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ORIGINAL ARTICLE

Predict Fluid Responsiveness by Stroke Volume Variation in Patients Undergoing Protective One-Lung Ventilation in Pressure-Controlled Ventilation Mode

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Objective: The aim of this study is to use stroke volume variation (SVV) as an indicator to predict fluid responsiveness in patients undergoing protective one-lung ventilation (OLV) in pressure-controlled ventilation mode. **Design and Setting:** A prospective clinical study in an operating room in a medical center. **Patients:** Fourteen patients receiving video-assisted thoracic surgery while undergoing OLV in pressure-controlled ventilation mode. **Methods:** After starting OLV in pressure-controlled ventilation mode, all patients were administered 6 ml/kg 6% hydroxyethyl starch for 20 min. Vigileo-FloTrac system was used to record hemodynamic variables before and after volume loading. The ability of SVV to predict fluid responsiveness was tested by calculating the area under the receiver operating characteristic (ROC) curve for an increase in stroke volume index of ≥10% after volume loading, and the optimal threshold value of SVV was calculated. **Results:** The area under the ROC curve for SVV to discriminate between responders and nonresponders was 0.89 (95% confidence interval, 0.700–1; $P = 0.03$). The optimal threshold value of SVV was 8.5% (sensitivity 88.89%; specificity 75%). **Conclusions:** SVV may be suitable for predicting fluid responsiveness in patients undergoing protective OLV in pressure-controlled ventilation mode.

Key words: Stroke volume variation, goal-directed fluid therapy, One-lung ventilation, fluid responsiveness

INTRODUCTION

Goal-directed fluid therapy (GDT) plays an important role in enhanced recovery after surgery program.[1-5] Perioperative fluid management is especially crucial for thoracic surgeries because liberal fluid administration may be associated with major cardiopulmonary complication or mortality.[6-8] The Vigileo-FloTrac system is one of the minimal invasive monitors that can be used as a GDT technique to estimate cardiac index (CI), stroke volume index (SVI), and predict fluid responsiveness in various clinical settings by stroke volume variation (SVV).[9-11] The previous study revealed that SVV-guided fluid management could be prescribed in thoracic surgeries requiring lateral position and one-lung ventilation (OLV) and does not result in pulmonary fluid overload.[12] However, it is controversial whether SVV measured by the Vigileo-FloTrac system can predict fluid responsiveness in patients undergoing pulmonary lobectomy with OLV after thoracotomy.[13-17] Besides, the SVV values and the threshold values to determine fluid responsiveness may change during OLV.[16] On the other hand, protective ventilation strategies such as pressure-controlled ventilation (PCV) with low tidal volumes (TV)[18-20] are also employed to reduce mechanical stress to lung tissue during OLV.[21] There are studies comparing the influence of conventional TV (8 ml/kg) and protective TV (6 ml/kg) to predict fluid responsiveness in OLV.[15,22] However, few studies investigate the influence of PCV with protective TV in predicting fluid responsiveness based on SVV. The aim of this study is to estimate the value of fluid responsiveness by SVV in patients undergoing protective OLV in PCV mode.

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METHODS

This prospective study was approved by the Ethics Committee (TSGHIRB No: 2-102-05-042) of Tri-Service General Hospital, Taipei, Taiwan on May 29, 2013, and was conducted in accordance with the approved guidelines. We obtained informed consent from each patient enrolled in this study, between July 2013 and October 2013. Fourteen patients were included in the study. The inclusion criteria were patients aged 20–80 years scheduled for video-assisted thoracic surgery (VATS) with lobectomy or wedge resection requiring general anesthesia with OLV. The exclusion criteria were the American Society of Anaesthesiologists physical status >II, the risk of coexisting severe cardiac/renal/hepatic disease, arrhythmia, and morbid obesity (BMI ≥35). Discontinued OLV due to desaturation or hemodynamic instability during intervention was also excluded from the study. All patients' demographics and operation site were documented. After patients enter the operating room, routine monitoring, such as noninvasive blood pressure, electrocardiography, and pulse oximetry, were started. Anesthesia was induced with fentanyl, propofol, and rocuronium or cisatracurium/succinylcholine in all patients. The patients were then intubated with COVIDIEN Mallinckrodt™ endobronchial Tube (37 Fr. for male and 35 Fr. for female) by orotracheal intubation 1 min later and fixed appropriately after correct positioning was confirmed by fiberoptic bronchoscopy. After intubation, percutaneous radial artery cannulation was performed and then connected with the Vigileo-FloTrac system (Edwards Lifescience LLC, Irvine, CA, USA) to measure mean arterial pressure (MAP), heart rate, CI, SVI, and SVV. Maintenance were achieved by anesthetic sevoflurane and analgesic fentanyl. The PCV mode was adopted for mechanical ventilation. After starting OLV, the pressure was set at 20 to 25 cmH_2O to keep TV achieved 6 ml/kg during OLV. The fractional inspired oxygen concentration (FiO_2) was 80%, the respiratory ratio was 1:2, and the end-tidal CO_2 partial pressure was kept between 35 mmHg and 45 mmHg by adjusting the respiratory rate. Twenty-five minutes after the initiation of OLV, a 5-min (T1) period of stable hemodynamic parameters (HR, MAP, CI, SVI, and SVV) were measured,[13-15,17,23,24] followed by fluid administration of 6 ml/kg colloid solution (Voluven® [6% hydroxyethyl starch 130/0.4]) over 20 min. After fluid loading, a 5-min period (T2) of hemodynamic variables were measured again [Figure 1].[23] All measurements were acquired during stable periods. The monitor of Vigileo-FloTrac system was turned away from the attending anesthesiologist while an independent research staff recorded the hemodynamic variables on the Vigileo-FloTrac system. Patients showing an increase in SVI of 10% or more after fluid loading were defined as responders, whereas patients whose SVI increased by <10% were classified as nonresponders. Based on the findings of previous studies, the 10% cutoff value of SVI was considered clinically significant.[25,26] The ability of SVV to predict fluid responsiveness was tested by calculating the area under the receiver operating characteristic (ROC) curve, and the optimal threshold value of SVV was calculated. Student's t-tests were used to evaluate differences in continuous variables, including patient demographic characteristics and hemodynamic parameters. Duing OLV in responders and non-responders, Mann-Whitney U tests were used to evaluate differences in the change of MAP, CI, SVI, and SVV after fluid loading. A value of $P < 0.05$ was considered statistically significant. Data were analyzed using SPSS software (version 16, SPSS Inc., Chicago, IL, USA) and SigmaPlot for Windows Version 10.0 software.

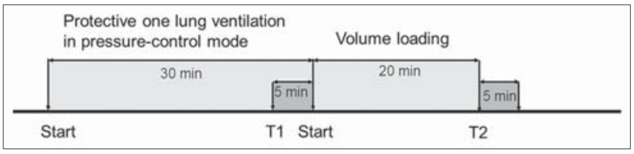

Figure 1: The time course of sample points

RESULTS

Fourteen patients were enrolled and one patient's intervention was interrupted because the duration of OLV was <30 min. Total thirteen patients (male: 6; female: 7) were included in this study. The patients' characteristics and surgical site are shown in Table 1. The hemodynamics parameters before and after fluid loading are shown in Table 2. The MAP, CI, SVI, and SVV in responders significantly increased after fluid loading [Table 2]. The change of MAP, CI, SVI, and SVV after fluid loading during OLV in responders was significantly different from nonresponders [Table 3]. The SVV before fluid loading in responders were significantly higher than in nonresponders [Figure 2]. The area under the ROC curve for SVV to discriminate between responders and nonresponders was 0.89 (95% confidence interval, 0.700–1; $P = 0.03$) [Figure 3]. The optimal threshold value to distinguish responders from nonresponders was 8.5% (sensitivity 88.89%; specificity 75%).

DISCUSSION

Major thoracic surgeries that usually require OLV and significant hemodynamic change may encounter vessel injury with bleeding during surgical manipulation and therefore need immediate recognition. The study demonstrated that SVV might also be applied toward predicting fluid responsiveness using

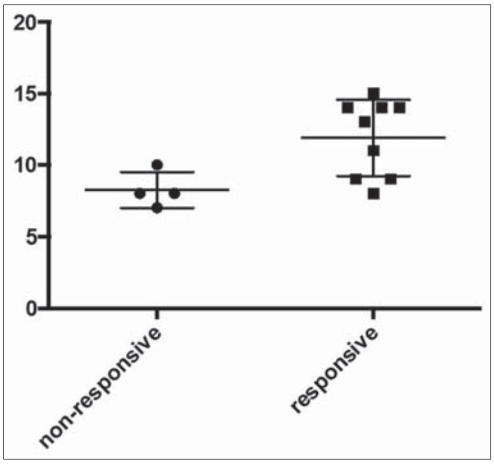

Figure 2: Stroke volume variation before fluid loading in responders and nonresponders

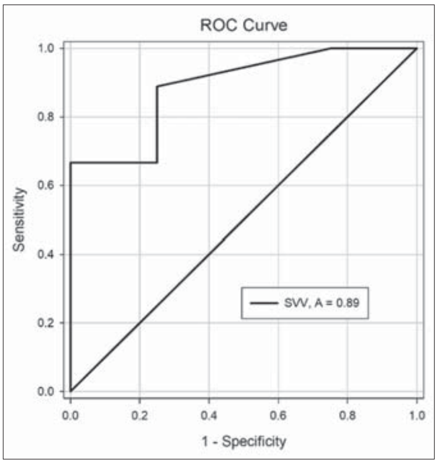

Figure 3: The area under curve of the receiver operating characteristic of stroke volume variation before fluid loading to predict fluid responsiveness in protective one-lung ventilation

Table 1: Demographic characteristics

Variables	
Age (year)	58.4±13.5
Gender (male/female)	6/7
BMI	22.4±2.9
Operation side (left/right)	8/5

Values are expressed as mean (SD) except for gender and operation side. SD=Standard deviation; BMI=Body mass index

Table 2: Comparison of hemodynamic parameters before and after fluid loading during one-lung ventilation

	Responders (*n*=9)			Nonresponders (*n*=4)		
	Before	After	*P*	Before	After	*P*
MAP (mmHg)	71.4±7.5	89.9±8.8	0.001	85.8±8.8	86.0±8.9	0.638
HR (rate/min)	68.1±14.6	66.9±14.3	0.645	78.8±11.1	80.5±5.6	0.599
CI (L/min/m^2)	2.4±0.5	3.1±0.4	0.002	3.1±0.6	2.9±0.8	0.337
SVI (mL/m^2)	35.9±6.0	46.0±8.2	0.007	39.0±11.1	36.8±11.3	0.444
SVV (%)	11.9±2.7	5.8±1.2	<0.001	8.3±1.3	4.8±2.4	0.012

Values are expressed as mean (SD). MAP=Mean arterial pressure; HR=Heart rate; CI=Cardiac index; SVI=Stroke volume index; SVV=Stroke volume variation

Table 3: Comparison of hemodynamic difference between T1 and T2 during one-lung ventilation in responders and nonresponders to fluid loading

Hemodynamic difference (T2-T1)	Responders	Nonresponders	*P*
ΔHR	−1.22±7.66	1.75±5.97	0.28
ΔMAP	17.11±13.37	0.25±0.96	0.03
ΔCI	0.63±0.43	−0.05±0.10	0.01
ΔSVI	10.11±8.49	−2.25±5.12	0.01
ΔSVV	−6.11±2.09	−3.50±1.29	0.04

Δ: The difference of hemodynamic parameters (T2-T1); MAP=Mean arterial pressure; HR=Heart rate; CI=Cardiac index; SVI=Stroke volume index; SVV=Stroke volume variation

protective ventilation in PCV mode during OLV. The cause of SVV is intrathoracic pressure-induced variations in right atrial pressure changing intrathoracic blood volume over the ventilatory cycle, so using SVV to predict fluid responsiveness in OLV is feasible.[23,27-29] SVV may also be modified by chest wall compliance, contractility, and tidal volume due to altered inspiration-associated decreases in the right ventricular stroke volume.[30] Previous studies suggested when using SVV as a predictor of fluid responsiveness in patients with OLV, tidal volume should be set in at least 8 ml/kg.[15,27] However, one study by Lee *et al*.[31] reported that fluid responsiveness could also be predicted by pulse pressure variation, which is another widely used functional dynamic parameter, during protective OLV (TV 6 ml/kg). Fu *et al*.[22] reported that SVV could predict fluid responsiveness in protective OLV, but the accuracy its prediction was relatively weak compared with the role in conventional ventilation strategy (TV 8 ml/kg). In the present study, the ROC analysis showed that the optimal thresholds for SVV discriminate responders from nonresponders was 8.5% with a sensitivity of 88.89% and a specificity of 75%.

The conventional SVV threshold values in the prediction of fluid responsiveness are ranged from 10% to 13%.[32] However, the SVV value and threshold to discriminate fluid responsiveness in low tidal volume setting may be decreased.[33,34] Therefore, the threshold value of SVV should be interpreted carefully during OLV. One study by Lema *et al*.[16] demonstrated that SVV values decreased during protective OLV and suggested not to use the same threshold values to determine fluid responsiveness. The optimal threshold in our study is 8.5%, which is lower than the standard threshold cutoff value in SVV and consistent with other studies.[15,22]

The volume of fluid administration and duration of infusion time may affect fluid responsiveness during fluid loading.[35]

Two studies used a fixed dose of fluid administration.[15,23] However, the amount may be inadequate or overload based on the individual body weight. In addition, some studies use a 30-min infusion period during fluid loading.[13-15,23,24] Jeong *et al*.[24] used a 30-min infusion period and reported that SVV was not useful for predicting fluid responsiveness either in VATS or open thoracotomy surgery. However, a systematic review and meta-analysis showed that the proportion of responders decreased with a long infusion time (≥30 min).[35] In our study, we chose 6 ml/kg in a 20-min period in accordance with the suggestion of the previous study.[36] The cutoff value considered clinically significant for SVI increase after fluid loading in our study was 10%.[24-26] However, some studies used 15%[14,22]–25%[23] increase of SVI or the increase of CI[13,31] as fluid responsiveness and showed different results. Although the definition of fluid responsiveness is not clear, especially during cardiac and thoracic surgery,[34] the lower cutoff value in our study might increase the sensitivity and therefore should be viewed cautiously.

There are some limitations to our study. First, the sample size is relatively small; nevertheless, it revealed statistical significance. Second, the hemodynamic parameters were measured during surgical manipulation which may increase the variability and bias; however, it helps evaluate the usefulness in real clinical practice. Third, the present study did not measure chest wall compliance which may also altered SVV.[23,37] Fourth, this study didn't investigate the effect of the side of lateral decubitus position on SVV. However, previous studies reported that the left or right decubitus or recumbent position may not affect SVV.[24,38] Further investigations were needed.

CONCLUSIONS

This study demonstrated that SVV may be suitable for predicting fluid responsiveness in patients undergoing protective OLV in pressure-controlled ventilation mode.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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