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Use of the FloTrac/Vigileo System™ for Adequate Fluid Management in a Patient Undergoing Lobectomy for a Complex Type of Pulmonary Arteriovenous Fistula

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Abstract

We report a case of a 15-year-old girl who underwent the left lower lobectomy for a complex type of pulmonary arteriovenous fistula, which caused a huge right-to-left shunt in the pulmonary circulation. During the operation with one-lung ventilation anesthesia, the right heart failure in company with severe hypoxemia or malignant ventricular arrhythmias, might be induced as the result of the sudden reduction of shunt flow. Furthermore, possible pulmonary edema due to ischemic reperfusion-like injury might be possible to develop by fluid overload, after the normal pulmonary perfusion restarted. FloTrac/Vigilleo System™ can provide useful hemodynamic parameters such as arterial pressure-based cardiac output and stroke volume variation based on the concept of fluid responsiveness. In our case, this system was successfully applied to achieve optimal cardiac preload for organ perfusion without transfusion and to prevent the right heart failure and pulmonary edema.

Key words; pulmonary arteriovenous fistula, FloTrac/Vigilleo System™, one-lung ventilation, general anesthesia

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Introduction

A pulmonary arteriovenous fistula (PAVF) due to abnormal congenital communications between the pulmonary arteries and veins causes a right-to-left shunt resulting in improperly oxygenated blood[1). The clinical manifestations may include hypoxemia, polycytemia, massive hemoptysis, or life-threatening cerebrovascular complications such as stroke. PAVFs can be classified as either simple or complex. Only 10–20% of cases are of the complex type, defined as PAVFs with many feeding arteries or draining veins[1~3). Our present case showed a rare complex type of PAVF, multiple and diffuse PAVF, with a large number of inflow and outflow vessels. In cases involving numerous right-to-left shunts in the pulmonary circulation, pulmonary arterial pressure (PAP), pulmonary arterial wedge pressure (PAWP), and cardiac output (CO) cannot be accurately assessed by a pulmonary artery catheter. Furthermore, central venous pressure (CVP), which is obtained under the lateral position in one-lung ventilation (OLV), cannot accurately reflect intravascular volume status and cardiac preload.

The FloTrac/Vigileo System™ (FTVS; Edward Lifesciences, CA, USA) has been recently used to determine arterial pressure-based cardiac output (APCO), stroke volume (SV), and stroke volume variation (SVV) from the waveform analysis of peripheral arterial pressure[4~7). The FTVS is based on the concept of fluid responsiveness and can be used

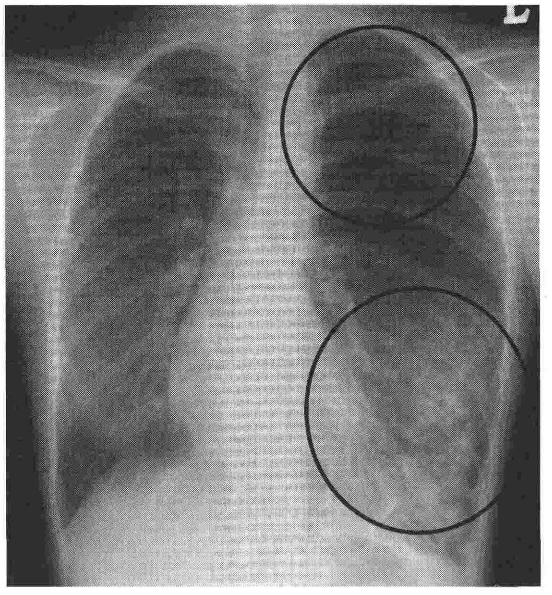

Figure 1 Chest of x-ray film

A decrease in the lung's blood vessel shadow of the left upper lobe, and a stiffening of the left lower lobe were revealed.

for hemodynamic monitoring during anesthesia. This system has many advantages compared with standard measuring techniques, including a simple operating procedure, minimally invasive characteristics, and quick and continuous feedback of analytical data for adequate fluid management.

To our knowledge, this is the first case report describing the use of the FTVS for adequate fluid management in a patient undergoing lobectomy for a complex type of PAVF under general anesthesia with OLV.

Case presentation

The patient was a 15-year-old female (height, 160 cm, weight, 43 kg) with a persistent slight fever and exertional dyspnea without improvement. Since birth, she had repeatedly suffered from symptoms like common cold and sometimes experienced bloody sputum and hemoptysis. Physical signs included cyanosis of the lips and clubbing of the digits. There was no relation identified to heredity hemorrhagic telangiectasia in the patient and her families. Blood gas analysis with inhaling room air revealed moderate hypoxemia with hypocapnia, (pH, 7.420; $PaCO_2$, 33.4 mmHg; PaO_2, 54.1 mmHg; and SaO_2, 87.5%). The severity of her respiratory symptoms was categorized as grade 2, according to the Hugh-Jones classification. Laboratory tests showed moderate polycytemia (erythrocyte count, 592×10^4 cells/mm^3; hemoglobin, 15.6 g/dl; and hematocrit, 47.5%). A chest radiograph showed an extensive abnormal shadow in the left lower lung field (**Fig. 1**), and a three-dimensional computed tomography scan of the chest revealed numerous fistulas with a large number of inflow and outflow vessels (**Fig. 2**). Electrocardiography showed moderate left ventricular hypertrophy due possibly to the right-to-left shunt, and rigtht-to-left shunts did not exist in the heart. Perfusion scintigraphy with technetium-99m macroaggregated albumin revealed that an estimated perfusion rate of 13% in the left lung and the calculated right-to-left shunt of the pulmonary circulation value was 42.9%. Thus, her PAVF was diagnosed as a complex, multiple and diffuse type of PAVF involving a large number of inflow and outflow vessels. On the basis of this diagnosis, embolotherapy was ruled out, and a left lower lobectomy under an open thoracotomy was scheduled.

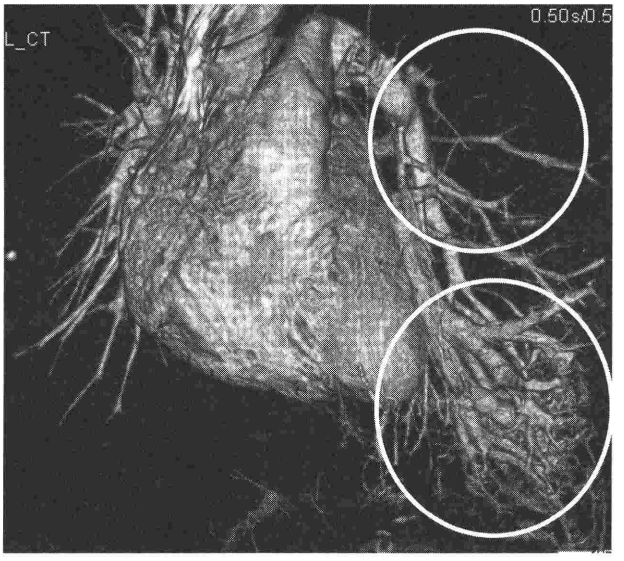

Figure 2 3D-CT examination of the chest

Decreased lung's blood vessels of the left upper lobe and diffuse pulmonary arteriovenous fistula (PAVF) in the left lower lobe were confirmed.

Anesthetic course and surgical procedure

After the placement of a thoracic epidural catheter (Th 7/8) for relieving postoperative pain, anesthesia was induced with intravenous propofol, fentanyl, and vecuronium bromide. Intraoperative monitoring was accomplished with American Society of Anesthesiologists (ASA) standard monitors, Bispectral Index (BIS) measurement, and capnography. Intubation of a double lumen tube (Blue Line 35Fr-Lt, Portex, Smiths Medical Japan Ltd., Tokyo, Japan) was easily performed with correct positioning, and after anesthesia induction, the right radial artery was cannulated with a 22-gauge catheter. To cope with possible malignant arrhythmias, defibrillation pads were placed on the chest wall, and an external defibrillator was available during all surgical procedures. Maintenance of anesthesia was achieved mainly with propofol (target-controlled infusion, 2μg/ml) and intermittent fentanyl infusion; sevoflurane (0.5-2.0%, end-tidal concentration) was used as needed to maintain BIS values at target levels of 40-45.

Heart rate, invasive blood pressure, and intermittent blood gas values were monitored throughout the procedure. The monitoring of APCO and SVV by FTVS was used to guide continuous intravascular volume therapy. During the operation with OLV in the right lateral position, mechanical ventilation was performed at a tidal volume of 270 ml, a respiratory rate of 16 breaths/min, and a peak inspiratory pressure of 20 cmH_2O. **Table 1** and **2** show the changes in hemodynamics and blood gas values, which were determined during OLV (baseline data) after anesthesia induction as well as during two-lung ventilation (TLV), and after ligation of the left inferior pulmonary artery and left lower lobectomy.

During the surgery, we initially planned to administer 120 ml/h of acetated Ringer's (AR) solution for maintaining fluid balance. However, the volume of blood loss gradually increased during the operation, and SVV was elevated in a corresponding manner. At the time of ligation of the left inferior pulmonary artery, the total volume of bleeding amounted to 550 ml, and a reduction in blood pressure (75/45 mmHg) and an increase in heart rate (120 beats/min) were observed. At that time, SVV had increased substantially from a baseline value of 10% to 25% (normal range, 10-13%), which reflected the reduction in circulating blood volume (**Table 1**). Therefore, in addition to AR, rapid fluid preloading with hydroxyethyl

Table 1 Changes in hemodynamics

	BP (mhg)	HR (bpm)	CI (l/min/m^2)	SVV (%)
After OLV	80/40	85	2.0	9
1 hour after OLV	90/40	95	3.0	12
2 hours after OLV	85/40	90	2.4	10
Immediately after ligation of the left lower PA	75/40	120	2.7	25
1.5 hours after ligation of the left lower PA	80/35	90	3.2	15
Before extubate	95/40	105	3.6	15

OLV: one lung ventilation, PA: pulmonary artery, BP: blood pressure, HR: heart rate, CI: cardiac index, SVV: stroke volume variation

Table 2 Changes in blood gases data

	FiO_2	PH	$PaCO_2$ (mmhg)	PaO_2 (mmhg)	SaO_2 (%)
Before OLV	1.0	7.325	38.4	90.2	90.2
1 hour after OLV	1.0	7.222	60.7	122.4	97.7
2 hours after OLV	1.0	7.221	38.4	90.2	97.4
After ligation of the left lower PA	0.6	7.268	49.8	217.3	99.7
1.5 hours after ligation of the left lower PA	0.6	7.370	38.6	274.8	100
Immediately after operation	0.21	7.294	45.6	115.8	97.8

OLV: one lung ventilation, PA: pulmonary artery

starch (Hespander®; HES70/0.5, Fresenius-Kabi, Bad Homburg, Germany) was performed to maintain SVV between 10% and 13%. After replacement of the circulating blood volume by the rapid infusion of HES 70/0.5 (approximately 1,500 ml/3 h), the SVV level was reduced to 15%, thus restoring circulation dynamics at the end of the lobectomy (**Fig 3**). The blood gas levels also temporarily deteriorated during OLV (**Table 2**). However, no manifestations of pulmonary edema or evidence of right heart failure were observed.

After the operation, since the respiratory and hemodynamic conditions of the patient were stable, the trachea was extubated in the operating room, and she was transferred to the intensive care unit. The volume of urine was 200 ml, blood loss amounted to 690 ml, and the fluid infusion volume was 2,620 ml (AR: 1,300 ml, HES 70/0.5: 1,500 ml). The duration of the surgery and anesthesia was 299 and 393 min, respectively. Neither right heart failure nor arrhythmia occurred during the postoperative period. Nine days after the operation, the patient was discharged from the hospital without any complications.

Discussion

In the present case report, the patient was diagnosed with PAVF of a multiple and diffuse type, which resulted in high-flow right-to-left shunting. We were thus anticipating some difficulties and complications during and after lobectomy under OLV. The sudden reduction in shunt flow after surgery results in an acute increase in afterload on the right ventricle, which may induce right heart failure, severe hypoxemia, and malignant ventricular arrhythmias[8~12]. Furthermore, the pulmonary vessels in the left upper lobe, which had not been exposed to normal pulmonary blood pressure and flow from birth, may have consisted of immature and weak vascular structures. Thus, pulmonary edema due to ischemic reperfusion-like injury may have developed, even from minimal excess volume loading, after normal pulmonary perfusion was restored[13]. Large-scale bleeding may also occur during lobectomy with such large fistulas, and adequate fluid infusion or blood transfusion management is vital to prevent perioperative circulation failure.

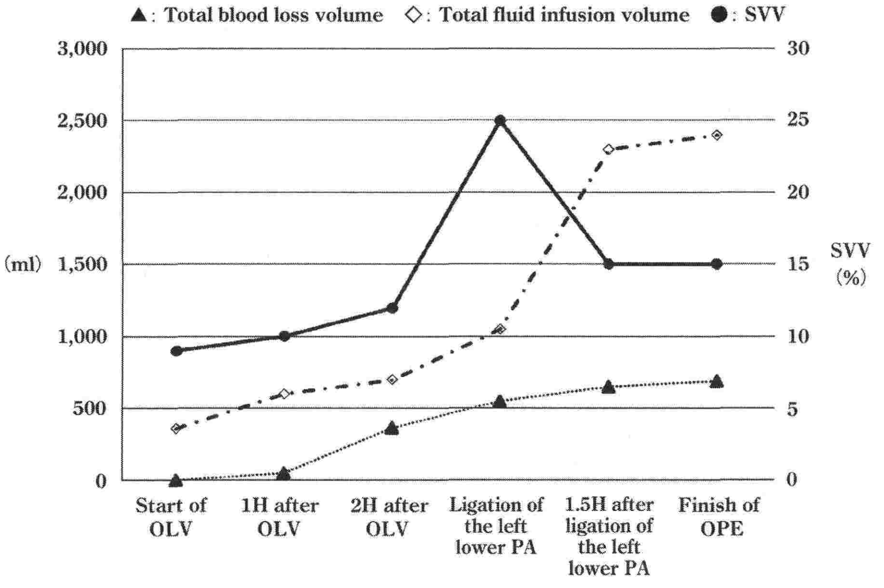

Figure 3 Transition of hemodynamics

SVV rose to 25% as the amount of blood loss increased. Afterwards, SVV decreased to 15% when the volume of infusion was increased.

OLV: one lung ventilation, PA: pulmonary artery, BP: blood pressure, HR: heart rate, CI: cardiac index, SVV: stroke volume variation

Under these conditions, proper fluid management must be based on careful and adequate volume evaluation. Transesophageal echocardiography (TEE), pulmonary artery catheterization (PAC) and central venous catheterization (CVC) techniques are well-established conventional methods for monitoring circulation during anesthesia[14~16]. However, TEE and PAC are highly invasive and increases the risk of developing pulmonary vascular damage and pulmonary or cerebrovascular embolism in PAVF cases. Furthermore, PAP, PAWP, and CO values obtained by PAC are less reliable when a right-to-left shunt is present in the pulmonary circulation of PAVF patients. CVP is also not very accurate during surgery in a patient in the lateral position under OLV. Accordingly, FTVS, which evaluates cardiac preload and heart function by analyzing only the peripheral arterial pressure waveform, may be more appropriate in such a setting.

In a normal situation and under mechanical ventilation, SVV values is calculated by the system on the basis of the concept of fluid responsiveness, with a level in the range of 13% over considered to indicate decreased circulating blood flow[7]. However, pulmonary blood flow change in a lateral position is affected by the gravitational shift of blood flow and hypoxic pulmonary vasoconstriction, which is likely to cause an underestimation of SVV during OLV. In the present patient, effective pulmonary blood flow to the left lung was extremely reduced as compared to before the lobectomy. Since changes in pulmonary blood flow are affected by lateral positioning and HPV was low in the present case, the reliability of SVV obtained by the system was high. During the above described surgical procedure, the change in SVV level responded to bleeding volume and fluid therapy with HES 70/0.5 in a very sensitive manner and was shown to be an appropriate index for determining intravascular volume.

In conclusion, in a patient with complex PAVF, FTVS was successfully used to achieve optimal cardiac preload for organ perfusion without blood transfusion and to prevent right heart failure and pulmonary edema. Therefore, we suggest that FTVS may be a more suitable monitoring device than PAC or CVC in patients with PAVF.

References

1) Gossage JR, Kanji G: Pulmonary arteriovenous malformations. A state of the art review. Am J Respir Crit Care Med 1998; 158: 643-61.
2) Higgins CB, Wexler L: Clinical and angiographic features of pulmonary arteriovenous fistulas in children. Radiology 1976; 119: 171-5.
3) White RI Jr, Mitchell SE, Barth KH, et al: Angioarchitecture of pulmonary arteriovenous malformations: an important consideration before embolotherapy. AJR Am J Roentgenol 1983; 140: 681-6.
4) Manecke GR: Edwards FloTrac sensor and Vigileo monitor: easy, accurate, reliable cardiac output assessment using the arterial pulse wave. Expert Rev Med Devices 2005; 2: 523-7.
5) Biais M, Nouette-Gaulain K, Cottenceau V, et al: Uncalibrated pulse contour-derived stroke volume variation predicts fluid responsiveness in mechanically ventilated patients undergoing liver transplantation. Br J Anaesth 2008; 101: 761-8.
6) Mayer J, Boldt J, Schöllhorn T, et al: Semi-invasive monitoring of cardiac output by a new device using arterial pressure waveform analysis: a comparison with intermittent pulmonary artery thermodilution in patients undergoing cardiac surgery. Br J Anaesth 2007; 98: 176-82.
7) Cannesson M, Musard H, Desebbe O, et al: The ability of stroke volume variations obtained with Vigileo/FloTrac system to monitor fluid responsiveness in mechanically ventilated patients. Anesth Analg 2009; 108: 513-7.
8) Sperling DC, Cheitlin M, Sullivan RW, et al: Pulmonary arteriovenous fistulas with pulmonary hypertension. Chest 1977; 71: 753-7.
9) Sapru RP, Hutchison DC, Hall JI: Pulmonary hypertension in patients with pulmonary arteriovenous fistulae. Br Heart J 1969; 31: 559-69.
10) Le Roux BT, Gibb BH, Wainwright J: Pulmonary arteriovenous fistula with bilharzial pulmonary hypertension. Br Heart J 1970; 32: 571-4.
11) Rodan BA, Goodwin JD, Chen JT, et al: Worsening pulmonary hypertension after resection of arteriovenous fistula. AJR Am J Roentgenol 1981; 137: 864-6.
12) Tajima M, Kinoshita H: Anesthetic management of a patient with pulmonary arteriovenus fistulas. J Clin Anesth. (Jpn) 2000; 24: 684-8.
13) Della Rocca G, Pierconti F, Costa MG, et al: Severe reperfusion lung injury after double lung transplantation. Crit Care 2002; 6: 240-4.
14) Kallmeyer IJ, Collard CD, Fox JA, et al: The safety of intraoperative transesophageal echocardiography: a case series of 7200 cardiac surgical patients. Anesth Analg 2001; 92: 1126-30.
15) Swan HJ, Ganz W, Forrester J, et al: Catheterization of the heart in man with use of a flow-directed balloon-tipped catheter. N Engl J Med 1970; 283: 447-51.
16) Jernigan WR, Gardner WC, Mahr MM, et al: The internal jugular vein for access to the central venous system. JAMA 1971; 218: 97-8.