Transoesophageal Doppler compared to central venous pressure for perioperative hemodynamic monitoring and fluid guidance in liver resection

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ABSTRACT

Purpose: Major hepatic resections may result in hemodynamic changes. Aim is to study transesophageal Doppler (TED) monitoring and fluid management in comparison to central venous pressure (CVP) monitoring. A follow-up comparative hospital based study. **Methods:** 59 consecutive cirrhotic patients (CHILD A) undergoing major hepatotomy. CVP monitoring only (CVP group), ($n = 30$) and TED (Doppler group), ($n = 29$) with CVP transduced but not available on the monitor. Exclusion criteria include contra-indication for Doppler probe insertion or bleeding tendency. An attempt to reduce CVP during the resection in both groups with colloid restriction, but crystalloids infusion of 6 ml/kg/h was allowed to replace insensible loss. Post-resection colloids infusion were CVP guided in CVP group (5-10 mmHg) and corrected flow time (FTc) aortic guided in Doppler group (>0.4 s) blood products given according to the laboratory data. **Results:** Using the FTc to guide Hydroxyethyl starch 130/0.4 significantly decreased intake in TED versus CVP (1.03 [0.49] versus 1.74 [0.41] Liter; $P<0.05$). Nausea, vomiting, and chest infection were less in TED with a shorter hospital stay ($P<0.05$). No correlation between FTc and CVP ($r=0.24$, $P > 0.05$). Cardiac index and stroke volume of TED increased post-resection compared to baseline, 3.0 (0.9) versus 3.6 (0.9) L/min/m^2, $P<0.05$; 67.1 (14.5) versus 76 (13.2) ml, $P<0.05$, respectively, associated with a decrease in systemic vascular resistance (SVR) 1142.7 (511) versus 835.4 (190.9) dynes.s/cm^5, $P<0.05$. No significant difference in arterial pressure and CVP between groups at any stage. CVP during resection in TED 6.4 (3.06) mmHg versus 6.1 (1.4) in CVP group, $P=0.6$. TED placement consumed less time than CVP (7.3 [1.5] min versus 13.2 [2.9], $P<0.05$). **Conclusion:** TED in comparison to the CVP monitoring was able to reduced colloids administration post-resection, lower morbidity and shorten hospital stay. TED consumed less time to insert and was also able to present significant hemodynamic changes. Advanced surgical techniques of resection play a key role in reducing blood loss despite CVP more than 5 cm H_2O. TED fluid management protocols during resection need to be developed.

Key words: *Central venous pressure, liver resection, monitoring, transoesophageal Doppler*

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INTRODUCTION

Hepatic resection in non-cirrhotic patients is associated with a perioperative mortality rate of 1-2%. This rate can increase in cirrhotic patients according to their Child-Pugh (CHILD) classification to as high as 8% perioperatively.[1-5]

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Major blood loss from liver parenchyma resection is increasingly less reported with the developments in surgical hepatic resection techniques during the last few years, together with the experience gained particularly in high flow liver centers where many liver resection procedures are performed with almost no blood transfusion requirements. This will definitely reflect on the perioperative anesthetic and critical care management provided which could benefit from using less invasive monitors for these procedures and hence reduces the risks of inserting invasive catheters for the measurement and monitoring of the hemodynamic parameters.

Central venous pressure (CVP) has been used frequently during liver resection due to its close relationship with the expected blood loss during hepatic resection. Maintaining a low CVP during hepatectomy by fluid restriction and administration of diuretics and vasodilators such as nitroglycerine is practiced by many Anesthesiologist to provide an optimum surgical condition with the aim of reducing blood loss.[6,7]

The central vein cannulation process and the care required perioperatively can consume time and cost. The associated serious morbidity and mortality with CVP catheters had been reported several times in the literature. These risks could be avoided if a minimally invasive technique could be adopted for monitoring instead.[8]

Peripheral venous pressure and external jugular venous pressure measurement were also investigated by others as an alternative to the conventional internal jugular CVP during right lobe donor's hepatectomies with an acceptable estimation of the CVP.[9,10]

Transesophageal Doppler (TED) is another minimal invasive bedside monitor that can allow the continuous monitoring of several hemodynamic variables, with this technique a pulsed, competitive-frequency continuous-wave Doppler signal is emitted from a probe placed in the distal esophagus and directed at the descending thoracic aorta. TED has been suggested to be a useful supplement to the current standard monitoring. TED can also allow early recognition of hypovolemia and guides intravascular volume replacement.[11-14]

The primary goal of this study is to explore the ability of TED as a minimal invasive hemodynamic monitor to replace CVP for fluid administration and for monitoring the hemodynamic changes during and after hepatic resection in cirrhotic patients undergoing right hepatotomy, together with reporting the incidence of perioperative complications and difficulties encountered in the each group.

METHODS

After approval by the local ethics committee of the Liver Institute, Menoufiya University, Shebeen el Kom, Egypt, (N°. 2010/13, Chairperson Prof. Magdy Kamal) on 22 November 2010 and obtaining written informed consent, 59 consecutive cirrhotic patients undergoing major liver resection were enrolled in this follow-up comparative hospital based study that will be conducted at the National Liver Institute Hospital, Menoufiya, Egypt. The inclusion criteria were hepatic patients with cirrhosis between 18 years and 60 years of American Society of Anaesthesia (ASA) classification I-II and CHILD A classification undergoing major liver resection (more than three segments) with no Pringle Maneuver. Liver resection was performed by using the surgical technique of anterior intrahepatic parenchymal resection with the help of cavitron ultrasonic surgical aspirator (CUSA), bipolar diathermy and harmonic scalpel hepatic patients were diagnosed to be cirrhotic based on clinical laboratory and ultrasound evidence.

The exclusion criteria included contra-indication for esophageal Doppler insertion (esophageal or nasopharyngeal pathology, coarctation of the aorta), any patient with perioperative arrhythmia (frequent ectopic beats) or history of bleeding tendency, no written informed consent.

The participating patients were allocated into two groups, either Doppler or CVP monitored group using a random number generator in sealed envelopes: CVP group (*n*=30) monitored by CVP and Doppler group (*n*=29) monitored by transoesophageal Doppler.

All patients were monitored by standard routine monitoring which includes a 3-lead electrocardiography, a non-invasive blood pressure, pulse oximetry, capnography, fractional inspired oxygen concentration (FiO_2), neuromuscular blockade monitoring via nerve stimulator and core temperature (using a nasopharyngeal probe). After preoxygenation, general anesthesia was induced with Propofol 2 mg/kg IV, Fentanyl 1 ug/kg IV and Rocronium 0.6 mg/kg IV followed by the endotracheal intubation after the loss of train of four. Maintenance of general anesthesia with a mixture of Sevoflurane with 50% oxygen in the air to keep Entropy reading between 40 and 60 (GE Datex-Ohmeda S/5 Anesthetic Delivery Unit System)., mechanical ventilation was performed in all patients on a semi closed system adjusted to keep SaO_2>95% and end-tidal CO_2 between 35 mmHg and 40 mmHg. A 7 F triple lumen central venous catheter was inserted in the right internal jugular vein ultrasound guided. The central venous catheter was connected to a pressure transducer, and the pressure trace displayed continuous in CVP group while in TED group the CVP parameter was not allowed on the screen so as to keep the Anesthesia team blinded to it. Left radial artery was cannulated and an indwelling urinary bladder catheter was inserted.

Head and extremity wraps and warmer systems in the form of forced warming system (Model 750-Bair Hugger Temperature Management Unit, Arizant Healthcare Inc, USA) was applied to each patient to maintain body temperature. Post-operative analgesia was provided with a regime of patient controlled intravenous Fentanyl.

Esophageal Doppler

The Cardio QP cardiac output (COP) monitor (EDM™; Deltex Medical, chichester, UK) is a continuous, beat to beat, minimally invasive CO monitor measuring blood flow velocity in the descending aorta by esophageal Doppler technique. Continuous point-to-point measurement of stroke distance is performed by the Cardio QP for the calculation of stroke volume (SV) (mean of five cycles) using the aortic diameter from a nomogram based on the patient's age, weight, and height. CO (l/min) is then calculated as the product of SV and the heart rate, which is also measured by the Cardio QP. The TED monitor displays blood-flow velocity waveforms that represent the velocity of blood flow within the descending thoracic aorta. A nomogram incorporated in the monitor was used to estimate the aortic cross-sectional area, enabling calculation of the left ventricular SV from the area of the velocity–time waveform. This nomogram includes the patient's height, weight, and age. The time needed for blood to flow in a forward direction within the aorta is the systolic flow time. This is corrected for heart rate to give the corrected flow time (FTc). The FTc has been shown to be a good index of systemic vascular resistance (SVR) and is sensitive to changes in left ventricular preload.[12-15] Following induction of anesthesia; Patient data (age, weight, height) were registered in the monitor in the Doppler monitor. An esophageal Doppler probe was greased with a lubricating gel and passed nasally into the mid-esophagus until aortic blood flow signals were best identified.

Esophageal Doppler monitor parameters includes FTc which is the systolic FTc for heart rate (330-360 ms), SV; Volume of blood ejected from left ventricle/beat (50-100 cc/beat), COP (4-8 l/min) and SVR (1900-2400 dynes.s/cm^5).

In the Doppler group

Boluses of colloid were administered, guided by an algorithm depending on the Doppler estimations of SV and FTc. This algorithm was similar to that used by Sinclair, *et al.*,[15] Post-resection 200-ml of 6% hydroxyethyl starch in saline (6% Hydroxyethyl starch (HES) 130/0.4 Voluven®; Fresenius-Kabi, Bad Homburg, Germany) was given when the FTc reached less than 0.35 s. If the SV was maintained or increased by the fluid challenge and the FTc remained below 0.35 s, the fluid challenge was repeated. If the SV increased by more than 10% and the FTc exceeded 0.35 s, the fluid challenge was repeated until no further increase in SV occurred. If the FTc increased above 0.40 s with no change in SV, further colloids were not then administered until the SV decreased by 10% of the last value. The procedure was started immediately after probe placement and continued every 15 min until maximum SV and targeted FTc values had been reached. This protocol was applied post-resection and on 1st day post-operative. CVP readings were kept blind to the Anesthetist in TED group during surgery and post-operative in intensive care.

In the CVP group

Post-resection hemodynamic variables triggering colloid administration involved a urinary output less than 0.5 ml/kg/h, a decrease in mean systolic blood pressure less than 20% below baseline or CVP<5 mmHg.

During the hepatic resection phase a trial to reduce CVP with colloid restriction. After resection, the CVP was targeted between 5 mmHg and 10 mmHg with boluses of 200 ml of colloid.

In both groups

(Ringer acetate) was infused intraoperatively at approximately constant rate (6 ml/kg/h) via an infusion pump (Fresenius-Kabi, Germany) to cover fluid deficit and basal fluid requirements, later at 1 ml/kg/h post-operatively in the intensive care unit.

Blood products

All throughout surgery packed red blood cells (300 ml) were transfused when Hematocrite percentage (Hct) was <25%. Fresh frozen plasma (unit of 200 ml) was administrated when a PTT>70 s, Fibrinogen was <2 g/dl, or International Normalized Ratio (INR) >2.

Patients were extubated either in the operating room (OR) or post-operatively in intensive care unit. The length of hospital stay was recorded. All patients were studied at the following times, T1:10 min after induction of anesthesia when hemodynamicaly stable with controlled ventilation established, T2: During resection of the tumor with no Pringle maneuver, T3: Immediately after right hepatectomy, T4: At the end of surgery, T5:24 h after surgery.

Statistical analysis

Data were statistically analyzed using SPSS (Statistical Package for Social Science) program version 13 for windows and Epi info program version. For all the analysis, a $P<0.05$ was considered statistically significant. Data were shown as mean and standard deviation (SD), frequency and percent. Fischer exact test for 2 × 2 tables when expected cell count of more than 25% of cases was less than 5. Student *t* test used for normally distributed quantitative variables.

Mann-Whitney test used for quantitative variables, which are not normally distributed. Paired *t* test performed to detect mean and SD of normally distributed pre and post values of the same variable.

Wilcoxon test used for mean and SD of not normally distributed pre- and post-values of the same variable.

Repeated measures ANOVA test performed to differentiate changes in different follow-up results of normally distributed studied variables. Friedman test was to differentiate changes in different follow-up results.

Power and sample size

A total of 29 patients in group 1 with Doppler and 30 patients in group 2 using other method than Doppler were recruited based on the following assumptions: With the power of 80%, $\alpha = 0.05$. The annual rate of using Doppler method in liver resection at NLI is 40% and the annual rate of using other method than Doppler in liver resection at NLI is 54%. The required sample size was determined using PS (Power and Sample size calculation) software.

RESULTS

This study was conducted between June 2010 and November 2011. There were no differences in the demographic data between TED and CVP groups in Table 1. Operative time in TED group was 302 (54) min versus 286 (44) in CVP group, $P>0.05$. The post-resection duration to end of surgery was 39.2 (12.1) min in TED group versus 32.7 (13.9), $P>0.05$.

Total mean intraoperative urine output in TED group was 780.5 (399.3) ml and in CVP group was 957.0 (735.4) ml, $P>0.05$.

The colloids HES administered post-resection in TED group 1.03 (0.4) liter were significantly less than that of the CVP group 1.74 (0.4) liter, $P<0.05$. There was no statistically significant difference between both groups regarding fresh frozen plasma and Ringers acetate [Table 2].

Packed red blood cell transfusion requirement were not needed for both groups of patients enrolled in the study except for one case in the TED group which required 6 units of packed red blood cells. This patient was excluded from the study due to repeated failure of the probe during surgery, may be due to associated surgical manipulation of the liver during the process of controlling the bleeding, this required repeated repositioning of the probe which could affect the readings. All TED probes were affected by the intraoperative surgical Diathermy interference when in use.

Table 1: Patients' demographic data, age, weight and height differences between groups were presented as mean (standard deviation), tested by paired *t* test, while sex difference was tested by Fisher exact test, *P*<0.05 statistically significant

Variables	Control	TED	*P*
Age (year)	50.80±8.63	48.16±11.65	0.051
Weight (kg)	81.30±11.85	79.26±9.58	0.06
Height (cm)	173.15±7.16	173.63±7.23	0.84
Sex male/female	15/5	15/4	0.69
ASA I/II	6/14	7/12	0.46
Operative time (min)	302±54	286±44	0.1

TED – Transesophageal Doppler; ASA – American society of anesthesia classification

Table 2: Fluids mean (standard deviation) requirement for both groups

Variable	CVP	TED
RA (l)	4.40 (1.59)	4.14 (0.55)
HES (l)	1.74 (0.41)	1.03 (0.49)*
FFP (unit)	4	4

RA – Ringer acetate; HES – Hydroxyethyl starch; FFP – Fresh frozen plasma; PRBC – Packed red blood cells; CVP – Central venous pressure; TED – Transesophageal Doppler; **P* 0.02 considered statistically significant

Central venous cannulation was performed by the same Anesthetist each time. Time consumed to prepare the site and insert the CVP catheter until transducing was longer than TED insertion (13.2 [2.9] min versus 7.3 [1.5], $P<0.05$). Three patients required more than one attempt to locate the Internal Jugular Vein despite the ultrasound guidance. No carotid artery puncture was reported in this group. Cardiac arrhythmia was reported during insertion in the form of extrasystoles in 11 patients, which disappeared once the guide wire was removed.

Hemoglobin concentration, Hct, INR and Platelets preoperative values were 12.9 (1.3) g/dl, 37.8 (7.4)%, 1.19 (0.05) mm^3 and 217.1 (42.1) mm^3 respectively, versus post-operative values of 11.4 (0.7) g/dl, 33 (1.7)%, 1.46 (0.18) mm^3 and 152.5 (32.6) mm^3 ($P<0.05$).

The TED group demonstrated significant hemodynamic changes that could be summarized in post-resection increase of SV [Figure 1] and cardiac output associated with a decrease in SVR [Figure 2] despite stable CVP and FTc readings [Table 3]. Table 4 demonstrates no statistically significant difference between the two studied groups regarding heart rate, mean blood pressure, and CVP. The restricted colloid infusion from start of surgery and during resection failed to lower the CVP to lower than 5 cm H_2O.

There was no mortality reported during the study period in any case involved in the study. Complications in the form

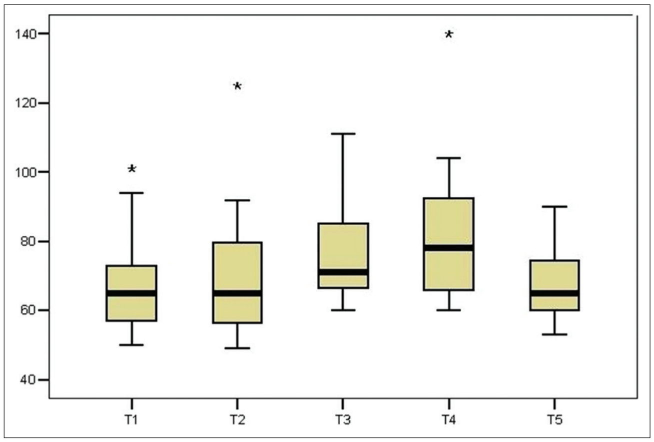

Figure 1: Box and whisker plots graph showing stroke volume changes (ml/beat) in Doppler group. Median (black line), inter-quartiles and ranges at five independent points. T1, after induction of anesthesia; T2, immediately after abdominal fascia opening; T3, during hepatectomy; T4, end of surgery; T5, 24 h after surgery. Repeated measures ANOVA test presented significant changes throughout measuring points *P*<0.05

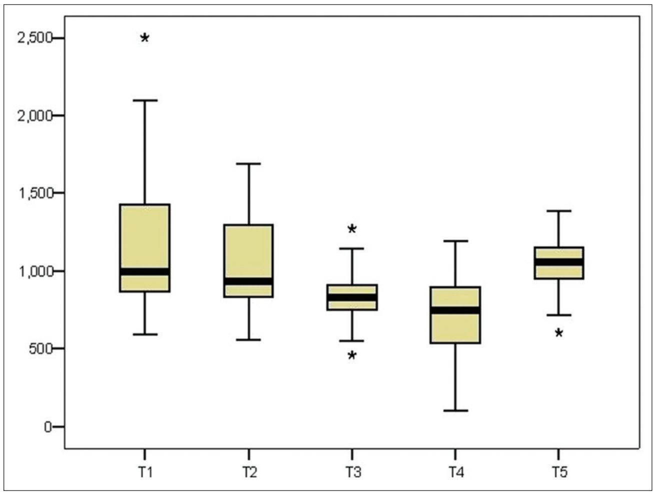

Figure 2: Box plot graph of systemic vascular resistance (dyns. s/m^5) changes in Doppler group as median and inter-quartile range in five independent points, T1 after induction of anesthesia; T2, during resection; T3, hepatectomy phase; T4, at the end of surgery; T5, 24 h after surgery. Repeated measures ANOVA test presented significant changes, *P*<0.05

Table 3: Hemodynamic changes for the Doppler (TED) guided group

Variable	Mean (SD)	*P* value
SV (ml/beat)		
T1	67.16 (14.55)	0.00001
T2	69.53 (18.76)*	
T3	76.05 (13.26)**	
T4	82.11 (19.93)**	
T5	68.05 (9.98)	
CI (l/min/m^2)		
T1	3.08 (0.92)	0.0009
T2	3.18 (0.87)**	
T3	3.68 (0.91)**	
T4	4.01 (1.09)**	
T5	3.08 (0.61)	
FTc (msec)		
T1	372 (35.07)	0.32
T2	367 (44.02)	
T3	373 (38.71)	
T4	370 (76.27)	
T5	369 (14.23)	
SVR (dyns.s/cm^5)		
T1	1142.78 (511.51)	0.0008
T2	1058.56 (343.13)	
T3	835.49 (190.91)**	
T4	738.78 (285.75)**	
T5	1044.04 (190.33)	

Values expressed as mean (SD); SV – Stroke volume; CI – Cardiac index; FTc – Corrected flow time; SVR – Systemic vascular resistance; T1 – After induction of anesthesia; TED – Transesophageal Doppler; T2 – During resection; T3 – After resection; T4 – At end of operation; T5 – 1st day post-operative, Variables compared with T1 using paired *t* test; *Significant with T1 (*P* <0.05); **Highly significant with T1 (*P* <0.01); Repeated ANOVA test used to study the follow up

of chest infection and post-operative nausea and vomiting were significantly lower in the Doppler fluid guided group; this was accompanied with a significant reduction in the hospital stay. (*P*<0.05) [Tables 5 and 6].

Surgical complications reported in TED group were one patient with an injury to the left hepatic duct requesting intraoperative reconstruction and stent placement. Sudden blood loss (more than 400 ml) due a slipped vascular clamp was reported in one patient. In CVP group three patients suffered bile leak, which were treated with endoscopic retrograde cholangiopancreatography and stent insertion in all the three patients.

Nine patients in the CVP group requested antiemetics in comparison to three patients in the Doppler guided group. All patients were extubated immediately post-operative in the OR and admitted to the intermediate care unit for the first 24 h.

No significant statistical correlation was detected between CVP and FTc values at different measuring time points. T1:10 min after induction of anesthesia when hemodynamicaly stable with controlled ventilation, ($r=-0.17$, $P=0.49$). T2: During resection of the tumor with no Pringle maneuver, ($r=0.244$, $P=0.31$). T3: Immediately after right hepatectomy, ($r=-0.075$, $P=0.76$) T4: At the end of surgery, ($r=0.356$, $P=0.14$). T5: 24 h after surgery, ($r=0.090$, $P=0.71$).

DISCUSSION

Liver resection in our study was performed by using anterior intrahepatic parenchymal resection. This was associated with minimal perioperative blood transfusion

Table 4: Hemodynamic data difference between the two studied groups

Variable	TED mean (SD)	CVP mean (SD)	*P*
HR (beat/min)			
T1	89.26 (12.88)	84.35 (10.31)	0.19
T2	89.89 (12.12)	85.70 (9.75)	0.24
T3	92.53 (11.62)	89.35 (8.41)	0.33
T4	95.47 (7.37)	93.25 (10.05)	0.44
T5	88.79 (7.44)	86.50 (4.76)	0.26
MBP (mmHg)			
T1	85.26 (15.19)	90.70 (9.30)	0.4
T2	80.68 (21.58)	85.45 (7.47)	0.27
T3	73.42 (17.66)	80.40 (9.14)	0.61
T4	75.66 (18.66)	84.43 (8.95)	0.07
T5	80.37 (19.13)	89.90 (8.81)	0.051
CVP (cmH$_2$O)			
T1	8.11 (2.36)	8.15 (2.64)	0.41
T2	6.63 (3.20)	7.30 (2.47)	0.08
T3	6.42 (3.06)	6.10 (1.48)	0.68
T4	6.11 (2.54)	5.35 (1.42)	0.13
T5	7.16 (1.54)	7.60 (1.60)	0.39

Values are presented as mean (SD); HR – Heart rate; MBP – Mean blood pressure; TED – Tranoesophageal Doppler; CVP – Central venous pressure; T1 – After induction of anesthesia; T2 – During resection; T3 - After resection; T4 – End of operation; T5 – 1st day post-operative; Tested by paired *t* test; $P<0.05$ statistically significant

Table 5: Post-operative complications for both TED and CVP groups

Variable	TED		CVP		*P*
	n (5)	%	*n* (10)	%	
PONV	3	60.0	9	90.0	0.24
Chest infection	2	40.0	1	10.0	

TED – Tranoesophageal Doppler; CVP – Central venous pressure; PONV - Post-operative nausea and vomiting; Data presented by a number (*n*) and percent shows a significant difference between the two group sin PONV; using Fisher exact test; $P<0.05$ indicated statistical significance

Table 6: Hospital stay for both groups

Variable	CVP	TED	*t* test	*P*
Hospital stay (days)	7.55 (1.82)	6.21 (0.98)**	2.88	<0.01

TED – Transoesophageal Doppler; CVP – Central venous pressure; Data are given as mean (SD); $^{**}P<0.01$, highly significant

and less hemodynamic supportive therapy. This should allow for the use of less invasive techniques for monitoring during and after resection by the anesthetic team.

The study was able to demonstrate the ability of minimally invasive TED to reduce colloid fluid therapy when compared to CVP guided fluid management with an associated reduction in morbidity.

Significant hemodynamic changes was also detected by TED which would not have been available if CVP only was used, particularly the increase in SV and the reduction in SVR post-resection, this could be of help to diagnose and manage reasons of hypotension in this particular group of patients if encountered.

Moderate pulmonary edema was reported previously by Thasler, *et al.,* study as a significant perioperative effect of hepatic resection surgery, which could have an effect on the hemodynamics and pulmonary fluid balance, suggesting that some patients might benefit from a restrictive fluid strategy.[16] Several previous studies performed restriction of intraoperative fluids to maintain low CVP during hepatic resection and then replaced the cumulative fluid deficit after resection in right hepatectomy for living donors, this is similar to the restriction policy implemented in our current research protocol which allowed only for insensible loss to be replaced during resection.[17-19]

Few liver centers reported that CVP monitoring was not used during liver resections performed in their centers, only fluid treatment with >0.5 ml/kg/h urine output during hepatic resection was their target. A European review of hepatic resection discussed also the fact that CVP during this operation might not be reliable. The pressure of the retractors on the diaphragm and mobilization of the liver can compress the portal vein and vena cava reducing venous return and lowering CVP. Compression of the liver can release a significant quantity of blood. Another review of 30 living donors who underwent a right or left hepatectomy for a transplant found no correlation between maintaining a low CVP and blood loss. 10 The average CVP in their study was 7.7±2.8 cm H$_2$O and blood loss was 55 ml. According to the authors of the above mentioned study, maintaining a low CVP is desirable (but not essential) to reduce hepatic venous bleeding and improve hemostatic control during resection. Meticulous surgical hemostasis appears to be more important.[17,20,21] The results of our current study agree with the fact that surgical technique used in resection plays an important role in reducing blood loss and that despite CVP in our study was between 6 mmHg and 7 mmHg, the blood loss was kept to the minimal with no blood transfusion required. It seems that the careful surgical technique of anterior parenchymal transection with CUSA, bipolar electrocautery and harmonic scalpel are important contributers in reducing blood loss, in addition to the experience of surgeons working in high flow liver centers and units with an adequate learning curve.

Smyrniotis, *et al.,*[6] studied in 2004 the various techniques of vascular control and maintenance of a low central venous pressure (CVP) used in order to prevent intraoperative blood loss and post-operative complications and came to the conclusion that the Pringle maneuver if used should be accompanied with CVP 5 mm Hg or less and that the selective vascular clamping should be used whenever CVP remains high despite adequate anesthetic management. Both techniques were not adopted by the surgeons in our study, but instead the new developments in the surgical techniques were used in all patients included in the study. The anterior parenchymal resection was used and this technique did not require significant reduction in the CVP. An average of 6 mmHg to 7 mmHg was adequate particularly in cirrhotic patients in which keeping an adequate filling pressure is important for vital organ perfusion.

The Doppler guided colloid fluid administration group TED in our study received significantly lower colloids with a lower incidence of morbidity and shorter hospital stay. In a study by Lee, *et al.,*[22] FTc and PPV (Pulse Pressure Variation) of Doppler were found to be better than CVP and LVEDAI (left ventricular end-diastolic area index) in predicting fluid responsiveness and that changes in the stroke volume index caused by fluid loading correlated significantly with the FTc values.

CVP readings in our study were not in correlation with the FTc of the Doppler. This could be contributed to the technical difference and anatomic variation between both sites of measurements.

The use of CVP readings and its reliability are facing challenges. Michard, *et al.,* study[23] revealed that CVP and pulmonary artery occlusion pressure did not correlate with the changes in CI after volume expansion in septic patients mechanically ventilated. Two other studies by Hoffman, *et al.*,[24] and Reuse, *et al.,*[25] have also shown no correlation between CVP and changes in CI in response to fluid resuscitation in critically ill patients.

In a literature review, Marik, *et al.,*[26] showed a very poor relationship between CVP and blood volume in response to a fluid challenge in critical care patients.

There are several physiological and anatomical factors that can influence CVP measurement and waveform during liver surgery, such as the vascular tone which were shown in our study results to be markedly reduced post-resection and also the intrathoracic pressure changes from the continuous effect of the surgical retractors on the diaphragm. The twisting the portal vein or inferior vena cava during manipulation or mobilization of the liver to help expose the tumor can lead to a reduction in venous return and reduce the CVP readings.[27,28] Continuous CVP can help only to define the relative trending toward hypervolemia. There is no clinical evidence that CVP monitoring improves outcome in critically ill-patients, and attempts to normalize CVP in early goal directed therapy during resuscitation do not display any benefits.[29] Improvements in surgical techniques and the reduction in required blood transfusion during liver resections favor the use of a minimally invasive cardiovascular monitor. The use of CVP monitoring could be limited to patients with cardiac events that need close monitoring as right cardiac dysfunctions.[30]

The Doppler measured SV and CI as shown in the results of our current study immediately increased after right hepatotomy and were associated with a significant reduction in the SVR. Similar changes in cardiac output (CO) were previously described by Niemunn, *et al.,* but among patients with healthy livers subjected to major hepatic resection for living donor liver transplantation.[31] Neimunn, *et al.,* study had to inject Indocyanine green and measure plasma levels with a pulse dye densitometry which is not usually available in the OR and would be considered as a research tool. In contrast to the TED which could be available in OR and intensive care units as an easy to use and less invasive monitor.

These significant hemodynamic changes after hepatotomy could be explained by the possible reduction in portal blood flow[32] or to the release of various splanchnic mediators such as endotoxin, during liver surgery[33] and changes in the levels of nitric oxide, a potent vasodilator, which could be elevated in response to endotoxin and cytokine release.[34,35] Boermeester, *et al.,* also found that these hemodynamic changes improved after the administration of endotoxin-neutralizing protein.[36]

In an experimental study by Nonami, *et al.*,[37] they reported that a pharmacologically induced hyperdynamic circulation by dopamine or dobutamine improved the hemodynamics and metabolism in the remnant residual liver after massive hepatectomy in dogs, this could explain the reason behind such changes.

In recent years, several experimental studies have also shown that significant changes in hepatosplanchnic and systemic hemodynamics happens after major hepatectomy, this could be due to rapid regenerative response and activity of the remnant liver parenchyma, with increased demand for oxygen consumption in relation to the extent of regeneration and consequently an increase in hepatosplanchnic blood flow, or to the significant increase in prostacyclin after hepatectomy.[38-40] Failure of CO to increase during surgery and after hepatectomy may predict the likelihood of major complications.

In contrast to our current study findings, Boermeester, *et al.,* study reported depressed hemodynamic parameters in rats (CO decreased 40%) 4 h after partial hepatectomy, may be due to species differences.[36]

Length of the hospital stays in the TED guided fluid management group of our study was significantly less than that of the CVP group. In a study by Wakeling, *et al.*, they reported that the application of esophageal Doppler guided fluid management has produced a similar improvement in recovery for patients undergoing different surgical operations.[41]

Sinclair, *et al.,* studied the use of esophageal Doppler optimization in 40 patients undergoing orthopedic surgery and found a significant reduction in the hospital stay.[15]

In the current study, chest infection and post-operative nausea and vomiting were significantly less reported in the Doppler guided fluid group. This was also supported by Mythen and Webb study, which demonstrated that the esophageal Doppler-guided plasma volume optimization significantly reduced the incidence of gastric mucosal hypoperfusion leading to a significant reduction in complication rates and length of hospital stay following cardiac surgery.[42]

Limitations of the study could be summarized in the number of the population involved due to the restricted inclusion of only the right hepatotomy procedures in cirrhotic patients and not any other type of resection. Another limitation was that TED was only studied in one group and not both groups.

The liver mobilization during resection of hepatic tumors and associated abdominal surgical maneuvers required frequent repositioning of the Doppler probe. The patient exclude from the study due to bleeding that required more maneuvers and mobilization of the liver, which frequently affect the TED probe position and hence readings. This can be consider as an important weak point in the TED monitoring system which needs always frequent attention from the anethesist.

In conclusion, TED in comparison to the CVP monitoring was able to reduced colloids administration post-resection, lower morbidity and shorten hospital stay. TED was also able to present significant hemodynamic changes that associated major liver resection. Advanced surgical techniques of resection played an important role in reducing blood loss despite an average CVP more than 5 cm H_2O. Further studies involving more patients undergoing major liver resection is recommended to study the interrelationship of FTc and CVP and decide which reflects better the patient's fluid requirements. This could lead to the establishment of new guided protocols for fluid replacement in this category of hepatic patients during their perioperative period based on a minimal invasive technique as esophageal Doppler without the need for invasive monitoring.

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