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Effect and Outcome of Intraoperative Fluid Restriction in Living Liver Donor Hepatectomy

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: The purpose of this study was to evaluate the effect and outcome of intraoperative fluid restriction in living liver donor hepatectomy, regarding changes in intraoperative CVP levels, blood loss, and postoperative renal function.

Material/Methods: The charts of 167 patients were reviewed and analyzed retrospectively. Intraoperative central venous pressure levels, blood loss, fluids infused, and urine output per hour, before and after the liver allograft procurement, were calculated. Perioperative renal functions were also analyzed.

Results: Fluid infused before and after liver allograft procurement was 3.21±1.5 and 9.0±3.9 mL/Kg/h and urine output was 1.5±0.7 and 1.8±1.4 mL/Kg/h, respectively. Intraoperative estimated blood loss was 91.3±78.9 mL. No patients required blood transfusion. Their preoperative and postoperative hemoglobin were 12.3±2.7 and 11.7±1.7 g/dL. CVP levels decreased gradually from 10.4±3.0 to a low of 8.1±1.9 mmHg at the time of transection of the liver parenchyma. Renal functions were not significantly affected based on the determination of BUN and creatinine levels.

Conclusions: The methods used to lower CVP are moderate and slow, with 2 main goals achieved: minimal blood loss (91.3±78.9 ml) and no blood transfusion. Furthermore, it did not have any negative effect on renal function.

MeSH Keywords: Blood Loss, Surgical • Liver • Liver Transplantation • Living Donors

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Background

The main concern in living donor hepatectomy is ensuring donor safety while preserving graft viability for the recipient and ensuring sufficient functional remnant liver volume for the donor [1]. This concern is justified by the risk of surgical mortality and morbidity in the otherwise fully healthy live donor, who undergoes surgery for no direct physical self-benefit [2,3]. There are many arguments for preventing intraoperative massive blood loss and subsequent massive blood transfusion, which increases risk of surgical mortality and morbidity [4]. The volume of blood loss in liver surgery is correlated with central venous pressure (CVP) [5–7]. Maintaining lower CVP level during liver surgery is therefore recommended to minimize surgical bleeding [5–7]. Many methods have been reported to decrease CVP, but the optimum method to achieve low CVP during hepatectomy has not been established [7]. Commonly used methods include fluids restriction and forced diuresis. Morphine and nitroglycerine are occasionally used, which both dilate the venous system and decrease venous filling pressure and CVP [8]. The main advantage of fluids restriction in lengthy operations such as donor hepatectomy is its ability to maintain hemodynamic stability and organ perfusion, particularly renal perfusion, to avoid postoperative renal insufficiency [9]. In this article, we report on our experience in anesthesia management of 167 cases of living liver donor hepatectomy without blood products transfusion.

Material and Methods

Approval for this retrospective study was obtained from the Institutional Review Board (970689B) of Chang Gung Memorial Hospital.

The patients were brought to the operation room without premedication or intravenous line. After establishment of the intravenous (IV) line, anesthesia was induced with thiopental, Fentanyl, and atracurium to facilitate tracheal intubation. The anesthesia was maintained with sevoflurane and atracurium as muscle relaxant, and Fentanyl was given as needed. All patients were monitored by ECG, arterial line for continuous blood pressure monitoring, central venous pressure (CVP), pulse oximetry, end-tidal CO_2, body temperature, and urine output. Our method to lower CVP was restriction of intravenous fluids, using furosemide to force the diuresis and giving morphine and nitroglycerine as venodilators when needed. No fluids replacement was needed to compensate for the slight fluids loss resulting from no per os (NPO) intake, and intraoperative fluids were maintained at 2–4/kg/h before the liver allograft was procured. If the CVP was higher than 10 mmHg, 5–10 mg furosemide was given, 3 mg morphine was administered if easy bleeding was found by the surgeons, and nitroglycerine was also given when the surgeons noticed that oozing in the operation field persisted. A second dose of furosemide was also administered to protect renal function if the urine output was less than 0.5 ml/kg/h. After the liver allograft was procured, intravenous fluids were increased to 10 ml/kg/h to the end of the operation, aiming to replace the cumulative fluid deficits from the previous fluid restriction. After the operation, the patients were extubated in the operating room and sent to the liver transplant intensive care unit for further observation. Intravenous patient-controlled analgesia with morphine or Fentanyl was prescribed for pain control. Liver enzymes, serum BUN, and creatinine were routinely tested in the first 3 postoperative days and thereafter if required. The surgical technique used to minimize surgical bleeding without control of portal inflow by the surgeons was as previously reported [10]. Data are expressed as mean ± standard deviation. Changes in BUN and creatinine were compared using the paired *t* test.

Table 1. Patients'perioperative details (n=167).

Patient characteristics	
Age (year), mean	33.2±8.0
Weight (kg), mean	60.3±10.3
Anesthesia time (hour), mean	10.2±1.3
Hemoglobin pre-op(g/dL), mean	12.3±2.7
Hemoglobin post-op (g/dL), mean	11.7±1.7
Blood loss(ml), mean	91.3±78.9
Blood transfusion, number of patient	0
Medications use	
Lasix (mg)	10.1±5.7
Morphine (number of patient)	10
Nitroglycerien (number of patient)	0
Type of surgery (number of patient)	
Left lateral segment	90
Right hepatectomy	85

Results

We included 167 consecutive patients undergoing living liver donor in the study. Table 1 shows the patients' characteristics and medications used to decrease CVP; 90 of them donated left lateral segment and 85 patients underwent right hepatectomy. Mean intraoperative blood loss was 91.3±78.9 ml and no patients required blood transfusion.

Table 2 shows that the mean procurement time of the liver grafts was 7.0±1.2 h. Total crystalloids given in this time period was 1 413±608 or 3.2±1.5 ml/kg/h, while the total fluids

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Table 2. Fluid and urine output during the operation period.

Operation period	Fluid		Urine	
	Before graft procurement	After graft procurement until completion of the operation	Before graft procurement	After graft procurement until completion of the operation
Total amount (ml)	1413.3±608	2000±746	669±291	331±242
Rate (ml/kg/h)	3.2±1.5	9.0±3.9	1.5±0.7	1.8±1.4
Procurement time (h)	7.0±1.2	3.2±1.5		

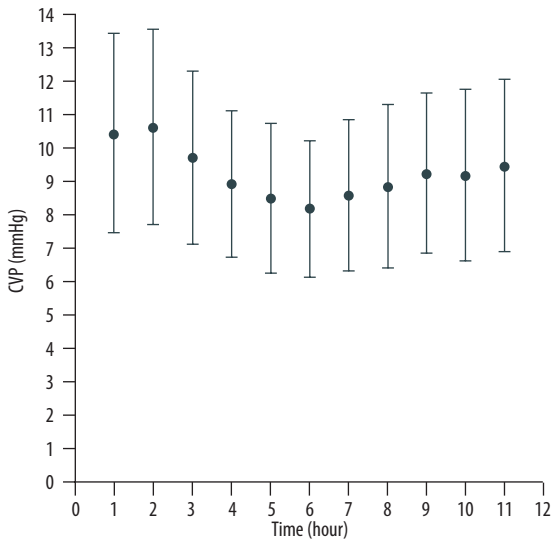

Figure 1. Intraoperative changes in CVP levels.

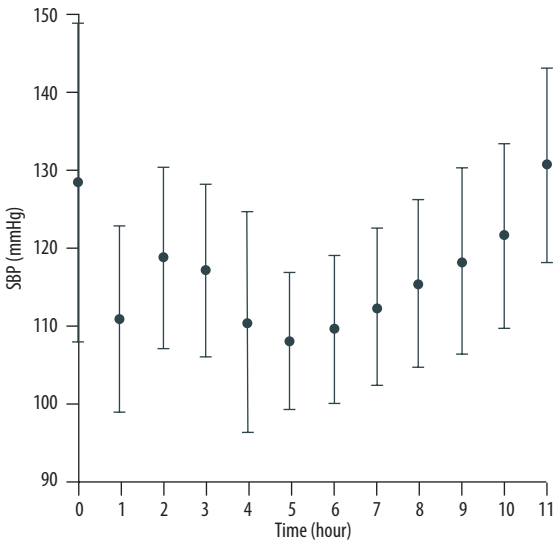

Figure 2. Changes in systolic blood pressure (mean ± standard deviation mmHg).

given after graft procurement to the end of the operation was 2000±746 ml or 9.0±3.9 ml/kg/h. Urine output before and after graft procurement was 1.58±0.7 ml/kg/h and 1.8±1.4 ml/kg/h. Figure 1 shows the dynamic changes in CVP levels, it decreased very slowly but gradually from 10.4±3.0 to the lowest of 8.1±1.9 mmHg at the time of transection of the parenchyma of the liver and then increased slowly after graft procurement to the end of the operation (Figure 1). Systolic blood pressure decreased slightly from the fluid restriction, but was still within acceptable ranges and normalized slowly to the end of the surgery, as shown in Figure 2. The heart rate of the patients increased slowly during fluid restriction and normalized after fluid replacement, as shown in Figure 3. Figures 4 and 5 show that the changes in BUN and serum creatinine compared to preoperative values from postoperative day 1 to day 3 were not significant.

Discussion

Living related liver transplantation (LRLT) is an alternative way to treat end-stage liver diseases and to solve the organ donor shortage problem [11]. However, the safety of this otherwise healthy donor should be taken into consideration medically and ethically [12]. This concern is reasonable since the liver is a vascular-rich organ, and partial hepatectomy risks massive blood loss requiring blood transfusion, and massive blood transfusion significantly increases postoperative morbidity and mortality [4,13]. However, expert surgery for pathologic conditions allows liver resections with minimal blood loss [8], as well as hepatectomy for graft procurement in a healthy donor without blood transfusion [10]. Reports show that the volume of blood loss during liver resection correlates significantly with CVP [5–7], and maintaining a low CVP has been suggested to be an effective method to help surgeons minimize blood loss during liver surgery [5–7]. A low CVP means that there is also low pressure in the hepatic venous system, and less blood

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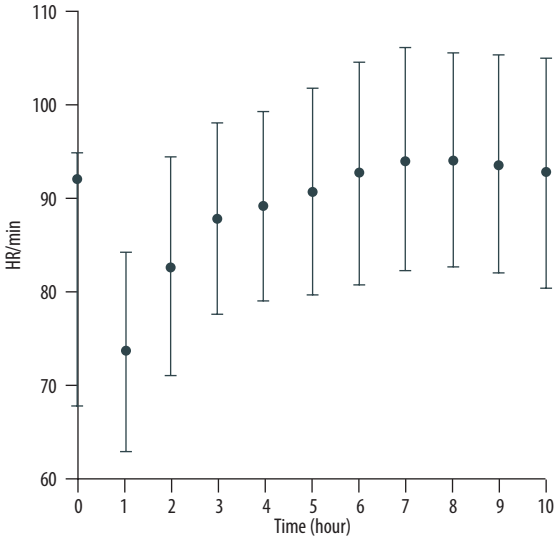

Figure 3. Changes in heart rate.

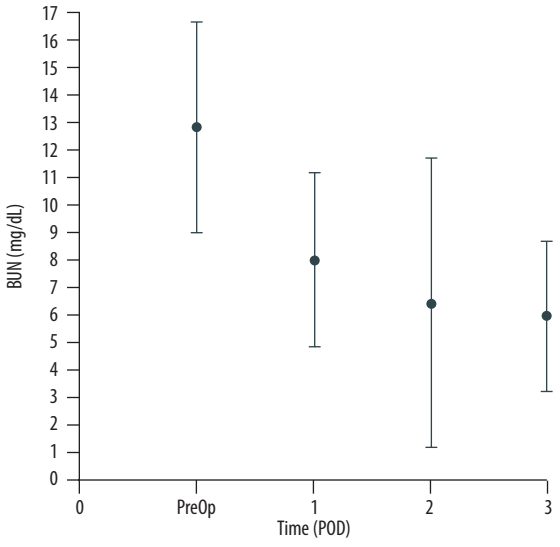

Figure 4. Changes in BUN from preoperative to postoperative days 1–3.

loss during parenchymal transaction is to be expected and allows easier control in case of inadvertent venous injury [10]. However, the best method for achieving low CVP during hepatectomy has not been established [7]. The anesthesiologist is responsible for achieving optimal CVP and providing a clear operative field for the surgeon, while also ensuring patient safety. There are many methods to lower CVP levels, but some methods, such as infrahepatic IVC clamping [14,15] and Pringel's maneuver [16,17], can decrease CVP and reduce blood loss. Both can be used in segmental hepatectomy in liver pathology,

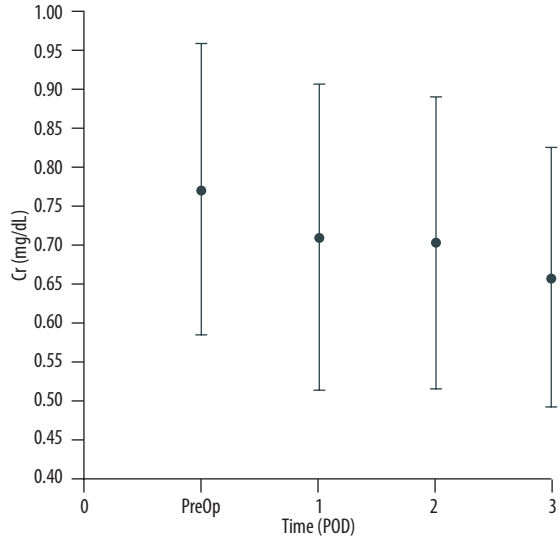

Figure 5. Changes in serum creatinine from preoperative to postoperative days 1–3.

but not for living liver donor hepatectomy. IVC clamping can increase thrombo-embolic events [14] and it negates the benefit of low CVP and low blood loss, as well as the ischemia induced by inflow occlusion [16,17]. This can affect the viability of the liver graft and it is not used in our transplant center [10]. Epidural anesthesia is used in some centers to lower CVP and reduce blood loss in hepatectomy [18,19]. It can be used as effective postoperative pain management, but concerns about coagulopathy secondary to a liver resection affecting catheter removal must be taken in consideration [20]. Intraoperative phlebotomy without fluid replacement to lower CVP and reduce blood loss is used in some liver transplant centers [21]. We provided optional autologous blood donation 2 days before the living donor hepatectomy, but this protocol was unnecessary because the blood loss was minimal; none of the autologous predonated blood was used and it was all discarded after the operation [22]. The method we used to lower CVP is described in the Methods section. Figure 1 shows that the mean initial CVPs of our patients were higher than 10.4±2.9 mmHg. It decreased slowly and gradually, starting at 3 h and reaching the lowest CVP of 8.1±1.9 mmHg at 6 h, then increasing slowly again after having increased the infusion rate after graft procurement, and the mean CVP level of 9.4±2.5 mmHg was recorded at the end of the operation. The method used in our series to lower CVP during surgery was fluids restriction, with an infusion of crystalloids 3.2±1.5 ml/kg/h during liver resection (7±1.2 hours), followed by 9±3.9 ml/kg/h after procurement of the allograft until the end of the operation (3.2±1.5 h). All patients received furosemide at 1 h after anesthesia; 10 of them required morphine and only 1 required nitroglycerine to lower the CVP. The insensible loss

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(2 ml/kg/h) of patients who had been fasting for at least 8 h was not preoperatively replaced as conventionally done and as Jenkins recommended [23]. We also did not perform fluid maintenance at 2 ml/kg/h and fluids replacement of approximately 6–8 ml/kg/h for third-space loss for major surgery such as hepatectomy [24,25]. The blood loss during resection was also not replaced volume-for-volume by blood products, colloids, and/or crystalloids for as long as the hemodynamics remained stable. Adequate and sufficient fluids administration during surgery is usually given to ensue hemodynamic stability and organ perfusion, particularly renal perfusion, to avoid postoperative renal insufficiency [26]. In our series, fluids restriction to 3.2±1.5 ml/kg/h during liver resection followed by 9±3.9 ml/kg/h after procurement of the graft to the end of the operation seemed to be able to maintain acceptable systolic blood pressure (Figure 2), which was compensated by sinus tachycardia (Figure 3) and ensuring sufficient urine output of 1.5±0.7 and 1.8±1.4 ml/kg/h during resection and after graft procurement, respectively. Postoperative BUN and serum creatinine (Figures 4, 5) level indicated that patient renal function was well preserved despite fluid restriction during hepatectomy. Fluids restriction associated with diuretics alone seemed to be effective in more than 90% of our patients in lowering CVP, but at least 10 of the patients required additional morphine. Morphine, an analgesia with venodilator effect [27,28], which has been extensively used in treatment of acute pulmonary edema by decreasing intravascular volume and shifting the blood volume into peripheral vascular beds, subsequently decreasing pulmonary wedge pressure and CVP [27]. Most reports recommend CVP should be less than 5 mmHg [5–7]. However, exceedingly low CVP should be avoided, as a negative CVP can allow the entrance of air through unrecognized hepatic vein lacerations, which might result in a serious air embolism [5,10]. Venous air embolisms can endanger the patient more than blood loss. For early recognition of air embolus, end-tidal carbon dioxide should be monitored continuously. Any abrupt drop in end-tidal carbon dioxide suggest air embolus, especially if associated with hemodynamic changes [5]. Monitoring transesophageal echocardiography is sensitive in detecting air embolisms [29].

Conclusions

The methods used to lower CVP to less than 5 mmHg, as mostly recommended [5–7], were not effective, although the mean CVP in our study was only around 8 mmHg, but the 2 main goals of achieving minimal blood loss (91.3±78.9 ml) without blood transfusion were met. Furthermore, it did not have any negative effect on renal function.

Conflict of interest

None.

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