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Does Inferior-Vena-Cava Collapsibility Correlate with Fluid Regimen and Outcome in Patients Undergoing Liver Resection?

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Abstract

Aim: We retrospectively investigated whether inferior-vena-cava diameter variations due to mechanical ventilation, correlates with fluid regimen and outcome in hepatic resection.

Methods: We analyzed data from 91 cases of liver resection during which inferior vena cava collapsibility was measured in duplicate, before and after the resection phase of the operation (IVCI1 and IVCI2). IVCI was calculated according to the following formula: [IVCDmax-IVCDmin]/[0.5 × (IVCDmax+IVCDmin)], where IVCDmax and IVCDmin stand for the maximal and minimal IVCD within one a respiratory cycle. IVCI variation (ΔIVCI) was defined as: (IVCI pre-resection-IVCI post-resection)/IVCI pre-resection. Fluid management focused to maintain CVP <6 mmHg during the parenchymal dissection in an effort to reduce the backflow bleeding and limit the blood loss. Therefore, fluid administration included a volume input 3-5 ml/kg/h of crystalloid solutions from the induction of anesthesia until parenchymal dissection was concluded. Additional fluid administration was at the judgment of the anesthesiologist. Then we searched for any correlation between IVCI and other hemodynamic parameters, fluid regimen administration and the post-operative outcome.

Results: Among 91 patients enrolled in the study, 57 (63%) were male and 34 (37%) female aged from 34 to 85 years (median 62 years). The median ASA was 2 (range 1-3). The median operation time was 374 min (range 150-720). Liver transaction was accomplished employing the Pringle maneuver and the median total liver ischemic time was 82 min (range 9-182).

After liver resection ending many variables differed significantly from starting values: IVCI from 0.26 ± 0.21 to 0.18 ± 0.16 ($p<0.001$); HR from 68 ± 14 to 78 ± 13 bpm ($p<0.001$); CI from 2.6 ± 0.7 to 3.0 ± 0.8 L/min/m2 ($p<0.001$). All BGA values changed significantly ($p<0.001$). Serum lactate concentration showed a significant increase during the parenchymal dissection changing from 0.95 ± 0.5 to 4.1 ± 2.0 mmol/L ($p<0.001$). Serum hemoglobin lowered from 11.3 ± 1.7 g/dl to 9.8 ± 1.8 g/dl ($p<0.001$). In contrast, CVP and SVV did not change significantly. Both IVCI1 and IVC2 showed a weak correlation with CI ($r=-0.166$ and $r=-0.087$), CVP ($r=-0.049$ and $r=-0.083$) and SVV ($r=0.138$ and $r=0.121$). According to postoperative outcome patients were divided in two groups: Group 1 (complicated) and Group 2 (non-complicated). The IVCI resulted not significantly different between two groups (0.12 ± 0.11 vs 0.16 ± 0.13; $p=0.105$) which were homogeneous for global fluid regimen (7.25 ± 2.63 ml/kg/h vs 7.98 ± 2.93 ml/kg/h; $p=0.341$).

Conclusions: Although retrospectively, it seems clear that, during hepatic resection, IVCI is not sensible to fluid administration and is not correlated with postoperative outcome.

Keywords: Inferior vena cava collapsibility; Fluid responsiveness; Fluid regimen administration; Hepatic surgery; Outcome

Introduction

Intraoperative fluid management aiming to ensure adequate circulating volume is a challenging issue both in critically ill patients and during major surgery. The optimization of fluid administration is a target of paramount importance to ensure good outcome in surgical patients [1-2]. However there is a worldwide consensus about the need of monitoring indices which should guide the fluid administration [3].

Many trials compared central venous pressure (CVP) with ultrasound measurement of inferior vena cava diameter (IVCD) and its variations by mutual agreement with respiratory pressures [4-8]. However, the correlation between CVP and IVCD still remain object of debate. A good correlation is reported between IVC collapsibility (inferior vena cava index, IVCI) and fluid responsiveness (FR), this latter defined as an increase of cardiac index (CI) by at least 15% in response to fluid administration, during both mechanical and spontaneous ventilation [9].

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The role of IVCI in hemodynamic response after fluid administration has been investigated both in emergency department and septic patients. As reported, IVCI represents a predictive factor of FR and help to discriminate between responder and non-responder [10-13]. However it should be noted that the majority of studies on indices predicting FR and hemodynamic setting has been focused on critically ill patients or in surgical patients during the perioperative period. Therefore, accurate intraoperative predictors of the hemodynamic status are needed for an optimal patient's management.

The fluid management of patients undergoing liver resection may be challenging for several reasons: 1) underlying liver disease (i.e., cirrhosis, chronic hepatitis or steatosis); 2) need of low CVP in order to minimize the backflow bleeding; 3) long lasting operation and prolonged intermittent cumulative clamping time [14] occurring in case of very complex tumor presentation. Therefore, the issue is to match the hemodynamic needing by a restrictive fluid regimen with an adequate organ perfusion.

In such context the usefulness of the IVCI in the setting of hepatic surgery has been poorly investigated. Therefore, the aim of this study was to evaluate whether IVCI measured intraoperatively, was affected by fluid administration and could add any helpful information about the hemodynamic during hepatic resection. In addition, given the correlation between the intraoperative fluid regimen and surgical outcome [1-3], we investigated whether IVCI was somehow correlated with the risk of postoperative complication.

Materials and Methods

Trial registration on clinicaltrials.gov ID: NCT02404909.

Definitions

IVCI was calculated according to the following formula: [IVCDmax-IVCDmin]/[0.5 × (IVCDmax+IVCDmin)], where IVCDmax and IVCDmin stand for the maximal and minimal IVCD within one a respiratory cycle [12]. IVCI variation (ΔIVCI) was defined as: (IVCI pre-resection-IVCI post-resection)/IVCI pre-resection.

The target hemodynamic values were considered as follows: CVP 0-6 mmHg; CI 2-3 L/min/m^2 Body Surface Area; stroke volume variation (SVV) baseline ≤ 15% and SVV ≤ 10% once liver dissection was concluded according to authors' Institutional policy. Liver anatomy and surgical procedures were classified according to the Brisbane terminology, [15]. Surgical complications were scored according to the Dindo-Clavien classification [16].

Patients

The present retrospective study was conducted according to the STROBE Statement [17]. Out of 1108 consecutive patients who underwent hepatectomy for primary and secondary liver tumors at the Department of Hepatobiliary Surgery, Humanitas Research Hospital, Milan, 91 (8%) patients in whom ICV diameters were intraoperatively measured for clinical reasons were retrospectively selected and analyzed.

Patients with tumoral thrombosis or full tumoral involvement/compression of IVC were excluded. Patients unrespectable at laparotomy for any extra-hepatic or intrahepatic reason and patients previously submitted to hepatectomy were not included. Primary endpoint was to investigate the influence of the liver resection on hemodynamic status in terms of hemodynamic indexes changes.

Secondary endpoints were: 1) to assess the correlation between IVCI and other hemodynamic indexes (i.e., CI, SVV and CVP) at baseline and after parenchymal dissection; 2) to investigate the correlation between IVCD ranging 1.6-2.2 cm and CVP, according to Brennan criteria [18]. Tertiary endpoint was to investigate the capability of the IVCI in predicting the short-term outcome after hepatectomy.

Anesthesia and intraoperative monitoring

After induction of general anesthesia with fentanyl 0.1 mcg/kg +Propofol 2.5 mg/kg, an oral-tracheal tube was inserted after the administration of cis-atracurium 0.15 mg/kg. Anesthesia was prolonged with a gas mixture (oxygen+air) and sevoflurane 2% by mechanical ventilation (tidal volume 6 ml/kg; Respiratory Rate 12 apm; FiO_2 0.4-0.5; PEEP 5 cm H_2O); myorelaxation was obtained by cis-atracurium administration 1-2 mcg/kg/min. For intraoperative analgesia remifentanil 0.2 mcg/kg/min was selected.

Besides SVV and CI, the other hemodynamic data recorded were: electrocardiogram (D2-V5), heart rate (HR), invasive arterial blood pressure (IABP) by insertion of radial artery line, peripheral oxygen saturation (SpO_2), end-tidal carbon dioxide ($EtCO_2$), CVP, body temperature (T°C), diuresis. Each hemodynamic measurement was obtained by FloTrack/VigileoTM (Edwards Lifescience, Irvine, CA, US).

Fluid management

Fluid management focused to maintain CVP ≤ 6 mmHg during the parenchymal dissection in an effort to reduce the blackflow bleeding and limit the blood loss. Therefore, fluid administration included a volume input 3-5 ml/kg/h of crystalloid solutions from the induction of anesthesia until parenchymal dissection was concluded. Additional fluid administration was at the discretion of the anesthesiologist based on clinical signs of systemic hypoperfusion (e.g., serum lactate and/or any significant decrease in CI or mean arterial pressure). Albumin and/or fresh frozen plasma (FFP) were administered to increase plasma oncotic pressure and to compensate for potentially reduced hepatic synthetic function in cirrhotic patients, according the hemodynamic assessment and blood-gas analysis (BGA). After liver resection 5-15 ml/kg/h of crystalloid solution was generally administered until patient awakened. For fluid replacement during the postoperative period, lactate-free solutions such as 0.9% normal saline or Isolyte (Baxter® healthcare Corporation, Italy) were used until 3rd postoperative day (1-1.5 ml/kg/h). Urine output target was ≥ 0.5 ml/kg/h.

Intraoperative blood transfusion was generally considered based on the following criteria: haemoglobin<7 g/dl in patients without cardiovascular disease; haemoglobin<10 g/dl in patients suffering from coronary heart disease (CAD).

Surgical details and intraoperative ultrasound

J-shaped laparotomy or thoraco-phreno-laparotomy (TPL) was performed to achieve adequate exposure. Intraoperative ultrasound (IOUS) was performed using an Aloka machine (Aloka ProSound F75, Aloka, Tokyo, Japan) equipped with both a linear T-probe and a microconvex probe (7.5-10 MHz frequency) and a standard convex probe (2-6 MHz frequency). An Esaote Twice (Esaote, Genova, Italy) equipped with an intraoperative T-shaped probe (IOT332 probe, Esaote, Italy) working at 3-11 MHz frequency was also used. All IOUS were performed by a surgical team with the expertise in ultrasound during liver surgery.

The IVCDs pre-resection (IVCD$_1$) were assessed just after the abdomen opened and before liver mobilization to avoid potential measurement distortions. The IVCDs post-resection (IVCD$_2$) were measured once the remnant liver was repositioned in the original anatomic location as much as possible. The probe was placed on the liver surface in order to visualize the IVC in the sagittal section. To standardize the measurement, the IVCD assessment was systematically performed at 2 cm caudal of the confluence of the middle hepatic vein into the IVC. M-mode probe was used to identify the minimum and maximum IVCD at the end-inspiration and end-expiration, respectively (Figure 1).

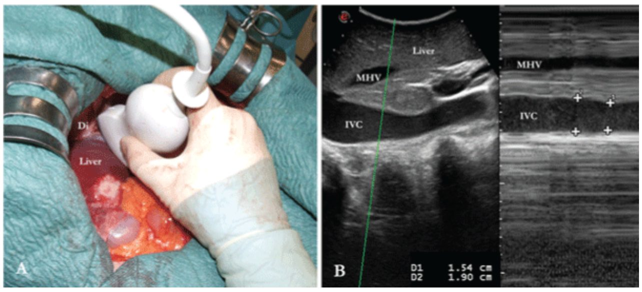

Figure 1: Intraoperative modality of IVCI measurement. A) Surgical image shows the position of the probe on the liver surface in order to visualize the inferior vena cava (IVC) in the longitudinal axis; B) (left), B-mode IOUS image shows the measurement point (green line) of the IVC diameters provided 2cm before the middle hepatic vein (MHV) empties into the IVC; (right), M-mode IOUS image shows the maximum (D2) and the minimum (D1) IVC diameters during mechanical ventilation. Di=Diagphram.

Liver was mobilized by dissecting the right and/or left triangular and coronary ligaments to control the cava vein-hepatic veins confluence, properly. Parenchymal dissection was carried out under intermittent pedicle clamping consisting of 15-20 minutes of inflow occlusion followed by 5 min of reperfusion in order to avoid irreversible ischemia-reperfusion injury.

CVP was maintained between 0 and 6 mmHg during liver transection, as much as possible, to limit the backflow bleeding from hepatic veins (HV) as aforementioned. Such bleeding should have been controlled by finger-compression technique or HV clamping whenever needed [19].

Postoperative management

Postoperative pain was routinely controlled by the continuous infusion of a saline solution (50 ml; 2.1 ml/h) containing opioid +nonsteroidal anti-inflammatory drugs. Rescue analgesia (if Numeric Rating Scale ≥ 4) consisted of Tramadol 100 mg+Ondansetron 4 mg in saline 100 ml i.v. bolus, no more than three times a day. Epidural analgesia was not adopted.

After awakening, patients were admitted to ICU according to the following criteria: 1) history of CAD with ejection fraction<0.40, severe respiratory disease; 2) operation time lasting ≥ 600 min; 3) intraoperative blood loss affecting the hemodynamic status (mean arterial pressure<50mmHg refractory to fluid challenge and/or requiring vasoactive drugs administration.

Statistical analysis

Categorical variables were reported as number and percentage. Continuous variables were expressed as mean, standard deviation or median (range); t-Student test for quantitative data and Fisher's Exact test for qualitative data were applied as appropriate and differences were considered significant when $p<0.05$.

Correlation analysis was performed by computing the Pearson coefficient (r) with its confidence interval. The correlation was considered weak when $r<0.4$, moderate when $r=0.4-0.59$, strong when $r=0.6-0.79$ and very strong when $r \geq 0.8$. Statistical analysis was performed by Stata 13, Software-StataCorp. 4905 Lakeway Drive College Station, Texas 77845-4512 USA.

Patients' characteristics and operative data	
Demographics	
Age (years), median (range)	62 (34-85)
ASA, median (range)	2 (1-3)
Sex (male-female ratio)	58:33
BMI (kg/m^2)	25.7 ± 4.8
Mean arterial pressure (mmHg)	92 ± 11
Heart rate (bpm)	71 ± 14
Hemoglobin (g/dl)	13.4 ± 1.8
Hematocrit (%)	40.5 ± 5.3
Serum creatinine (mg/dl)	0.87 ± 0.19
Preoperative risk factors	
Smoking, n. (%)	40 (44)
Diabetes mellitus, n. (%)	17 (19)
Hypertension, n. (%)	49 (53)
COPD, n. (%)	13 (14)
Myocardial disease, n. (%)	15 (16)
Background liver	
Cirrhosis, n. (%)	9 (10)
Steatosis, n. (%)	53 (58)
Chronic hepatitis, n. (%)	8 (9)
Normal, n. (%)	21 (23)

Values are given as mean values ± standard deviation (SD), unless otherwise indicated. BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease

Table 1: Patients' characteristics and operative data.

Results

Patients' characteristics and operative data

Demographic and operative data are summarized in Tables 1-2. Among 91 patients enrolled in the study, 57 (63%) were male and 34 (37%) female aged from 34 to 85 years (median 62 years). The median ASA was 2 (range 1-3). Nine (10%) patients had cirrhosis and 53 (58%) steatosis.

Surgical procedure and short-term outcome	
Type of liver resection	
Major hepatectomy, n. (%)	14 (15)
Minor hepatectomy, n. (%)	77 (85)
Thoraco-phrenolaparotomy, n. (%)	44 (48)
Operative time, min	374 (150-720)
Clamping time, min	82 (9-182)
Number of pringle maneuver	4 (1-9)
Intraoperative blood loss, ml	250 (50-1800)
Postoperative outcome	
90-day operative mortality, n. (%)	-
Overall morbidity, n. (%)	21 (23)
Major morbidity (class III–IV), n. (%)	8 (9)
Biliary fistula requiring percutaneous drainage	3 (3)
Ischemic stroke	2 (2)
Lung failure requiring intubation	2 (2)
Necrotizing pancreatitis	1(1)
Minor morbidity (class I–II), n. (%)	13 (14)
Biliary fistula	3 (3)
Pulmonary morbidity	4 (4)
Others*	6 (7)
Blood transfusion, no. (%)	8 (9)
Values are given as median (range) unless otherwise indicated	

Table 2: Surgical procedure and short-term outcome.

In 44 (48%) of 92 patients a TPL was required. Major hepatectomies were performed in 14 (15%) patients. The median operation time was 374 min (range 150-720). Liver transaction was accomplished employing the Pringle maneuver in all patients and the median total liver ischemic time was 82 min (range 9-182). The median intraoperative blood loss was 250 ml (range 50-1800).

Eight (9%) patients needed blood transfusions while FFP was administered in 46 (51%) patients. As shown in Table 3, all but one surgical data did not correlate with IVCI values: only blood transfusion correlated with variation of IVCI.

Correlation between variation of IVCI and surgical data		
	ΔIVCI	**p**
Thoraco-phrenolaparotomy Yes No	-0.7 ± 3.3 -0.7 ± 2.7	0.392
Surgical procedure Major hepatectomy Minor hepatectomy	0.4 ± 0.3 -0.9 ± 3.2	0.145
Background liver		
Normal	-1.6 ± 5.2	0.110
Steatosis	-0.5 ± 2.1	0.494
Chronic hepatitis	-0.1 ± 1.1	0.561
Cirrhosis	-0.1 ± 0.8	0.573
Clamping time <80 min ≥ 80 min	-1.1 ± 3.7 -0.3 ± 1.8	0.258
Number pringle manuever		0.368
<4	-1.1 ± 3.8	
≥ 4	-0.3 ± 1.8	
Operation time <360 min ≥ 360 min	-0.6 ± 2.9 -0.8 ± 3.1	0.370
Intraoperative blood loss		0.792
<250 ml ≥ 250 ml	-0.6 ± 2.7 -0.8 ± 3.2	
Blood transfusion Yes No	-2.9 ± 6.7 -0.5 ± 2.4	0.040
Values are given as mean values ± standard deviation (SD)		

Table 3: Correlation between variation of IVCI and surgical data.

Table 4 shows the hemodynamic data in the overall population before and after liver resection. Many variables differed significantly: IVCI from 0.26 ± 0.21 to 0.18 ± 0.16 ($p<0.001$); HR from 68 ± 14 to 78 ± 13 bpm ($p<0.001$); CI from 2.6 ± 0.7 to 3.0 ± 0.8 L/min/m^2 ($p<0.001$).

All BGA values changed significantly ($p<0.001$). Serum lactate concentration showed a significant increase during the parenchymal dissection changing from 0.95 ± 0.5 to 4.1 ± 2.0 mmol/L ($p<0.001$). Serum haemoglobin lowered from 11.3 ± 1.7 g/dl to 9.8 ± 1.8 g/dl ($p<0.001$). In contrast, CVP and SVV did not change significantly.

As shown in Figure 2 both IVCI1 and IVC2 had a weak correlation with CI ($r=-0.166$ and $r=-0.087$), CVP ($r=-0.049$ and $r=-0.083$) and SVV ($r=0.138$ and $r=0.121$).

According to Brennan criteria, 35 (38%) and 46 (51%) patients had IVCDs around 2 cm baseline and after liver resection, respectively. In each subgroup a significant correlation between ICVD and CVP was not found (r=0.064 and r=-0.205,). Although in the second subgroup the correlation was not statistically significant, it resulted slightly better than the first one but in opposite direction to what expected (Figure 3).

Hemodynamic data in 91 patients enrolled in the study			
	Baseline	**After liver resection**	**p**
Intraoperative data			
IVCI	0.26 ± 0.21	0.18 ± 0.16	<0.001
Mean arterial pressure (mmHg)	78 ± 13	73 ± 13	0.021
HR (bpm)	68 ± 14	78 ± 13	<0.001
CVP (mmHg)	7.3 ± 3.6	7.3 ± 3.4	0.777
CI (L/min/m^2)	2.6 ± 0.7	3.0 ± 0.8	<0.001
SVV (%)	9.0 ± 3.3	9.5 ± 5.0	0.997
pH	7.44±0.06	7.38 ± 0.05	<0.001
Base Excess (mmol/L)	1.5 ± 2.7	-2.3 ± 2.9	<0.001
Lactate (mmol/L)	0.95 ± 0.5	4.0 ± 2.0	<0.001
Hb (gr/dl)	11.3 ± 1.7	9.8 ± 1.8	<0.001
Intraoperative fluid regimen, median (range)			
Fluid Input (ml/kg/h)	7.5 (1.5÷15.6)		
Fluid Balance (ml)	-342 (-4208÷2939)		
Bleeding (ml)	250 (50÷1800)		
Diuresis (ml)	700 (25÷2520)		
FFP (ml)*	500 (240÷1000)		
RBC (ml)**	550 (250÷3300)		
Values are given as mean values ± standard deviation (SD), unless otherwise indicated. IVCI: Inferior Vena Cava Index; HR: Heart Rate; CVP: Central Venous Pressure; CI: Cardiac Index; SVV: Stroke Volume Variation; FFP: Fresh Frozen Plasma; RBC: Red Blood Cell; *46 patients; **8 patients			

Table 4: Hemodynamic data in 91 patients enrolled in the study.

Postoperative outcomes

Operative mortality was nil. Overall morbidity rate was 23% (n=21). Major morbidity occurred in 8 (9%) patients.

Based on postoperative outcome occurrence the patients were divided in two groups: Group 1 (complicated) and Group 2 (non-complicated). The IVCI resulted not significantly different between two groups (0.12 ± 0.11 vs 0.16 ± 0.13; p=0.105), which were homogeneous for global fluid regimen (7.25 ± 2.63 ml/kg/h vs 7.98 ± 2.93 ml/kg/h; p=0.341). As reported in Table 4 also the other hemodynamic variables not differed significantly.

In contrast, the intraoperative blood loss (p=0.035) and operation time (p=0.019) in the group 1 were significantly higher than in group 2.

Discussion

Recent studies have emphasized as the intraoperative optimization of fluid regimen improves postoperative outcome after abdominal surgery [1-2]. Thus, accurate predictors of FR are need. As reported, IVCI helps to discriminate between responder and non-responder and represents a predictive factor of FR [10-13]. However, the reliability of IVCI as hemodynamic index during liver resection was never investigated, at our knowledge. Thus, our hypothesis was that IVCD and its variations during liver resection could add helpful information about volemia assessment.

The data from the present study showed that during hepatic resection IVCI is not sensible to fluid administration and is not correlated with postoperative outcome. Furthermore, to experience or not a postoperative adverse event was not correlated to the fluid regimen. In fact, it resulted similar in complicated and non-complicated patients. To note that, even not significantly, CVP was higher in patients who experienced complications, despite the fluid input was slightly lower than non-complicated patients.

One of the comparisons was between the intraoperative modification of IVCD during mechanical ventilation and CVP, which was maintained as much as possible within 0-6 mmHg. ICVD evaluation was considered in two different surgical steps: before liver mobilization (baseline) and after parenchymal dissection. The choice was related to the crucial importance of these two time-points in the management of fluid administration during operation. As shown, we did not find a reliable correlation between IVCI and CVP both before and after liver dissection. A weak relationship was found also between IVCI and the other hemodynamic indices as CI and SVV.

As reported by Brennan et al., IVCD values around 2 cm and the IVC collapsibility represent valid predictors of right atrial pressure [18]. However, the present study reported a poor correlation between CVP and IVCI both during first and second measurement. Contrasting results were found even considering IVCD cut-off around 2 cm. Contrary to what awaited, a poor and inverse correlation between IVCD post-resection and CVP was found. An explanation for our unexpected results would be the different typology of patients: those enrolled by Brennan were neither surgical nor mechanically ventilated patients.

Probably comparing IVC and CVP during mechanical ventilation would be considered anecdotal: i.e., compare a linear measurement vs. a pressure, but both of them are considered indirect predictors of volaemia and FR. In addition how CVP is affected by intra-thoracic pressures variation, circulating blood volume and cardiac function, also IVCD should change according to respiratory pressures variation, blood volume and cardiac performance. Based on these considerations we expected a better relationship than that was found. Furthermore, as recently reported by van Lavieren et al. [20], who investigated the hemodynamic effects of laparotomy; the SVV decreases significantly in open surgery approach. Therefore, according to such findings, we believe that the concept of FR should be reviewed in open abdominal surgery.

Previous studies reported that such a comparison showed a good correlation in particular patients (e.g., cardiac surgical subjects) and only when CVP was<11 mmHg, [5]. As known, CVP is strongly influenced by heart's function (above all the right ventricle) and cardiac valve diseases (mainly tricuspid regurgitation and stenosis). Then, any investigation of the relationship between CVP and other hemodynamic parameters cannot leave apart the cardiac performance assessment [21,22]. Our sample of patients did not suffer from any significant cardiac valves dysfunction, both any patient experienced hemodynamic impairment, and then we estimated the measurement as reliable.

A factor that may even partially explain our findings are that superior vena cava (i.e., CVP) is completely into the rib cage contrarily to IVC. Then it can result intuitive that IVC may be less affected by mechanical ventilation, especially when abdomen is open.

Initial hemodynamics showed a "lower profile" than after the end of the resection. It was expected because of our habit to limit fluid input in the first operation phase in order to avoid a "wet" surgical field and potential backflow bleeding [19]. As consequence, the risk of hypovolemia is lurking and then a closer monitoring is mandatory as a low-flow state may be very harmful. An explanation of such issue may be that once close to the end of the resection the anesthesiologist increased the fluid input in order to sustain the hemodynamics.

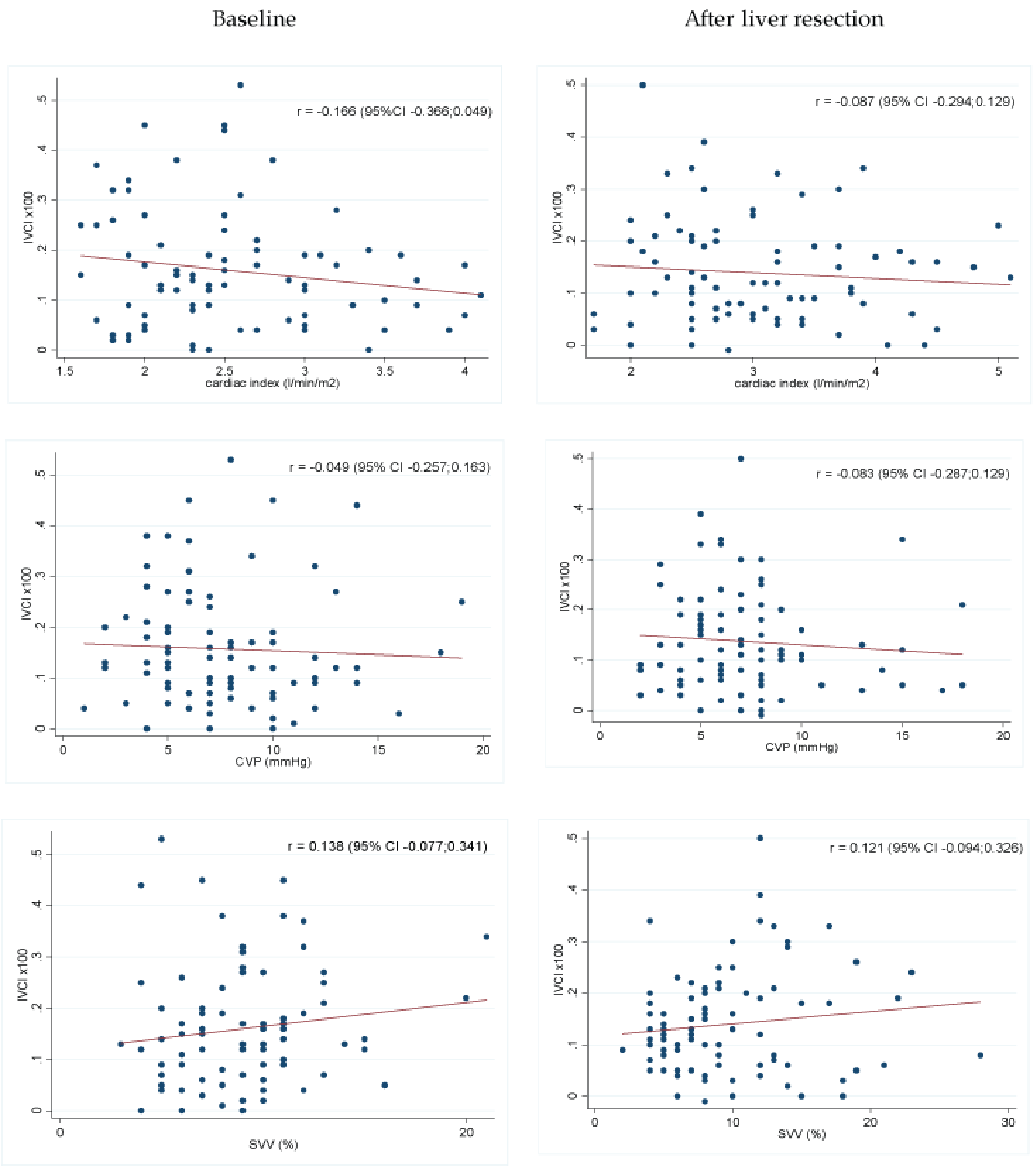

Figure 2: Relationship between IVCI and other hemodynamic parameters.

We consider that the increased HR at the end of the resection might be due to restrictive fluid management during first operation phase. SVV was unchanged and in a "normal" range before and after liver resection and then, might the HR be the unique reason of increased

CI? Although during general anesthesia, cardiocirculatory reflexes should be attenuated at least, HR rising may not either be considered a response neither to fluid restriction nor due to uncontrolled pain. We could be sure that pain control was adequate due to the recommended dose of remifentanil. Finally, HR has never resulted in tachycardia, and then it may not be considered a concern.

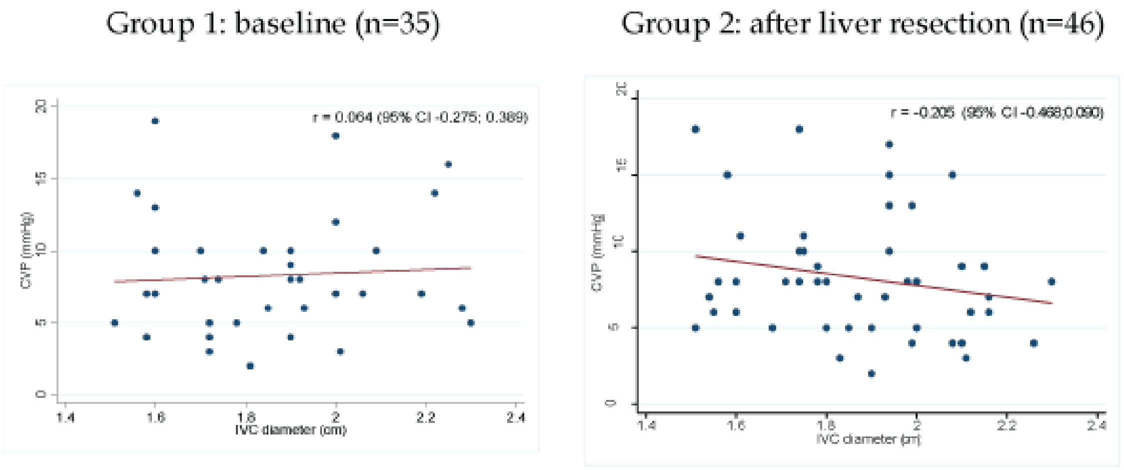

Figure 3: Correlation between IVC diameter and CVP according to Brennan criteria.

Unfortunately, we recorded IVCI only before and after hepatic resection, so we cannot know the trends during the dissection time when the restrictive fluid management was the rule.

Despite a poor correlation between IVCI and CI was found, it corresponded to an expected their opposite direction of changing before and after resection (IVCI reduced as cardiac output increased).

The final fluid balance was negative. May IVCI be dependent on cardiac function or vice versa, more than on fluid balance? Fluid balance during surgery is always a challenging estimation due to the troublesome measurement of perspiratio insensibilis and the fluid loss caused by traumatic surgical injury [23,24]. Then it is difficult do any reliable comparisons with fluid balance and given the weakness of our results, we cannot answer the question. A relationship between IVCI and cardiac output exists, according the concept of FR: the principle stands for an increase of cardiac output after fluid challenge in a patient with IVCI or another functional hemodynamic parameter (SVV, for instance) greater than a cutoff value [11-13].

The relationship between IVCI and SVV showed to be possible only after the resection phase. May it signify that IVCI is a poor parameter in a more “empty” patient? Brennan et al’s findings [18] could agree with such a suspicion. We retain that a specific trial would be necessary to investigate the issue.

We have to consider that almost half of patients required a TPL. It may have affected the inter-relationship between all parameters related to FR, as intra-thoracic pressures influenced them, although we can speak about FR when the chest is open [9]. However based on our analysis the TLP did not affect the IVCI (p=0.789), disproving the hypothesis that the IVCD would have changed by opening the chest due to the leak of intra-thoracic pressure. Recent reports showed that SVV and FR have a reliable association only when the chest is completely or partially closed (e.g., thoracoscopic lobectomy) [25,26].

Finally, the capability of the IVCI in predicting early postoperative outcome was tested. To date some studies reported the prognostic value of CVP following adult cardiac surgery [26,27], focusing on its utility during the early postoperative period. However, no consideration is given to whether CVP has some implications for clinical outcome when measured intraoperatively. The prognostic value of IVCI measured by IOUS in liver surgery has been never investigated. However, the findings of this study demonstrate that the IVCI is not correlated with the short-term postoperative outcome in patients submitted to hepatectomy.

The results of the present study should be viewed considering several limitations. First, the sample might be too small to find a significant correlation between hemodynamic parameters. Second, in our study the IVCDs were assessed only twice: before and after liver resection, respectively. Then we lack data about an important phase of the operation. As a reason we could suggest that during hepatic resection we did not measure IVCD variations given the delicate phase of such a surgery when the surgeon has to be careful to technical issues. Third, ultrasound measurements suffer from the operator’s bias, even if in our trial he was always the same. Fourth, our IVC measurements were recorded as absolute values. According to a recent report, it would be more accurate to take such measurements indexed to the body surface area, [27,28]. Finally, as declared, our trial was a retrospective study.

Then we are aware that large and prospective studies need to be done about such an important issue which regards several aspects of perioperative patients management: fluid regimen, hemodynamic monitoring and fluid responsiveness.

In conclusion, our results suggest that IVCI evaluation during mechanical ventilation in patients submitted to hepatic surgery failed as additional index of hemodynamic assessment and predictor of postoperative outcome. Thus, we believe that further studies are needed to confirm or not our considerations about the role of the IVCI in this surgical setting.

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