessels. This results in extremely high V/Q units in the occluded areas and low V/Q units in the non-occluded regions due to overperfusion [7]. On the occluded side, high V/Q ratios produce a dead space-like effect [8] and removal of CO₂ is low.

Patients with malignant pulmonary artery obstruction showed marked right ventricular stress, hence the urgent indication for therapy because of right-side heart failure. Pulmonary artery stenting has been reported in the management of pulmonary artery compression due to other mediastinal malignant tumors [9–11]. However, in this case, pulmonary artery stenting was not necessary since there were no signs of heart failure.

Previously, intrabronchial capnography was applied to patients with lung cancer to investigate the effects of lobectomy on regional lung function [12]. Yoshimasu et al. [12] reported that intrabronchial capnography was useful for assessing the ventilation and perfusion of individual lobes as single units. Furthermore, new bronchoscopic methods for real-time gas exchange assessment of lobes and lung segments have been reported [13]. Freitag et al. [13] showed that local endocapnometry and endoximetry curves can allow for a better identification of target zones for endoscopic emphysema treatments and for the improvement of ventilation strategies for patients on respiratory support. In our current report, we only assessed the perfusion status after stenting, since oxygenation worsened after the initial stent placement. In the future, we would like to utilize perfusion status assessment to predict the outcome of the stenting procedure by intrabronchial capnography.

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