Original Article

DOI: 10.7860/JCDR/2022/59603.17275

Anaesthesia Section

Efficacy of Stroke Volume Variation-guided Fluid Management of Patients undergoing Off-pump Coronary Artery Bypass Grafting: An Observational Comparative Study between Open and Closed Chest

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ABSTRACT

Introduction: Functional haemodynamic monitoring using dynamic parameter such as Stroke Volume Variation (SVV), based on pulse contour analysis, helps in predicting fluid responsiveness in off-pump Coronary Artery Bypass Grafting (CABG) surgery. This allows adequate volume replacement to achieve optimal cardiac performance.

Aim: To evaluate the efficacy of SVV in predicting volume responsiveness and effect on haemodynamic variable in patients undergoing off-pump CABG in both closed and open chest.

Materials and Methods: This single-centre, non randomised observational study was conducted at a tertiary medical college and hospital (LokmanyaTilak Municipal Medical College and General Hospital) Mumbai, Maharashtra, India, from December 2016 to December 2018. A total of 34 patients undergoing elective off-pump CABG were included. Haemodynamic measurements Stroke Volume (SV), Cardiac Output (CO), Cardiac Index (CI), and SVV, were recorded with the transducer positioned at the level of midaxillary line. If the SVV was equal to or higher than 12, 100 mL fluid aliquot was given to patients. Endpoints for fluid aliquots was increase in CO by 15%, decrease in SVV of less than 12 or an increase Central Venous Pressure (CVP) upto 15 millimetre of mercury (mmHg). Number of times SVV above 12 during the procedure was recorded. SVV was considered as fluid responsive "if there was an increase in SV by 5%". Statistical analysis was done using Student's t-test (two tailed, dependent) on continuous parameters. The p-value <0.05, was considered significant.

Results: Out of 103 events of rise in SVV, 65 (63.1%) occurred when chest was open and 38 (36.9%) while chest was closed. The SVV-guided fluid response was 76.3% in closed chest and 75.4% in open chest and there was no significant difference. (p-value=0.91). There was a significant increase in SV (p-value <0.01), CO (p-value=0.04), and significant decrease in SVV (p-value <0.01) and heart rate (p-value <0.01) after fluid loading in the responsive group when compared with non responsive group. There was no statistically significant difference between percentage change in SV, CO, CI, SBP, DBP, MAP and CVP between closed and open chest conditions after fluid replacement.

Conclusion: The SVV is not affected by open or closed chest conditions in mechanically ventilated patients undergoing CABG and can be used as a guide for fluid replacement. Weather open or closed chest conditions, few patients do not respond to fluid replacement when SVV are more than 12 by an increase in SV, cardiac output or CI, the cause of which remains to be determined.

Keywords: Dynamic parameter, Flotrac vigileo device, Preload variables

INTRODUCTION

Adequate volume replacement to achieve optimal performance is a primary goal of haemodynamic management of patients undergoing cardiac surgery. In off-pump CABG the open chest causes evaporative loss of fluid. Blood loss occurs during sternotomy, harvesting of Internal Mammary Artery (IMA) and saphenous vein as well as during coronary anastomosis. Preoperative fasting, induction of general anaesthesia, diuretics, intraoperative bleeding may decrease intravascular volume. Hypotension can be caused by hypovolaemia or due to decrease ventricular function. Intraoperative CO may be very low if the negative fluid balance is not minimised whereas excessive fluid results in pulmonary oedema in a patient with weak heart. Judicial fluid replacement increases the CO, maintain tissue perfusion and provide haemodynamic stability during heart positioning and anastomosis [1]. The positive intrathoracic pressure generated during inspiration in mechanically ventilated patients causes compression of the major blood vessels. Reduced preload due to venous compression added-on with aortic compression results in decreased SV. During expiration the compression on major blood vessel is reduced implying larger SV. This indicate that SVV occur within a respiratory cycle [2,3].

Hypovolaemia increases the collapsibility of the venous system, thus increasing the SVV whereas adequate volume status or hypovolaemia makes veins non collapsible, negating the changes on CO with cyclic changes of respiration. Hypovolaemia also puts right ventricle and left ventricle on ascending portion of Frank-Starling curve. Thus changes in preload that occur with respiration have a more pronounced effect on SV and arterial pressure reflecting as higher SVV [4]. Overall SVV variation can be an excellent continous parameter to monitor fluid status of a patient. After sternotomy when the pericardium is open, the heart is open to atmosphere thus negating the effect of intrathoracic pressure on venous return and ventricular preload and modifying the cardiopulmonary interactions [5].

Due to the fluid shifts, off-pump CABG may be pushing the patients towards the steeper Frank-Starling's curve thus making SVV more pronounced. In other words, the effect of intrathoracic pressure on venous return in open chest may be overwhelmed by deficit [6].

Some studies have shown that SVV correlates with preload status in open chest as well [5,6]. Vigileo system is an automatic and continuous monitoring of CO based on pulse contour analysis. The Vigileo monitor with Flotrac sensor can display key flow parameter such as CO, SV, SVV, and CI [7,8]. In mechanically ventilated patients, the present prospective observational study was designed to compare efficacy of SVV (acquired from vigileo Flotrac device) guided fluid management of patients undergoing off-pump CABG in closed as well as open chest conditions. The primary aim of efficacy in the study was defined as the number of times SVV more than 12 responded to fluid replacement in patients by an increase in SV equal to or more than 5%. The secondary aim of the study was to evaluate the clinical benefits in terms of SV, CO, CI, and haemodynamic variable after SVV guided fluid replacement.

MATERIALS AND METHODS

This singe-centre non randomised comparative observational study was conducted at Lokmanya Tilak Municipal Medical College and General Hospital Mumbai Maharashtra India, from December 2016 to December 2018. Institutional Review Board and Human Research Ethic Committee approval was obtained. This trial has been registered in Clinical Trial Registry–India (CTRI/2017/04/0139995).

Inclusion criteria: Patients aged more than 18 years planned for elective off-pump CABG procedure under general anaesthesia were included in the study.

Exclusion criteria: Patients with American Society of Anaesthesiology (ASA) grade IV, Left ventricular ejection fraction less than 30%, preoperative dysrhythmias, valvular heart disease, intracardiac shunt, severe pulmonary artery hypertension, severe obstructive lung disease were excluded from the study. Withdrawal criterion were patients requiring Intra-Aortic Balloon Pump (IABP), patients requiring cardiopulmonary bypass and patients developing persistent arrhythmias.

Based on above assumptions a sample size of 103 completed cases was needed to assess the study objective at 80% power and 5% level of significance using formula:

$$N=\frac{4\times Z^2_{1-\alpha/2}\times S^2}{W^2}$$

Study Procedure

After application of routine haemodynamic monitor according to institute protocol (pulse oximetry, 5 lead ECG, non invasive Blood Pressure (BP) monitoring) patient was sedated before securing arterial and central venous line. A transducer (Flo Trac Edward lifesciences^R) was connected to radial artery on one end and to vigileo system on the other hand. Haemodynamic variable CO, CI, SV and SVV were obtained. Vigileo monitor with Flotrac sensor was used for continuous monitoring of CO based on pulse contour analysis. After induction of anaesthesia and tracheal intubation, patients were mechanical ventilated with a tidal volume of 6-8 mL/kg to maintain end expiratory CO_2 of 32-35 mmHg during the surgery. Crystalloids were started at 4 mL per kg per hour. SVV was monitored continuously. Number of times SVV rose above 12 during the procedure was recorded. If the SVV was equal to or higher than 12, fluid aliquots of 100 mL were given. Endpoint for fluid aliquots was increase in CO by 15%, decrease in SVV of less than 12 or increase in CVP up to 15 mmHg. SVV was considered fluid responsive if there was an increase in SV by 5% or more. Change in CO, CI, Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP) and SV after fluid aliquots was recorded.

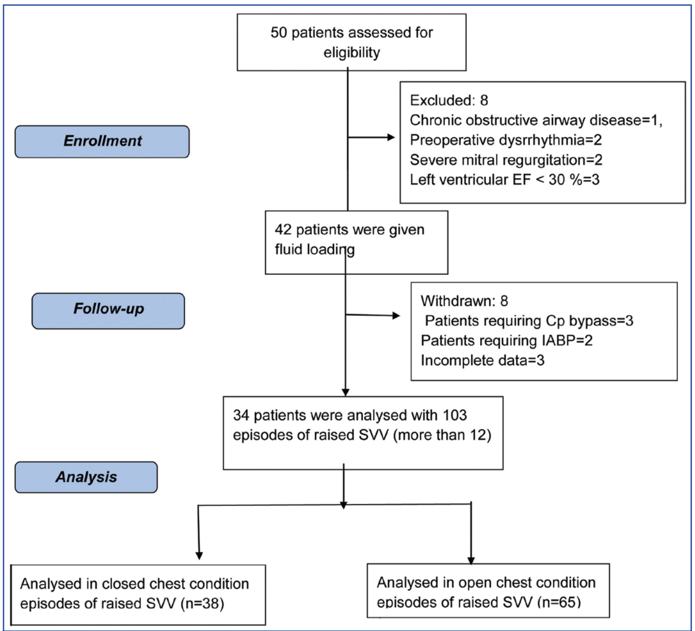
Sample size calculation [9]: Sample size for a descriptive study of a continuous variable with Confidence level=95%, W=6 (Desired total width of confidence interval), and S=15.5 (Standard deviation of the variable). W/S=0.39. Standard normal deviate for $\alpha=Z_{(1-\alpha/2)}=1.96$.

STATISTICAL ANALYSIS

After data collection, data entry was done in Microsoft excel. Data analysis was done with the help of Statistical Package for Social Science (SPSS) software for window version 10.0. Student's t-test used to find the significance of study parameters on continuous scale within each group.

RESULTS

Total 50 patients were enrolled for study. Eight patients were excluded and eight patients were withdrawn from the study. Finally, data of 34 patients and 103 episodes of raised SVV (more than 12) were analysed. [Table/Fig-1] shows CONSORT flowdiagram. [Table/Fig-2] show demographic data.



[Table/Fig-1]: CONSORT flowdiagram.

Study parameters	N	Mean±SD
Age male (years)	24	60.50±8.11
Age female (years)	10	58.70±7.54
Height (cm)	34	160.03±7.21
Weight (kg)	34	66.24±5.46

[Table/Fig-2]: Demographic data.

Out of 103 times that the fluid replacement was given, SVV was responsive in 78 (75.73%). The mean decrease in SVV was 49.86% (SD=13.77) in responsive group versus 12.96% (SD=13.13) in non responsive group (p-value <0.01). Responsive and non responsive after fluid loading differed significantly in their CO (p-value=0.04), SV (p-value <0.01), HR (p-value <0.01), but not in CVP, SBP, DBP, MAP, CI [Table/Fig-3].

Out of 103 events of rise in SVV, 65 (63.1%) occurred when chest was open and 38 (36.9%) while chest was closed. The SVV-guided fluid response was 76.3% in closed chest and 75.4% in open chest and there was no significant difference (p-value=0.91) [Table/Fig-4].

The baseline parameters including baseline CVP, were comparable among closed and open chest condition in responsive fluid loading except for prefluid loading SVV. Mean baseline SVV in responsive fluid loading was 19.10% (SD-6.13%) in closed chest as compared to 16.69% (SD-3.51%) in open chest [Table/Fig-5].

There was no statistically significant difference between percentage change in SV, CO, CI, SBP, DBP, MAP and CVP between open chest and open chest conditions [Table/Fig-6].

No significant correlation was found in amount of fluid required and increase in SV (p=0.062) in responsive group [Table/Fig-7].

% Change in parameters	Responsive (78)	Non responsive (25)	Unpaired t-test	p-value
Total fluid given	144.87	136	-0.578	0.56
% Change HR	-10.21	1.74	4.603	<0.01
% Change SBP	9.95	8.92	-0.275	0.78
% Change DBP	10.72	9.67	-0.324	0.74
% Change MAP	11.05	9.23	-0.556	0.57
% Change SVV	-49.86	-12.96	11.790	<0.01
% Change CVP	45.71	51.39	0.603	0.54
% Change SV	12.91	0.28	-5.128	<0.01
% Change CO	4.78	-0.46	-2.034	0.04
% Change CI	4.02	-0.77	-1.780	0.07

[Table/Fig-3]: Comparison of percentage change in various parameters among responsive and non responsive group.
HR: Heart rate; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; SVV: Stroke volume variation; CVP: Central venous pressure; SV: Stroke volume; CO: Cardiac output; CI: Cardiac index

Responsive (R) or Non responsive (NR)	Closed chest	Open chest	Total	p-value
R	29 (76.3%)	49 (75.4%)	78 (75.7%)	0.915
NR	9 (23.7%)	16 (24.6%)	25 (24.3%)	
Total	38 (100%)	65 (100%)	103 (100%)	

[Table/Fig-4]: Fluid responsiveness among closed and open chest condition.

Chest open/closed	Closed (mean)	Open (mean)	p-value
Total fluid given	144.83	144.90	0.997
Pre HR	91.90	91.96	0.984
Pre SBP	103.90	103.29	0.885
Pre DBP	57.00	60.94	0.137
Pre MAP	72.45	73.29	0.752
Pre SVV	19.10	16.69	0.030
Pre CVP	7.10	8.14	0.076
Pre SV	55.72	56.67	0.687
Pre CO	4.87	4.93	0.727
Pre CI	2.85	2.91	0.369

[Table/Fig-5]: Various parameters in responsive fluid loading.
HR: Heart rate; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; SVV: Stroke volume variation; CVP: Central venous pressure; SV: Stroke volume; CO: Cardiac output; CI: Cardiac index

Chest open closed	Closed (29)	Open (49)	Unpaired t-test	p-value
Total fluid given	144.83	144.90	-0.004	0.997
% Change HR	-9.60	-10.57	0.461	0.646
% Change SBP	8.49	10.82	-0.635	0.527
% Change DBP	9.83	11.25	-0.458	0.648
% Change MAP	11.05	11.05	0.000	1.000
% Change SVV	-52.74	-48.16	-1.431	0.157
% Change CVP	54.02	40.78	1.288	0.202
% Change SV	14.87	11.75	1.110	0.271
% Change CO	4.84	4.74	0.033	0.974
% Change CI	2.84	4.72	-0.599	0.551

[Table/Fig-6]: Percent change in various parameters in responsive fluid loading (Responsive group n=78).
HR: Heart rate; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; SVV: Stroke volume variation; CVP: Central venous pressure; SV: Stroke volume; CO: Cardiac output; CI: Cardiac index

Study parameters	Mean	Pearson correlation	p-value
Total fluid given	144.87±71.44	0.213	0.062
% Change SV	12.91±12.05		

[Table/Fig-7]: Correlation among total fluid required and percentage increase in Stroke Volume (SV) in responsive patients (N-78).

DISCUSSION

The SVV is preload dependent variable that occurs during the respiratory cycle which is estimated from arterial pressure waveform [10]. In the present study, authors compared the SVV guided fluid responsiveness in closed and open chest condition. There is more evaporative fluid loss, leading to fluid deficit, in open than closed chest conditions and this was reflected by more episodes of rise in SVV (65) in open than closed (38) chest conditions. The response to SVV guided fluid replacement was not significantly different in open or closed chest conditions. The rise in SVV more than 12% was responsive to fluid replacement with increase in SV and CO in 76.3% in closed and 75.4% in open chest conditions. The results of this study showed that SVV can be a useful indicator of fluid deficit in closed as well as open chest conditions in patients undergoing off-pump CABG.

Two factors seem to be responsible for SVV, the cycling intrathoracic pressure and a low intravascular volume. Open heart conditions with sternotomy and pericardectomy reduces the effect cycling intrathoracic pressure on major blood vessels but does not obliterate it. This is reflected in present study by a lower mean prefluid SVV (16) in open as compared to closed (19) chest conditions. One can explain this from basic anatomy. 50 percent of SVC and the two brachiocephalic veins are extrapericardial [11]. The short intrathoracic course of IVC is both intra and extrapericardial. The posterior aspect of intrapericardial inferior vena cava is not covered by the pericardium [12]. Hence, open pericardectomy may not abolish the effect of cyclic intrathoracic pressure on these vessels.

Another explanation is that the decrease in preload conditions during inspiration may be simple compression of small pulmonary vessels and capillaries as a study has shown that application of peep resulted in similar fall in arterial pressure in closed-chest and lateral thoracotomy conditions [13]. Hence, compression of these extrathoracic major veins and small pulmonary vasculature by the lungs during inspiration may be responsible for the decrease in venous return during ventilation in open chest [5].

On further analysis of present study there was no significant difference in prefluid bolus conditions (CVP, HR, SBP, DBP, MAP, SV, CO, CI) in the responsive group in closed as well as open chest conditions except the SVV value as discussed above. There was no significant difference in the percentage change in the above parameters in the closed and open chest group making the authors state that whatever be the reason for SVV, it was not affected by the chest being open or closed. Whereas, De Waal EE et al., found all static and dynamic preload indicators fail to predict fluid responsiveness under open chest conditions [14]. They have given a fluid challenge immediately after sternotomy. Sternotomy with sternal retractors squeezes the pulmonary blood into the left atrium adding to preload and decreasing in SVV [14]. This explains the low SVV before fluid challenge in the above study and their non responsive result in open chest.

Now coming to secondary aim, there was an increase in SBP, DBP, MAP, SV, CO, CI and decrease in HR and SVV after fluid replacement in both open and closed chest conditions in the responsive group. Change in SVV, SV, CO, was significantly different in responsive group than non responsive group. But the increase in SBP, DBP, MAP, and CI was not significantly different from non responsive group. Other studies have shown similar results with a percentage of raised SVV to respond to fluid replacement with increase in CO and CI but there were some non responders [15,16]. Though, SBP and DBP increased after fluid loading in responsive and non responsive group, the difference was statistically insignificant. As the blood pressure is not only a component of CO but also interplay of sympathetic system, the pressures in the non responsive group may have been maintained.

Limitation(s)

There was no difference in the change in CVP between fluid responders and non responders. Use of pulmonary artery capillary wedge pressure would have given a more precise difference in left ventricular preload.

CONCLUSION(S)

The SVV, are not affected by open or closed chest conditions in mechanically ventilated patients undergoing CABG and can be used as a guide for fluid replacement. Weather open or closed chest conditions, few patients do not respond to fluid replacement when SVV are more than 12% by an increase in SV, cardiac output or CI, the cause of which remains to be determined.

REFERENCES

[1] Heames RM, Gill RS, Ohri SK, Heat DA. Off-pump coronary artery surgery. Anaesthesia. 2002;57:676-85.

[2] De Backer D, Taccone FS, Holsten R, Ibrahimi F, Vincent JL. Influence of respiratory rate on stroke volume variation in mechanically ventilated patients. Anaesthesiology. 2009;110(5):1092-97.

[3] Michard F, Teboul JL. Using heart-lung interactions to assess fluid responsiveness during mechanical ventilation. Crit Care. 2000;4:282-89.

[4] Hofer CK, Müller SM, Furrer L, Klaghofer R, Genoni M, Zollinger A. Stroke volume and pulse pressure variation for prediction of fluid responsiveness in patients undergoing off-pump coronary artery bypass grafting. Chest. 2005;128:848-54.

[5] Reuter DA, Goepfert MSG, Goresch T, Schmoeckel M, Kilger E, Goetz AE, et al. Assessing fluid responsiveness during open chest conditions. British Journal of Anaesthesia. 2005;94(3):318-23.

[6] Sander M, Spies CD, Berger K. Prediction of volume response under open-chest conditions during coronary artery bypass surgery. Crit Care. 2007;11(6):R121. Doi: 10.1186/cc6181.

[7] Manecke GR. Edwards FloTrac sensor and Vigileo monitor: Easy, accurate, reliable cardiac output assessment using the arterial pulse wave. Expert Rev Med Devices. 2005;2:523-27.

[8] Manecke GR Jr, Auger WR. Cardiac output determination from the arterial pressure wave: Clinical testing of a novel algorithm that does not require calibration. J Cardiothorac Vasc Anaesth. 2007;21:03-07.

[9] Berkenstadt H, Margalit N, Hadani M, Friedman Z, Segal E, Villa Y, et al. Stroke volume variation as a predictor of fluid responsiveness in patients undergoing brain surgery. Anaesthesia & Analgesia. 2001;92(4):984-89.

[10] Marik PE, Cavallazzi R, Vasu T, Hirani A. Dynamic changes in arterial waveform derived variables and fluid responsiveness in mechanically ventilated patients. A systematic review of the literature. Crit Care Med. 2009;37:2642-47.

[11] Kwon TD, Kim KH, Ryu HG, Jung CW, Goo JM, Bahk JH. Intra- and extra-pericardial lengths of the superior vena cava in vivo: Implication for the positioning of central venous catheters. Anaesth Intensive Care. 2005;33(3):384-87.

[12] Standring S. (ed), "The anatomical basis of clinical practice" 41st edition page:1027-28:UK: Elsevier: 2015.

[13] Scott DB, Slawson KB, Taylor SH. The circulatory effects of the Valsalvamanoeuvre during anaesthesia and thoracotomy. J Cardiovasc Res. 1969;3:331-37.

[14] De Waal EE, Rex S, Kruitwagen CL, Kalkman CJ, Buhre WF. Dynamic preload indicators fail to predict fluid responsiveness in open-chest conditions. Crit Care Med. 2009;37:510-15.

[15] Angappan S, Parida S, Vasudevan A, Badhe AS. The comparison of stroke volume variation with central venous pressure in predicting fluid responsiveness in septic patients with acute circulatory failure. Indian J Crit Care Med. 2015;19:394-400.

[16] Cannesson M, Musard H. The ability of stroke volume variations obtained with Vigileo/FloTrac system to monitor fluid responsiveness in mechanically ventilated patients. Anaesth Analg. 2009;108(2):513-17.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Aug 24, 2022
- Manual Googling: Sep 19, 2022
- iThenticate Software: Oct 06, 2022 (5%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Aug 10, 2022**
Date of Peer Review: **Sep 13, 2022**
Date of Acceptance: **Nov 17, 2022**
Date of Publishing: **Dec 01, 2022**