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The Significance of Stroke Volume Variation During Hepatic Resection Under Infrahepatic Inferior Vena Cava and Portal Triad Clamping

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Abstract

Purpose : Stroke volume variation (SVV), which is measured by analyzing arterial blood pressure waveform characteristics, is a simple and sensitive indicator of fluid responsiveness. The current retrospective study was to investigate SVV and central venous pressure (CVP) during hepatic resection under clamping of both the infrahepatic inferior vena cava (IVC) and the portal triad.

Methods : All hepatic resections performed from December 2009 to February 2010 at the Department of Surgery at Iizuka Hospital in Japan were included in this study. Invasive hemodynamic monitoring including CVP and SVV were performed in 14 patients.

Results : CVP was significantly lower in patients with blood loss ≤ 486 g than in those with blood loss > 486g. SVV was significantly higher in patients with blood loss ≤ 486g than those with blood loss > 486 g during both IVC clamping and IVC + portal triad clamping. Estimated blood loss was significantly less in the group with SVV values > 18% compared to the group with values ≤ 18%. There was a significant correlation between SVV and CVP (R^2= 0.714 ; P < .01).

Conclusion : SVV is a useful indicator of intraoperative blood loss without the monitoring of CVP during hepatic resection under clamping of both the infrahepatic IVC and the portal triad.

Key words : Stroke Volume Variation (SVV) · Central venous pressure (CVP) · Hepatectomy

Introduction

Despite advances in the understanding of liver anatomy and the refinements of operative procedures, blood loss remains a major obstacle in hepatic resection. Excessive blood loss results in intraoperative death and has been linked to higher postoperative mortality and morbidity rates[1)~6)]. The inflow occlusion technique was originally described by Pringle to decrease blood loss[7)]. In addition, the reduction of central venous pressure (CVP) has gained wide acceptance among hepatobiliary surgeons as a tool to limit blood loss via hepatic veins[8)~11)]. Infrahepatic clamping of the inferior vena cava (IVC) is used to reduce CVP without the need for systemic fluid restriction[12)~14)].

Fluid management is often difficult to gauge during major surgery due to the lack of a reliable indicator of fluid status. It is reported that using a static indicator such as CVP, pulmonary artery occlusion pressure may be unreliable in detecting

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volume responsiveness in critically ill patients[15)~18)]. The FloTrac sensor in combination with the Vigileo monitor (Edwards Lifesciences, Tokyo, Japan) is a recently introduced arterial pressure-based system for continuously monitoring cardiac output (CO). The FloTrac sensor is a less invasive hemodynamic monitoring device that can be used to continuously monitor CO, stroke volume, and stroke volume variation (SVV)[19)]. The usefulness of SVV was previously reported in patients on mechanical ventilation, after major abdominal surgery and with reduced cardiac dysfunction[20)~22)]. Kobayashi et al.[23)] reported that SVV is an accurate predictor of intravascular hypovolemia during the perioperative period after esophagectomy, while Kim et al.[24)] reported that a low SVV was a significant independent predictor of blood loss ≥ 700mL during donor hepatectomy ; however no reports have been published about the trend of SVV during hepatectomy, especially under clamping of both the infrahepatic IVC and the portal triad.

Here we conducted a retrospective study to investigate SVV using the FloTrac sensor/Vigileo monitor system and CVP during hepatic resection under the clamping of both the infrahepatic IVC and the portal triad.

Patients and methods

All hepatic resections performed from December 2009 to February 2010 at the Department of Surgery at Iizuka Hospital in Japan were included in this study. Only patients who met the following criteria were enrolled : (1) liver resection without biliary reconstruction ; (2) no other malignancies and (3) compensated cirrhosis with Child-Pugh class A. Liver function was evaluated preoperatively using Child classification and an indocyanine green retention test at 15 minutes (ICGR15) in patients with underlying liver disease. The presence of ascites and an ICGR15 test value > 40% were considered absolute contraindications for resection. Hepatitis B surface antigen and hepatitis C antibody were routinely measured preoperatively.

Invasive hemodynamic monitoring was initiated after anesthesia was induced. An arterial line was inserted in the left radial artery (20G catheter), and a central venous line consisting of a double-lumen 8Fr catheter (Arrow International Inc., Pennsylvania, PA, USA) was inserted into the right internal jugular vein. CVP was measured continuously during the perioperative period using a low-pressure transducer. SVV was continuously displayed on the Vigileo monitor. All monitoring transducers were positioned and zeroed at the midaxillary level. The ventilator settings were standardized with volume-controlled ventilation with a tidal volume of 8-10mL/kg and zero end-expiratory pressure. The ventilatory frequency was adjusted to maintain end-tidal CO_2 levels of 35-40mmHg.

A background Ringer's lactate infusion rate of 4mL/kg/h was maintained throughout the surgery in all patients. Mean arterial pressure was maintained at > 65 mmHg using dopamine (0-5μg/kg/min). Surgical technique and intraoperative care was standardized by the same team in this study. These included a J-shaped incision for routine abdominal access, a slow and gentle hepatic dissection using an ultrasonic dissector with a coagulator (CUSA Excel ; Integra Co., USA), with systematic ligation of all sizable vessels, and close ultrasonographic guidance along the transection line. Cholecystectomy was performed in all patients in whom a gallbladder was present. An intraoperative bile leakage test was routinely performed to identify bile leakage[10)]. Following this procedure, we recognized and repaired small bile leakage sites on the cut liver surface by Z-suturing using 6-0PDSII (Johnson & Johnson Corp., Tokyo, Japan). Intraoperative vascular control was achieved using the Pringle maneuver[11)]. To prevent backflow bleeding, central venous pressure was decreased with careful circulating volume and respiratory assistance. Outflow control was achieved by clamping of the infrahepatic IVC[10)]. One or 2 closed drains

were inserted close to the cut surface of the liver parenchyma. Before the subcutaneous tissue was closed, the wound was washed with 1L of saline. The drains were removed when no bleeding or bile leakage was observed within 3days. Bile leakage was defined as the drainage of macroscopic bile from the surgical drains for > 7 days after surgery[25].

Statistics

We analyzed the associations among the continuous and categorical clinicopathological variables using the Student's t test and the Chi-square test, respectively. A P value < .05 was considered statistically significant.

Results

The patients'backgrounds and intraoperative data in this study are shown in Table 1. There was no hospital mortality in this study. Figure 1 shows the change of SVV and CVP at each individual phase compared with no clamping. No change was observed with portal triad clamping. The significant increase of SVV was observed with IVC clamping, whereas the decrease of CVP was not significant. A significant increase of SVV and decrease of CVP were observed with clamping of the IVC and the portal triad. Both SVV and CVP returned to baseline with the release of the portal triad and IVC clamping. Median blood loss was 486g (Table 1). We divided the 14patients into 2 groups, blood loss > 486g (n = 7) and blood loss ≤ 486g (n = 7). Table 2 compares the clinicopathological data of the groups. Operation time was significantly shorter in the group with blood loss ≤ 486g compared to the group with blood loss > 486g. During IVC clamping and IVC + portal triad clamping, CVP was significantly lower in the patients with blood loss ≤ 486g than in the patients with blood loss > 486g. SVV was significantly higher in the patients with blood loss ≤ 486g than in the patients with blood loss > 486g during IVC clamping and IVC + portal triad clamping.

Table 1 Patients background and intraoperative parameters

factors	n = 14
Age	66 (49-79)
Male/Female	10/4
Body mass index	23.1 ± 5.2
Albumin (g/dl)	3.9 ± 0.5
Total bilirubin (mg/dl)	0.8 ± 0.4
prothrombin time (%)	76 ± 31
Platelet count (x10^4/μl)	22.0 ± 11.0
ICGR15 (%)	15.0 ± 9.0
ASA score 1/2/3	2/7/5
HCC/non-HCC	9/5
cirrhosis (%)	7 (50)
Anatomical/non-anatomical	7/7
Operation time (min)	314 (169-581)
Blood loss (g)	486 (120-2214)
CVP (mmHg)	
no clamping	8.5 ± 2.0
with IVC clamping	8.1 ± 2.5
with portal triad clamping	8.0 ± 1.6
with both IVC and portal triad clamping	6.7 ± 1.9
SVV (%)	
no clamping	10.5 ± 4.2
with IVC clamping	14.7 ± 6.6
with portal triad clamping	11.5 ± 4.5
with both IVC and portal triad clamping	16.9 ± 7.5
Transfusion	2 (14.3%)
complication	3 (21.4%)
ascites	1
bile leakage	2
hospital stay (days)	16 ± 15

Data are expressed as means ± standard deviations, median (interquartile range), or number of patients (percentage) as appropriate.

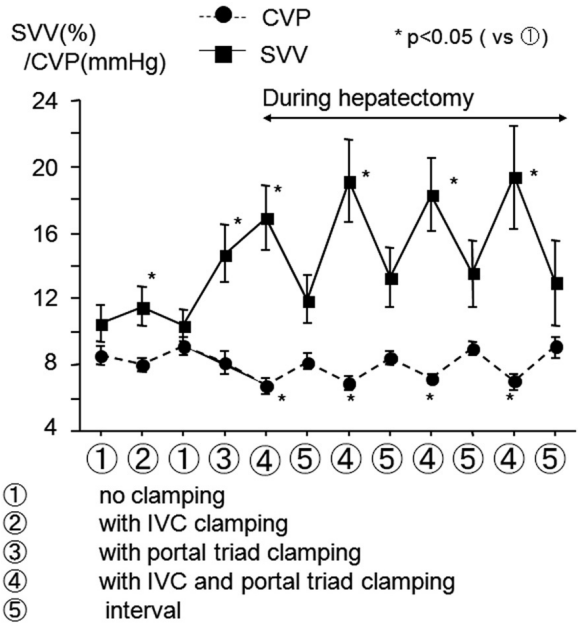

Fig. 1 Changes of SVV and CVP by phase. P values were evaluated as compared to with no clamping. Data are expressed as means ± standard deviations, median (interquartile range), or number of patients (percentage) as appropriate. CVP, central venous pressure ; SVV, stroke volume variation ; IVC, inferior vena cava.

Table 2 Comparison of clinicopathological data of the groups

variables	blood loss > 486g (n = 7)	≦ 486g (n = 7)	p value
Age	67 (59–77)	68 (49–79)	n.s.
Male/Female	6/1	4/3	n.s.
Body mass index	22.8 ± 4.2	23.8 ± 5.2	n.s.
Albumin (g/dl)	4.1 ± 0.3	3.8 ± 0.5	n.s.
Total bilirubin (mg/dl)	1.0 ± 0.4	0.7 ± 0.1	n.s.
prothrombin time (%)	92 ± 16	90 ± 30	n.s.
Platelet count ($x10^4/\mu l$)	24.2 ± 13.6	19.8 ± 8.2	n.s.
ICGR15 (%)	17.6 ± 15.0	12.5 ± 9.5	n.s.
ASA score 1/2/3	0/3/4	2/4/1	n.s.
HCC/non-HCC	4/3	5/2	n.s.
cirrhosis	3 (42.9%)	2 (28.6%)	n.s.
Anatomical/non-anatomical	4/3	4/3	n.s.
Operation time (min)	335 (252–581)	255 (169–375)	< 0.05
Blood loss (g)	755 (523–2214)	200 (120–450)	< 0.01
CVP (mmHg)			
no clamping	9.3 ± 1.6	9.0 ± 2.7	n.s.
with IVC clamping	9.6 ± 1.6	6.7 ± 2.4	< 0.05
with portal triad clamping	8.6 ± 1.5	7.6 ± 1.7	n.s.
with both IVC and portal triad clamping	7.8 ± 1.6	5.6 ± 1.5	< 0.05
SVV (%)			
no clamping	10.0 ± 3.5	11.1 ± 5.1	n.s.
with IVC clamping	11.1 ± 4.0	18.3 ± 6.9	< 0.05
with portal triad clamping	11.4 ± 5.2	11.7 ± 4.0	n.s.
with both IVC and portal triad clamping	14.4 ± 6.7	21.5 ± 5.3	< 0.05
Transfusion	1 (14.3%)	1 (14.3%)	n.s.
complication	2 (28.6%)	1 (14.3%)	n.s.
hospital stay (days)	20 ± 14	13 ± 3.8	n.s.

Data are expressed as means ± standard deviations, median (interquartile range), or number of patients (percentage) as appropriate.

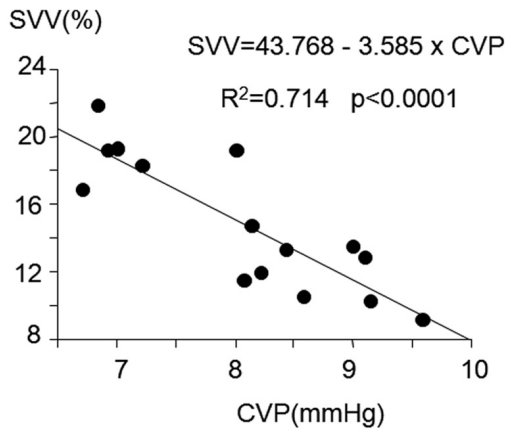

Fig. 2 The relationship of SVV and CVP. There was significant correlation between SVV and CVP (P <.01). SVV, stroke volume variation ; CVP, central venous pressure

No significant differences were recognized in the liver function evaluation. There were no significant differences in transfusion rate, post-operative complications, or hospital stay. We also divided the 14patients into 2 groups, SVV > 18% (n = 8) and SVV ≤ 18% (n = 6). Table 3 compares the clinicopathological data of the groups. Estimated blood loss was significantly lower in the group of patients with SVV > 18% compared to the group of patients with SVV ≤ 18%. CVP was significantly lower in the SVV > 18% group during IVC + portal triad clamping.

There was a significant correlation between SVV and CVP (R^2= 0.714 ; P <.01)(Fig. 2). The higher SVV value was correlated with the lower CVP level.

Table 3 Comparison of clinicopathological data of the groups

variables	SVV > 18% (n = 8)	SVV ≦ 18% (n = 6)	p value
Age	67 (49–79)	68 (59–78)	n.s.
Male/Female	4/4	6/0	n.s.
Body mass index	23.1 ± 3.2	24.0 ± 3.2	n.s.
Albumin (g/dl)	3.8 ± 0.4	4.1 ± 0.3	n.s.
Total bilirubin (mg/dl)	0.9 ± 0.5	0.9 ± 0.1	n.s.
prothrombin time (%)	86 ± 28	97 ± 13	n.s.
Platelet count ($x10^4$/μl)	24.9 ± 13.8	18.1 ± 3.8	n.s.
ICGR15 (%)	16.8 ± 16.3	12.7 ± 3.5	n.s.
ASA score 1/2/3	0/3/4	2/4/1	n.s.
HCC/non-HCC	5/3	4/2	n.s.
cirrhosis	3 (37.5%)	2 (33.3%)	n.s.
Anatomical/non-anatomical	5/3	3/3	n.s.
Operation time (min)	365 (252–581)	284 (169–375)	n.s.
Blood loss (g)	411 (120–650)	1079 (560–2214)	0.03
CVP (mmHg)			
no clamping	8.4 ± 0.7	8.8 ± 0.8	n.s.
with IVC clamping	7.3 ± 2.6	9.3 ± 1.8	n.s.
with portal triad clamping	7.5 ± 1.4	8.8 ± 1.7	n.s.
with both IVC and portal triad clamping	5.8 ± 1.6	7.8 ± 1.8	0.05
Transfusion	1 (12.5%)	1 (16.7%)	n.s.
complication	2 (25.0%)	1 (16.7%)	n.s.
hospital stay (days)	19 ± 13	13 ± 4.3	n.s.

Data are expressed as means ± standard deviations, median (interquartile range), or number of patients (percentage) as appropriate.

Discussion

In this study, we demonstrated the correlation between SVV and CVP and that a higher SVV level or lower CVP level leads to reduced blood loss, especially when SVV > 18%. Both CVP and SVV were good indicators of intraoperative blood loss. Excessive blood loss leads to intraoperative death and has been linked to higher postoperative mortality and morbidity rates. Surgeons monitor CVP during hepatectomy and try to keep CVP values low to reduce intraoperative blood loss. Some reports have demonstrated that IVC clamping decreases blood loss during major hepatectomy due to reduced CVP[12)~14)]. Uchiyama et al.[13)] reported that low CVP (< 3mmHg) significantly reduced bleeding during major hepatectomy, while Otsubo et al.[11)] reported that IVC clamping below the liver reduced the CVP values in patients with high CVP (> 5cmH_2O) and then reduced their estimated blood loss. The volume of blood loss during hepatectomy correlated with the CVP value.

SVV, which is measured by analyzing arterial blood pressure waveform characteristics, is a simple and sensitive indicator of fluid responsiveness. SVV is often measured during esophageal surgery, liver transplantation surgery, and many other major surgeries. Dynamic preload indices such as SVV can more accurately predict fluid responsiveness than static preload indices such as CVP in mechanically ventilated patients.

Kim et al.[24)] reported that a low SVV was a significant independent predictor of blood loss ≥ 700mL during donor hepatectomy and that CVP was not an independent hemodynamic factor of

intraoperative blood loss in living donor right hepatectomy. CVP is influenced by patient position, surgical manipulation and intrathoracic pressure. In this study, both high SVV and lower CVP values were good indicators of reduced blood loss, the latter of which was reported in previous reports.

Central venous catheter insertion carries the risks of pneumothorax, nerve puncture, major bleeding, infection and central venous catheter (CVC)-related vein thrombosis[30)~32)]. The complication is rare but serious. Use of the FloTrac sensor to monitor SVV is a less invasive hemodynamic monitoring method that uses only an arterial line. Hepatectomy using SVV monitoring may lead to a safe and simple surgery that reduces blood loss without requiring CVC insertion.

In conclusion, SVV is a simple and useful indicator of intraoperative blood loss that does not require CVP monitoring during hepatic resection under clamping of both the infrahepatic IVC and the portal triad.

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（和文抄録）

肝下部下大静脈併用肝切除において Stroke Volume Variation は CVP と逆相関し出血量の指標となりうる

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【はじめに】近年，stroke volume（一回拍出量）は呼吸性変動を受け，この変化量である stroke volume variation（SVV）が fluid responsiveness（輸液反応性）の指標として CVP よりも鋭敏であると言われている．動脈ラインに FloTrack™を接続すれば SVV は簡便に測定可能である．また肝切除における下大静脈クランプ（IVCC）は中心静脈圧（CVP）を下げ，出血コントロールに有用であるとの報告があるが，中心静脈路の確保が必要となる．
【目的】IVCC 併用肝切除時の SV が CVP の代用となり得るかを検討した．
【対象】平成 22 年 12 月から 2ヶ月間の肝切除 14 例（男 10 例，女 4 例，49～79 歳）．全例ダブルルーメンの中心静脈カテーテルを挿入し CVP を測定，SVV は FloTrack™を用いて測定した．肝切除は CUSA を用いて IVCC + Pringle 法下に行った．
【結果】IVCC にて有意に SVV が上昇したが CVP の有意な低下はみられなかった．Pringle のみでは両者とも変化を認めなかった．肝切除中，IVCC + Pringle にて有意に CVP 低下，SVV 上昇し，Pringle 解除にて速やかに前値に戻った．SVV と CVP は有意に逆相関した．14 例の出血量の中央値 486g（120～2214）であり，出血量が 486g 以下の症例を A 群（n=7），以上の症例を B 群（n=7）とし，A 群では IVCC 時に有意に CVP が低下し，SVV が上昇していた．SVV18% 以上の症例（n=4）では有意に出血量が少なかった．
【結論】SVV は CVP と有意に相関しており，SVV の測定は，IVCC 併用肝切除時には CVP の代用となりうる．また SVV18% 以上を目標にした IHVCC 併用肝切除は出血の軽減に寄与すると思われた．