Indian Journal of Clinical Anaesthesia 2022;9(3):316–321

Content available at: https://www.ipinnovative.com/open-access-journals

Indian Journal of Clinical Anaesthesia

Journal homepage: www.ijca.in

Original Research Article

A comparative study of hemodynamic stability through intraoperative fluid administration guided by stroke volume variation assessment versus conventional parameters in terms of inferior vena cava diameter and collapsibility index during spine surgery

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ARTICLE INFO

Article history:
Received 17-03-2022
Accepted 24-04-2022
Available online 13-08-2022

Keywords:
Hemodynamics
Intravenous fluid
Inferior vena cava diameter
Stroke volume variation
Collapsibility index
Spine surgery

ABSTRACT

Background: Stroke volume variation (SVV) is a naturally occurring phenomenon, often used by anesthesiologists for hemodynamic response to intra-operative fluid administration. In a mechanically ventilated patient under general anesthesia, the arterial pulse pressure rises during inspiration and falls during expiration due to changes in intra-thoracic pressure secondary to positive pressure ventilation.
Methodology: In this open labelled, parallel group, randomized controlled trial, we investigated the role of using SVV as a marker for optimal intra-operative fluid therapy versus the conventional parameters of hemodynamic monitoring i.e., blood pressure, pulse rate and urine output in patients undergoing major spinal surgery in prone position. It was a single centre study and each group consisted of 35 patients in the age group of 18 – 50 years having ASA grade I status and without any previous comorbidities. SVV was maintained between 10 to 13% and Non-Invasive Blood Pressure (NIBP) and pulse rate maintained within 20% of baseline pre-induction values. Ringer's lactate solution was chosen as fluid therapy in both groups.
Results: The study showed that the total amount of fluid infused to either group had no statistically significant difference; however, the change in Inferior vena cava maximum diameter (IVCmax) in patients of the SVV monitored group was significantly lower than the conventional arm, for a given amount of fluid in either group. (Levene's test for equality of variance $F = 45.46$, test statistics for equality of means $t = 3.86$; $p = 0.001$) Moreover, those patients who were maintained on lower margin of SVV range had a remarkable decrease of collapsibility index of IVC compared to pre-operative values. (Spearman's rank correlation $r = 0.533$; $p = 0.001$)
Conclusion: Thus, SVV proves to be a surrogate marker of administering intravenous fluid per-operatively maintaining euvolemic status as reflected by subsequent IVC collapsibility index (CI) values obtained in patients undergoing spinal surgery.

1. Introduction

Intraoperative fluid therapy has a pivotal role to improve outcome of any surgery. Maintenance of tissue perfusion by maintaining euvolemia is the goal for intra-operative monitoring of intravascular fluid volume and administration of intra-operative fluid therapy.[1,2] Hemodynamic stability is crucial for patients undergoing spine surgeries. In such patients, induction of general anaesthesia and intra-operative bleeding may decrease intravascular volume. Both hypovolemia and hypervolemia are associated with

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https://doi.org/10.18231/j.ijca.2022.064

considerable postoperative morbidity.[3] Thus, this study was undertaken to compare conventional versus Stroke Volume Variation (SVV) guided fluid administration to know the better method of fluid resuscitation intra-operatively.

Goal directed fluid therapy (GDT) aims for optimal peri-operative fluid management protocol to ensure adequate end-organ perfusion, by monitoring various hemodynamic parameters including cardiac output, cardiac index, stroke volume index (SVI), stroke volume variation (SVV). The conventional fluid management is based on the clinical signs such as mean arterial pressure (MAP), pulse rate, central venous pressure (CVP), blood loss during surgery or urine output that are related to the hemodynamic goals of fluid administration.[4] Previous studies indicated that fluid management based on the measurements of functional hemodynamic variables, such as SVV, was more useful to exert a superior effect in improving perfusion and oxygenation.[5] It can also decrease the rate of postoperative complications which might have lowered the median survival rate by 69% in different post-surgical patients.[6–8]

Focused bedside sonography of the inferior vena cava (IVC) has been shown to be useful in estimating intravascular volume status.[9] Diameter of IVC and CI can guide us regarding this. IVC is the largest vein with a low pressure in the venous system having a mean CI of 30%. Visualization of the IVC is easier using ultrasound, and the values can be measured in M-mode.[10] In the recent medical literature, there are few studies done evaluating SVV as a guidance tool for gauging intra-operative fluid therapy in major abdominal, cytoreductive or orthopaedics polytrauma surgery.[11] However, fluid given by assessing conventional parameters versus SVV monitoring has not been yet investigated to assess fluid therapy in spinal surgery in medical literature till date.

Thus, in this study, a comparative evaluation has been done using SVV calculated by Edward FloTrac monitor vis-a-vis hemodynamic changes in blood pressure, pulse rate and blood volume loss as a predictor of fluid responsiveness and guide for intra-operative fluid therapy in patients scheduled for elective spine surgery and change in IVCmax measurements along with collapsibility index used to determine the management outcome perioperatively. The objectives of the study were to determine efficacy for optimum fluid administration intra-operatively in patients using SVV versus conventional hemodynamic parameters like pulse, blood pressure, and by monitoring blood loss and urine output, and to evaluate the degree of hemodynamic stability and compare the post-operative fluid optimization by measurement of IVC diameter and CI in either arm.

2. Materials and Methods

The study was an open label, parallel group, randomized controlled trial, conducted among in-patient department posted for elective spinal surgery of a tertiary care referral public hospital, during the period of May 2020 to April 2021. Study population included Patients aged between 18-50 years, American Society of Anaesthesiology (ASA) physical status Grade I, posted for elective spine surgery. Exclusion criteria were defined as history of psychiatric/neurologic illness, pregnant and nursing women, patients with significant co-morbidity of vital organ system and patients on beta blockers, anticonvulsants, and other centrally acting medications.

Regarding study variables, primary outcome was considered as change in IVC diameter and CI per-operatively, and secondary outcomes were extent of hemodynamic stability like blood pressure and pulse rate, and amount of urine output. After obtaining institutional ethical committee clearance, 70 patients were enrolled in the study ageing 18 to 50 years with ASA status I and informed consent was taken from each one. The study population was allocated into two equal groups using computer generated randomization; Group 1 for patients who were administered intra-operative fluid therapy guided by SVV, and Group 2 for those who were managed with fluid therapy by conventional hemodynamic monitoring.

Patients was kept fasting for 8 hours before the surgery, but water was allowed until 2 hours before starting surgery. Arterial line was done in aseptic way to patients who will receive fluid via SVV monitoring (group 1). USG guided IVC diameter and CI of all patients was measured in 2D/M mode. IVC maximum diameter (IVCmax) was taken 2 cm caudal to the right atrial-IVC junction at end expiration.[12] The transthoracic echocardiographic subcostal window was used to view the IVC in the sagittal plane by angling and rotating the transducer to the left from the subcostal four-chamber view.[13] The maximum and minimum IVC diameters were calculated by tracking the distance between anterior and posterior walls in M mode. The real-time M mode IVC CI was calculated during a spontaneous breathing cycle obtained on frozen screen images.[14]

IVC collapsibility Index = max. diameter on expiration – min. diameter on inspiration/maximum diameter on expiration

On arrival to the operating room, patient's heart rate, non-invasive blood pressure and oxygen saturation was diligently noted by continuous ECG, NIBP monitor, and pulse oximetry monitor respectively. Induction of anaesthesia was done by Inj. propofol (2 mg/kg) followed by maintenance with 50% nitrous oxide in oxygen in low flow and sevoflurane titrated to a MAC below 1. Muscle relaxant Inj. Rocuronium 0.9 mg/kg was used to achieve intubation. Ringer lactate was used as crystalloid of choice in perioperative period. Patients were kept in prone position for surgery. Blood loss due to operation was collected in suction bottle and the volume in the suction bottle was considered for blood loss estimation.

In both groups, maximum allowable blood loss was calculated from standard formulae as depicted below derived from pre-operative hemoglobin values; and the excess loss was replenished with peri-operative blood transfusion. Blood transfusion was not done until the hematocrit decreased to 24 percent or hemoglobin 8gm/dl.[15] Maximum allowable blood loss was calculated as follows.[16]

= estimated blood volume X {preoperative hemoglobin(g%) - target hemoglobin(g%)}/Average hemoglobin(g%)

where average hemoglobin (g%) = [(preoperative Hemoglobin + target Hemoglobin)/2].

And estimated blood volume = body weight (in kg) X blood volume (ml/kg); where blood volume for adult male 75 ml/kg and adult female 65ml/kg.

Patients managed via conventional method, compensatory intravascular volume expansion (CVE)[17] with 5ml/kg ringer lactate was given simultaneously with induction of general anesthesia and the maintenance fluid was given by the Holliday-Segar 4-2-1 rule.[18] Ringer lactate solution was given three times the volume of blood loss until the transfusion point was reached. Transfusion point was determined preoperatively by calculating maximum allowable blood loss. Urine output was maintained 0.5 to 1.5 mL/kg/hour and fluid was given accordingly.

NIBP was maintained within 20% of pre-induction values and hypotension (Systolic BP< 20% of baseline) treated with iv fluids and if required, small dose of iv Phenylephrine (1.0 μg/kg). Heart Rate and Blood Pressure more than 20% of baseline was treated with supplemental analgesia in the form of Inj. Fentanyl 1μg/kg.

In patients of Group 1, fluid was given by measuring SVV. An arterial line was done and connected with FloTrac (Edwards Lifesciences) monitoring system to maintain SVV between 10% to 13% for fluid administration guidance.[19] MAP, pulse rate and SVV values were taken in consideration in 15 minutes interval intraoperatively to get mean values of above three parameters. Reversal of neuro-muscular blockade was obtained by Inj. Neostigmine (0.05 mg/kg) and Inj. Glycopyrrolate (0.01mg/kg). After extubating, IVC diameter and CI was again measured in all patients within first hour of post operative period in the recovery room.

Sample size for the study was calculated based on proportion of subjects in whom satisfactory intravascular volume status (i.e., neither hypovolemia nor hypervolemia) can be maintained as assessed though pre and post operative estimation of IVC diameter and CI. It was estimated that 35 subjects will be required per group to detect a difference of 25% in this proportion with 80% power and 5% probability of type 1 error. This calculation assumes successful proportion to be 75% in the control group (fluid administration guided by conventional hemodynamic assessment) and two-sided testing. Sample size calculation was done with nMaster 2.0 (Department of Biostatistics, Christian Medical College Vellore; 2011) software. Primary outcome data of the two arms were analyzed using independent t test to detect equality of means. Correlation statistics were calculated using Karl Pearson's and Spearman's rank correlation analysis to calculate statistical significance of the outcome data of the two treatment groups using SPSS 24 software version.

3. Results

The mean age of patients in SVV group (n=35) was 43 years (± 9.89) and in the conventional arm (n=35) was 40 years (±7.07). There was no significant difference in the two groups with respect to age, (p value = 0.255) as well as sex ratio between the two groups (p value = 0.881). Before randomization it was also ensured that pre-operative mean blood pressure, pulse rate, IVC diameter and CI in both the arms were properly matched. (Table 1)

The difference between the post and pre-operative IVCmax diameter, CI and total IV fluid given in both the SVV, and conventional arm was statistically analyzed using independent T tests. It was found that the change in IVCmax diameter between the two groups, by independent t test analysis, was statistically significant p = 0.001 (calculated by Levene's F test for homogeneity of variances F = 45.46 and test statistics for equality of means t = 3.86), but neither the change in CI (p = 0.591) nor amount of fluid infused intra-operatively (p = 0.693) in either group reached statistical significance. (Table 2) It signifies that intravenous fluid administered per-operatively with SVV monitoring had statistically significant lower change in IVC diameter (post-op IVCmax – pre-op IVCmax) for a given volume of fluid therapy.

For each group, the change in IVC diameter (delta IVC) was correlated with the total amount of fluid administered to the corresponding patient. Karl Pearson's correlation analysis was applied. In the SVV measured group the correlation coefficient between the delta IVC and fluid administered parameters was found to be r = 0.465 (positive correlation) with a significant p value of 0.005. Similarly, for the conventional group the correlation coefficient was calculated to be r = 0.387 with p value of 0.022. (Figures 1 and 2) (Supplementary data)

Subsequently, the relation of value of mean SVV maintained in patients of Group 1 (interventional arm) intra-operatively, for adequate hemodynamic stability, and the corresponding change in IVC diameter was analyzed i.e., post-operative IVCmax minus pre-operative. Spearman's rank test showed no significant result (p = 0.88), moreover a slight negative correlation is seen indicating the fact that fluid status is inversely proportional in relation to the above two variables.

			Delta IVC	Fluid
KARL Pearson's	Delta IVC	Correlation Coefficient	1.000	0.465
		Sig. (2- tailed)		0.005
		N	35	35
SVV	Fluid	Correlation Coefficient	0.465	1.000
		Sig. (2-tailed)	0.005	
		N	35	35

Fig. 1:

			Delta IVC	Fluid
KARL Pearson's	Delta IVC	Correlation Coefficient	1.000	0.387
		Sig. (2- tailed)		0.022
		N	35	35
Conventional	Fluid	Correlation Coefficient	0.387	1.000
		Sig. (2- tailed)	0.022	
		N	35	35

Fig. 2:

Again, for each group, the change in CI of IVC measured sonographically (delta CI) was correlated with the total amount of fluid administered to the corresponding patient. Karl Pearson's correlation analysis was applied; in the SVV measured group the correlation coefficient between the delta CI and fluid administered parameters was found to be r = 0.012 (negligible positive correlation) with a statistically insignificant p value of 0.947. Similarly, for the conventional group the correlation coefficient was calculated to be r = -0.055 (weak negative correlation) with p value of 0.754.

Spearman's rank test showed that there seems to be a positive correlation between the value of mean SVV maintained for adequate fluid management and the difference in IVC CI measurement obtained post and pre-operatively, correlation coefficient r = 0.535; p value = 0.001. (Figure 3) Thus, it may be concluded that patients if maintained on lower side of the reference SVV value, their post-operative CI significantly decreases with respect to its pre-operative observation, hence indicating a positive fluid balance response per-operatively and vice versa.

			Mean SVV	Delta CI
Spearman's Rho	Mean SVV	Correlation Coefficient	1.000	0.535
		Sig. (2.tailed)	.	.001
		N	35	35
	Delta CI	Correlation Coefficient	0.535	1.000
		Sig. (2.tailed)	.001	.
		N	35	35

Fig. 3:

4. Discussion

Goal-directed fluid therapy refers to operative and immediate postoperative techniques aimed at modifying the hemodynamic status of patients undergoing major surgery. The ultimate goal of these techniques is to achieve optimal oxygen delivery while avoiding the deleterious complications associated with over- and under-resuscitation.[20] First described decades ago,[21,22] the concept of SVV has gained increased attention in the recent years and it has been suggested that it could improve various peri-operative outcomes in selected patients. Randomized trials, however, have shown mixed results. While most trials agree in the safety of these techniques, peri-operative benefits have been seen only in selected procedures and patient populations. In small institutes with limited resources SVV guided fluid administration is not possible due to unavailability of EV 1000 hemodynamic monitor. Fluid administration by conventional method is only way for fluid resuscitation intraoperatively. Thus, this study may guide how conventionally fluid may be given where invasive hemodynamic monitoring is not possible.

Independent t test analysis done for delta IVCmax of both the groups of this study showed a remarkable statistical significance of p = 0.001; indicating the fact that there was a marked difference of delta IVCmax values in patients of SVV group in comparison to conventional arm, for the same amount of IV fluid charged per-operatively. However, the delta CI analysis between both the patient populations revealed no significant difference. Similarly, the amount of intravenous fluid required during surgery in either group was also comparable.

Significant positive correlation was obtained between delta IVCmax diameter and the amount of fluid administered intra-operatively in both the groups; however, a more positive correlation was noted in SVV guided arm where the Karl Pearson's coefficient of correlation was calculated to be 0.465, signifying a positive correlation between IV fluid infused versus change in IVCmax diameter obtained on sonographically. The conventionally monitored arm too had a significant positive correlation of 0.387, lesser than SVV group.

In SVV guided arm, the absolute value of SVV monitored intra-operatively had a meagre negative correlation with ultimate delta IVCmax response, justifying the fact that maintaining SVV on the higher side (within physiological limits) leads to lesser volume overload status, though there was no statistical significance to this observation. In a recent study conducted in by SB Shah et al,[11] delta IVCmax guided intravenous fluid therapy is valuable in low LVEF patients, undergoing major cyto-reductive surgery. They found a significant positive correlation of delta IVCmax with SVV and a regression equation was obtained for the above two variables. However, another prospective, interventional observer

Table 1:

Parameters	SVV Guided Group 1 (Mean ± S.D.)	ConventionalGroup 2 (Mean ± S.D.)	P value
Age (years)	43 ± 9.89	40 ± 7.07	0.255
Sex	M=17, F=18	M=18, F=17	0.881
Pre-op map (mm Hg)	86 ± 5.65	91 ± 4.41	0.613
Pre-op pulse rate	77 ± 3.53	83 ± 2.72	0.705
Pre-op IVC Diameter (in cm)	1.47 ± 0.097	1.48 ± 0.113	0.778
Pre-op CI in %	39.5 ± 1.71	43.5 ± 2.12	0.588

Table 2:

	Levine's test for equality of variances		T test for equality of Means		
	F	Sig.	t	Df	Sig. (2 tailed)
Delta IVC SVV vs. conventional (Equal variances assumed)	45.46	0.001	3.86	68	0.001
Delta CI SVV vs. conventional (Equal variances assumed)	0.497	0.483	0.54	68	0.591
I.V. Fluid SVV vs. conventional (Equal variances assumed)	0.037	0.849	-0.398	45	0.693

blinded study done by Lahner D et al, demonstrates that SVV obtained by Arterial Pulse Contour Analysis, using the FloTracTM/VigileoTM system, is not a reliable predictor of fluid responsiveness in the setting of major abdominal surgery.[23] The discordance in their findings might have surfaced due to smaller sample size of patient population and large fluid boluses necessary during the major surgical procedures. Moreover, they have used the doppler to study stroke volume assessment which is inherently user dependent.

When correlating delta CI data with the amount of intra-operative fluid administered in both groups of patients, we observe no significant correlation either patient population. However, when delta CI was analyzed for patients in the SVV guided arm, a significant positive correlation was observed with corresponding SVV in those patients, suggesting the fact that, maintaining the SVV on its lower side of reference range as in protocol, responds as a positive fluid balance, as the delta CI proportionately decreases and vice versa. Coherently, the study by Kaydu A et al, on 63 general surgical patients with ASA status I to III, the diameter of the IVC did not change preoperatively and postoperatively in adult patients with standard fluid regimen. Delta CI was positively associated preoperatively and postoperatively (regression coefficient = 0.438, $p < 0.01$)[24] as seen in our study.

Numerous studies have shown that SVV have good predictive ability for fluid responsiveness compared to CVP in liver transplant, hepatic resection, and cardiac surgery patients receiving mechanical ventilation.[25–27] These studies showed that an SVV threshold (>10%) had a sensitivity and specificity between 80% and 94%, suggesting that the Vigileo/ FloTrac can be used to guide fluid therapy in the operating room. The results of these studies showed that SVV is correlated well with an increase in SVI, and that receiver operating characteristic (ROC) curves suggested that SVV can predict fluid responsiveness, which agree with the findings in surgical patients. CVP and pulmonary artery occlusion pressure has been known as the criterion standard reflecting intravascular volume. Nevertheless, numerous studies have shown that CVP and pulmonary artery occlusion pressure monitoring are poor measures of volume status and cannot be used reliably to predict fluid responsiveness across large-scale patients.[28–33]

There were certain limitations pertaining to this study. Firstly, the study population was small with only 70 patients under investigation. Secondly, our patients were ASA grade I with baseline euvolumic status without any prior medical co-morbidity. Thirdly, physiological changes in prone position had not been studied in this study.

5. Conclusion

Stroke volume variation can be considered as a surrogate marker for fluid responsiveness, and as a guide for intra-operative fluid therapy maintaining euvolemic status during spine surgery.

6. Individual Contribution

SM: Patient recruitment, data collection, supervision; SG: Study design, data analysis, writing up of the final draft of the paper.

7. Source of Funding

None.

8. Conflict of Interest

The authors declare no conflict of interest.

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Cite this article: Ghosh S, Mukhopadhyay S. A comparative study of hemodynamic stability through intraoperative fluid administration guided by stroke volume variation assessment versus conventional parameters in terms of inferior vena cava diameter and collapsibility index during spine surgery. *Indian J Clin Anaesth* 2022;9(3):316-321.