Biphasic Cuirass Ventilation During Anesthesia for Tracheobronchial Stent Insertion or Removal by a Rigid Bronchoscope: A Case Report

Hideaki Mori, MD, Atsuko Shono, MD, Hirade Ritsuko, MD, Tetsuro Nikai, MD, PhD,
AQ1 and Yoji Saito, MD, PhD

Airway management and ventilation during a tracheobronchial stenting procedure are challenging given that mandatory positive pressure ventilation cannot be fully achieved while using a rigid bronchoscope due to leakage from the scope tip. Biphasic cuirass ventilation is a negative pressure ventilation method using an external cuirass fitted to the anterior chest, which could assist in spontaneous breathing and ventilation support. We report 3 successful anesthesia cases in which we could maintain adequate ventilation and oxygenation, supported by biphasic cuirass ventilation, in patients undergoing tracheobronchial stent placement or removal procedures using rigid bronchoscopy. (A&A Case Reports. 2017;XXX:00–00.)

Placement of a bronchial stent has become widely used for symptomatic inoperable tracheobronchial stenosis. Airway management and ventilation, during the procedure, are challenging given that mandatory positive pressure ventilation cannot be fully achieved while using a rigid bronchoscope due to leakage from the scope tip. Therefore, spontaneous breathing is preferred to avoid hypoventilation leading to hypoxia. Moreover, sufficient anesthesia to prevent a cough reflex during stimulation of the rigid bronchoscope is required, which may suppress spontaneous breathing and impair oxygenation. Maintaining an adequate depth of anesthesia while preserving spontaneous breathing is difficult, thus, it has been discussed widely within the literature. Some articles have reported successful use of extracorporeal membrane oxygenation (ECMO)[1–3]; however, tracheorrhagia is of major concern when heparin is administered to achieve anticoagulation.

Biphasic cuirass ventilation (BCV) is a negative pressure ventilation (NPV) method, which works using an external cuirass fitted to the anterior chest. Theoretically, BCV could assist in spontaneous breathing and support ventilation by enabling negative pressure in the inspiratory phase to actively move the diaphragm downward and positive pressure in the expiratory phase to push air back out of the lungs.

No clinical case reports or reviews have reported the usefulness of BCV in assisting spontaneous breathing during tracheal procedures. Thus, we report 3 successful anesthesia cases in which we maintained adequate ventilation and oxygenation, supported by BCV, in patients undergoing tracheobronchial stent placement or removal using rigid bronchoscopy.

From the Department of Anesthesiology, Shimane University Hospital, Izumo, Shimane, Japan.

Accepted for publication September 11, 2017.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (www.cases-anesthesia-analgesia.org).

Funding: None.

The authors declare no conflicts of interest.

Address correspondence to Atsuko Shono, MD, Department of Anesthesiology, Shimane University Hospital, 89-1 Enya-Cho, Izumo City, Shimane, 693–8501, Japan. Address e-mail to atsuko929shono@yahoo.co.jp.

DOI: 10.1213/XAA.0000000000000660

Consent for Publication

Written consent was obtained from all patients for the publication of this case report.

CASE DESCRIPTION

Case 1

A 46-year-old man, 160 cm, 48 kg, complained of dyspnea and exhibited obstructed breathing. He had severe stenosis of the trachea, due to compression by metastatic mediastinal cancer posterior to the trachea, secondary to right upper lung adenocarcinoma. Computed tomography showed a mediastinal mass compressing the carina of the trachea, with formation of a fistula between the esophagus, mediastinum, and right lung (Figure 1). Tracheal stenosis F1 and excessive secretions resulted in near-suffocation, rendering it impossible for him to lie flat. Physical examination revealed a blood pressure of 92/61 mm Hg, heart rate of 100 beats per minute, respiratory rate of 10 breaths per minute, and hemoglobin oxygen saturation (Spo_2) of 98%. Oxygen therapy was administered by nasal cannula at 2 L/min. Arterial blood gas (on 2 L/min oxygen) revealed a pH of 7.47, partial carbon dioxide pressure of 39.1 mm Hg, and a partial oxygen pressure of 113.5 mm Hg.

Insertion of a Silicon Y-shaped tracheal bronchial stent was planned. The procedure consisted of 4 steps: (1) insertion of a flexible bronchoscope over the larynx to observe the stenotic and fistula sites, (2) radiographic examination and insertion of a flexible bronchoscope to ascertain the correct position for stent placement, (3) expansion of stenotic site by balloon, and (4) insertion of Y-stent using a rigid bronchoscope.

General anesthesia was carefully induced with propofol at a target concentration of 1.0 µg/mL and 50 µg fentanyl. No muscle relaxant was used, and spontaneous ventilation was maintained. ECMO sheaths were inserted into bilateral femoral veins, as a precaution in the event of oxygenation failure. An external cuirass ventilator (Hayek RTX; United Hayek Industries, London, United Kingdom) (Figure 2) was applied F2 to the anterior thorax to support spontaneous breathing. The

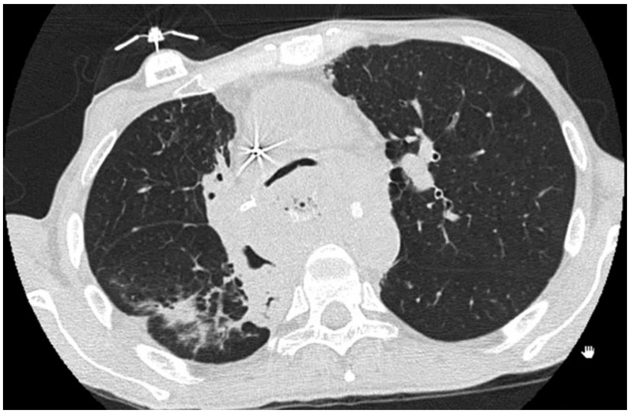

Figure 1. Preoperative chest computed tomography shows that the trachea was compressed by a tumor.

Figure 2. Hayek RTX, including power unit and cuirass, attached to an intubated patient (not included in our cases) in the intensive care unit.

BCV was set at "control mode" using 2 pressures, negative inspiratory pressure −21 cmH_2O and positive expiratory pressure +7 cmH_2O, and respiratory rate was set at 15 breaths per minute. After initiation of BCV, the patient's breathing cycle began to synchronize with the respiratory cycle of the cuirass ventilator. When the rigid bronchoscope was inserted into the trachea (Supplemental Digital Content, Video 1, http://links.lww.com/AACR/A139), we increased target concentrations of propofol and administered additional fentanyl to prevent noxious stimulus response, such as coughing or involuntary body movement. Despite profound anesthesia resulting in transient suppression of spontaneous breathing, Spo_2 was maintained and no critical desaturation occurred. Arterial blood gas analysis revealed a pH of 7.49, partial oxygen pressure of 76.9 mm Hg, and partial carbon dioxide pressure of 45.7 mm Hg during surgery. Although the patient required propofol at a target concentration of 3–3.5 µg/mL and 500 µg total fentanyl to maintain adequate depth of anesthesia, ventilation did not deteriorate and the procedure was accomplished without ECMO support.

Case 2

A 63-year-old man with undifferentiated lung carcinoma, with an I-shaped tracheal stent implanted, was scheduled for replacement with a Y-stent, due to recurrence of tracheal stenosis caused by progressive granuloma and a tumor advancing into the left main bronchus, over the I-stent. After induction of general anesthesia with propofol and fentanyl, BCV was initiated according to the procedures described in case 1. While this procedure was lengthy (215 minutes), and a high anesthetic dose was required to maintain adequate anesthesia (fentanyl, 500 µg; propofol, 1100 mg total), Spo_2 was stable throughout, and no complications occurred.

Case 3

A 32-year-old man, with stenting due to left bronchial stenosis caused by tuberculosis scarring 6 years ago, had dyspnea caused by granulation tissue at the distal end of the stent. We planned removal of the stent and ablation of the scar. After induction of anesthesia with propofol and fentanyl, BCV was initiated according to the procedures described in case 1. Though desaturation caused by ablation was a concern due to oxygen consumption in the airway, Spo_2 was maintained at >87% under BCV while blowing 40% oxygen from the inlet of the rigid bronchoscope during ablation.

DISCUSSION

In the described cases, BCV was useful for assisting spontaneous breathing during tracheobronchial stenting procedures, where positive pressure ventilation was almost impossible. Neither severe respiratory acidosis nor hypoxemia was observed. The operations were successfully completed without ECMO.

In tracheal stenting, there would be the moment that positive pressure ventilation cannot be provided adequately, due to leakage of inspired gases while using a rigid bronchoscope requiring spontaneous breathing preservation. However, if anesthesia depth is insufficient to prevent adverse reflexes, such as coughing and involuntary body movement, the procedure must be suspended temporarily. Additionally, laryngospasm could be triggered by a thick rigid bronchoscope, leading to oxygenation deterioration. Conversely, profound anesthesia would suppress the respiration response and weaken spontaneous breathing, resulting in hypoventilation and possible respiratory failure. Thus, controlling and maintaining optimal anesthesia depth during such procedures is challenging.

Techniques to maintain oxygenation during tracheobronchial stenting, such as high-frequency ventilation[4] or ECMO,[1–3] have been reported. However, these methods have disadvantages. High-frequency ventilation using a catheter connected to a ventilatory port equipped with a rigid bronchoscope is well documented; however, it can lead to severe and even fatal complications, such as barotrauma, pneumothorax, pneumomediastinum, or circulatory collapse. ECMO is also associated with severe complications,[5] including bleeding, acute neurologic complications, and leg ischemia. Bleeding, in particular during surgery, leads to airway manipulation mistakes and additional complications. In our hospital, we previously applied ECMO in cases with severe tracheal stenosis such as case 1. However, bleeding was always problematic when anticoagulation was established.

BCV is an emerging NPV technology. It only requires fitting of an external cuirass to the body to generate negative pressure, compared with positive pressure ventilation, which requires intubation or a mask. BCV has been reported to improve lung function, oxygenation, and cardiac output, and reduce the risk of barotrauma.[6–8] Therefore, BCV is being used in the treatment of diseases such as acute respiratory failure and neuromuscular disease. BCV is contraindicated for patients who are deformed or burned such that the cuirass cannot be applied and for patients who have absolute upper airway obstruction.

It is thought that the use of BCV in stenting procedures may be advantageous. It allows ventilation to continue without interruption throughout surgical maneuvers. Our 3 cases maintained oxygenation throughout severe tracheal stenosis, a long surgery, and surgery including ablation in the trachea using BCV. The effect of BCV on ventilatory volume during spontaneous breathing assistance has not been fully investigated. There is 1 report indicating that an intermittent NPV of −30 cmH_2O increases (more than doubles) tidal volume in healthy awake volunteers.[9] Though we could not measure augmented tidal volumes after using BCV due to leakage, it is presumed that BCV could assist in spontaneous breathing by synchronizing with patients' respiratory cycles and preserve ventilatory volumes such as in our cases. Additionally, concern over unexpected bleeding caused by anticoagulation is reduced with BCV, indicating that its use may be more suitable than ECMO when the tumor is hemorrhagic or the patient has thrombocytopenia.

Before using BCV for stenting procedures, it must be confirmed that the patency of the airway is maintained. When the airway is almost obstructed preoperatively and tumor resection is planned, which would greatly increase the risk of total obstruction from bleeding and tumor debris, other supportive measures should be considered such as ECMO on standby during complex procedures. Additionally, attention should be given to chest wall rigidity due to narcotics, which would presumably render the device ineffective.

In conclusion, BCV was useful for maintaining adequate ventilation during anesthesia for tracheal stenting, and no significant complications occurred. BCV could be used as an alternative to other means of anesthesia for these cases.

DISCLOSURES

AQ2

Name: Hideaki Mori, MD.
Contribution: This author helped anesthetic management and draft the article.
Name: Atsuko Shono, MD.
Contribution: This author helped anesthetic management and draft the article.
Name: Hirade Ritsuko, MD.
Contribution: This author helped anesthetic management and critical revision of the article for important intellectual content.
Name: Tetsuro Nikai, MD, PhD.
Contribution: This author helped critical revision of the article for important intellectual content.
Name: Yoji Saito, MD, PhD.
Contribution: This author helped final approval of the article.
This manuscript was handled by: Mark C. Phillips, MD.

REFERENCES

1. Chen A. ECMO-assisted rigid bronchoscopy for tracheal obstruction. *J Bronchology Interv Pulmonol*. 2009;16:296–297.
2. Gourdin M, Dransart C, Delaunois L, Louagie YA, Gruslin A, Dubois P. Use of venovenous extracorporeal membrane oxygenation under regional anesthesia for a high-risk rigid bronchoscopy. *J Cardiothorac Vasc Anesth*. 2012;26:465–467.
3. Hong Y, Jo KW, Lyu J, et al. Use of venovenous extracorporeal membrane oxygenation in central airway obstruction to facilitate interventions leading to definitive airway security. *J Crit Care*. 2013;28:669–674.
4. Putz L, Mayné A, Dincq AS. Jet ventilation during rigid bronchoscopy in adults: a focused review. *Biomed Res Int*. 2016;2016:4234861.
5. Zangrillo A, Landoni G, Biondi-Zoccai G, et al. A meta-analysis of complications and mortality of extracorporeal membrane oxygenation. *Crit Care Resusc*. 2013;15:172–178.
6. McBride WT, Ranaldi G, Dougherty MJ, et al. The hemodynamic and respiratory effects of cuirass ventilation in healthy volunteers: part 1. *J Cardiothorac Vasc Anesth*. 2012;26:868–872.
7. McBride WT, Ranaldi G, Dougherty MJ, et al. The hemodynamic and respiratory effects of continuous negative and control-mode cuirass ventilation in recently extubated cardiac surgery patients: part 2. *J Cardiothorac Vasc Anesth*. 2012;26:873–877.
8. Hino H, Suzuki Y, Ishii E, Fukuda M. Biphasic cuirass ventilation for treatment of an air leak after pneumothorax in a patient with nemaline myopathy: a case report. *J Anesth*. 2016;30:1087–1090.
9. Glérant JC, Jounieaux V, Parreira VF, Dury M, Aubert G, Rodenstein DO. Effects of intermittent negative pressure ventilation on effective ventilation in normal awake subjects. *Chest*. 2002;122:99–107.