World J Surg (2010) 34:1555–1562
DOI 10.1007/s00268-010-0495-3

Risk Factors for Massive Bleeding during Major Hepatectomy

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Published online: 25 February 2010

Abstract

Background Massive bleeding during hepatectomy is a risk for mortality and morbidity. We examined the risk factors for massive bleeding and their correlations with outcomes.

Methods The study was a retrospective case series. Among 353 consecutively hepatectomized patients, the mean estimated blood loss (EBL) was 825 ml. Ten patients (2.8%) experienced EBL of between 3000 and 5000 ml. Five patients (1.4%) experienced massive EBL defined as more than 5000 ml, and all five patients had undergone right major hepatectomy (RMH) for primary liver cancer (PLC). All the patients with PLC who underwent RMH were divided into two groups: group I with EBL $\leq$ 5000 ml ($n = 19$) and group II with EBL > 5000 ml ($n = 5$). Perioperative factors regarding massive bleeding and operative mortality and morbidity were compared between the two groups.

Results Among the ten patients who experienced EBL of between 3000 and 5000 ml, three had partial hepatectomy of no more than subsegmentectomy of the paracaval portion of the caudate lobe and three had central bisegmentectomy. The mean tumor size was 7.9 ± 4.7 cm in group I and 15.1 ± 2.2 cm in group II ($P = 0$ .0034). Tumor compression of the inferior vena cava (IVC) on CT scans was observed in all patients in group II, but in no patients in group I ($P < 0.0001$). Four of five patients in group II received surgery through an anterior approach. The liver-hanging maneuver (LHM) was applied in 14 of 19 patients (74%) in group I but could not be applied in group II ($P = 0.0059$). No postoperative and in-hospital mortalities occurred in group II and there were no significant differences in the incidence of mortality and morbidity between the groups.

Conclusions RMH for large PLCs, tumor compression of the IVC, and an anterior approach without the LHM are risks for massive bleeding during hepatectomy. Preparation of rapid infusion devices in these cases is necessary to avoid prolonged hypotension.

Introduction

Despite advances in the understanding of liver anatomy and refinements of operative procedures, blood loss remains a major complication in hepatic resection. Excessive blood loss is associated with intraoperative death and higher postoperative mortality and morbidity rates [1–5]. Recently, Katz et al. [6] demonstrated that the blood loss during hepatectomy can predict not only the early results after hepatectomy but also the recurrence and survival of hepatocellular carcinoma. We conducted a retrospective study at our institution to investigate the risk factors for massive bleeding during hepatectomy and the outcomes of the affected patients.

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Methods

The study included all 353 patients who underwent hepatic resections from April 2004 to October 2008 in the Department of Hepatogastroenterological Surgery at Aso Iizuka Hospital in Japan. Data for these patients were retrieved from a prospective database. The first author conducted all the surgeries in this consecutive series.

Overall, 242 patients had primary liver cancer (PLC), 65 patients had metastatic liver cancer, 30 patients had extrahepatic bile duct cancer (20 gallbladder cancers and 10 hilar cholangiocarcinomas), and 16 patients had other diseases. The types of hepatic resection performed were no more than subsegmentectomy in 226 patients, segmentectomy in 59 patients, left major hepatectomy (no less than left lobectomy) in 30 patients, right major hepatectomy (no less than right lobectomy) in 34 patients, and central bisegmentectomy in 4 patients.

Among the 34 patients who underwent right major hepatectomy, 24 had PLC, 5 had extrahepatic bile duct cancer, 2 had metastatic liver cancer, and 3 had other diseases. Combined resection was performed in 13 of the 34 patients. The types of combined resection were extrabile duct and lymph nodes in seven patients with extrahepatic bile duct cancer, portal vein thrombectomy in four patients with PLC, partial resection of the inferior vena cava (IVC) in one patient with PLC and right adrenal cancer of 22 cm in diameter, and IVC thrombectomy in one patient.

The mean estimated blood loss (EBL) of all 353 patients was 825 ml. The distribution of EBL is shown in Fig. 1. Eighty-three patients (23.5%) experienced EBL > 1000 ml, 26 patients (7.3%) experienced EBL > 2000 ml, and 10 patients (2.8%) experienced EBL between 3000 and 5000 ml. The types of resection in the latter ten patients were no more than subsegmentectomy in three patients, left major hepatectomy in two patients, right major hepatectomy in two patients, and central bisegmentectomy in three patients. Of the 353 patients, 62 (17.6%) underwent blood transfusion. The mean EBL was 2492 ± 3111 ml in 62 patients with blood transfusion and 479 ± 507 ml in 291 patients without blood transfusion.

Overall, five of the 353 patients (1.4%), experienced massive EBL, defined as more than 5000 ml, and all these patients had had a right major hepatectomy for PLC. The patients with PLC who underwent right major hepatectomy ($n = 24$) were divided into two groups: those with EBL ≤ 5000 ml (group I, $n = 19$) and those with EBL > 5000 ml (group II, $n = 5$). The median EBL during major right hepatectomy for PLC was 1683 ml (range = 100–17,000 ml). The mean EBL was 3508 ± 4695 ml.

Liver function in patients with underlying liver disease was evaluated preoperatively using the Child classification and the indocyanine green retention at 15 min (ICGR15) test. These scales were applied as previously described [7]. The presence of ascites and an ICGR15 test value of more than 40% were considered to be absolute contraindications for resection. Hepatitis B surface antigen (HBs Ag) and hepatitis C antibody (HCV Ab) levels were routinely measured preoperatively. The indications for a right major hepatectomy for PLC were based on previously reported criteria [8]. When the preoperative liver function was Child-Pugh class B or C or the estimated remnant liver volume was less than 250 ml/m^2 by CT volumetry, minor resection was considered.

The surgical technique and intraoperative care were standardized by the first author of this study. The

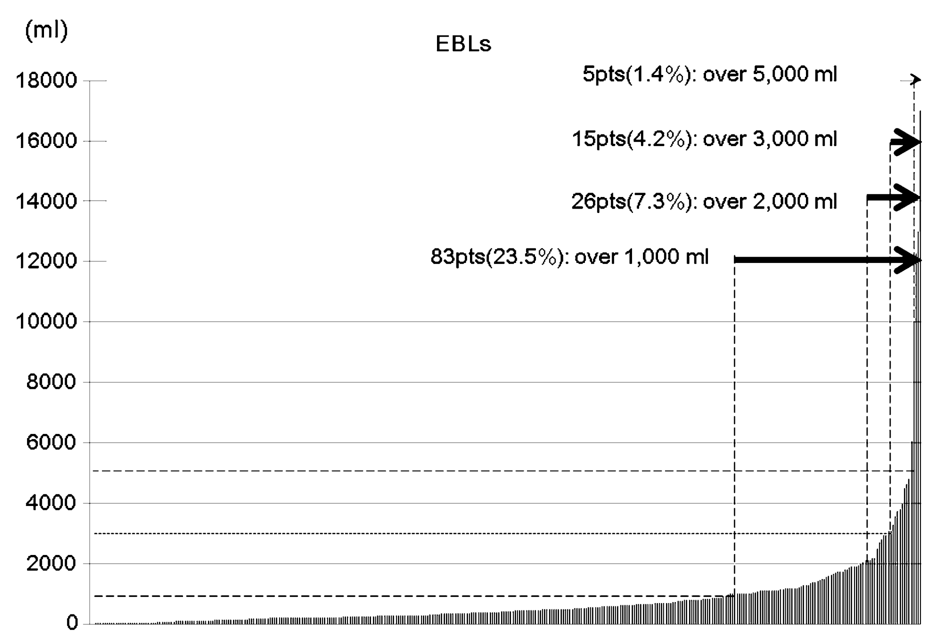

Fig. 1 The distribution of EBL. Eighty-three patients (23.5%) experienced EBL > 1000 ml and 26 patients (7.3%) experienced EBL > 2000 ml

procedures 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), systematic ligation of all sizable vessels, and close ultrasonographic guidance along the transection line. Cholecystectomy was performed in all patients if the gallbladder was present. When mobilization was difficult because of a huge tumor, a parenchymal transection was carried out with no mobilization of the right lobe of the liver (anterior approach). The anterior approach was used in 11 patients. Intraoperative vascular control was achieved by the Pringle maneuver. To prevent backflow bleeding, the central venous pressure was decreased to as low as 5 mmHg when possible with careful circulating volume and respiratory assistance. When the central venous pressure control was insufficient, outflow control was achieved by selective vascular exclusion [9] or by clamping of the infrahepatic IVC [10]. The liver-hanging maneuver (LHM) was used for right major hepatic resection in cases without contraindications or technical difficulty [11]. The intraoperative variables included in the analysis were type of inflow and outflow control during hepatic resection, LHM, and anterior approach. In addition, the reasons why the LHM was abandoned were examined.

Histological examinations were carried out to evaluate the extent of hepatitis, fibrosis, and steatosis. The evaluations were performed by KK without knowledge of the clinical outcomes. Liver fibrosis and necroinflammatory activity were evaluated semiquantitatively according to the METAVIR scoring system [12, 13]. Fibrosis was staged on a scale of 0-4 as follows: F0, no fibrosis; F1, portal fibrosis without septa; F2, portal fibrosis and few septa; F3, numerous septa without cirrhosis; F4, cirrhosis. Necroinflammatory activity was graded as follows: A0, none; A1, mild; A2, moderate; A3, severe. Steatosis was categorized by visual assessment as follows: 0, none; 1, steatosis in fewer than 33% of hepatocytes; 2, steatosis in 33–66% of hepatocytes; 3, steatosis in more than 66% of hepatocytes.

The aims of this study were to clarify the risk factors for massive bleeding during hepatectomy and to compare groups I and II with respect to the preoperative clinical and intraoperative data, operative mortality (defined as death within 30 postoperative days), in-hospital mortality, and postoperative complications. The preoperative variables of liver function included in the analyses were age, sex, hepatitis viral infection status, ICGR15 test values, levels of serum albumin and total bilirubin, and prothrombin time. Based on preoperative CT scans, the following factors were determined: tumor size, estimated whole-liver volume, estimated liver volume to be resected, nearest distance from the IVC to the tumor edge, IVC compression by the tumor, middle hepatic vein compression by the tumor, presence of portal vein invasion into the first branch and/or main trunk, and first resection or re-resection. Figure 2 is an example of a CT scan in which IVC compression was determined. The presence of an extrahepatic arterial feeder of the tumor was diagnosed by preoperative hepatic angiography.

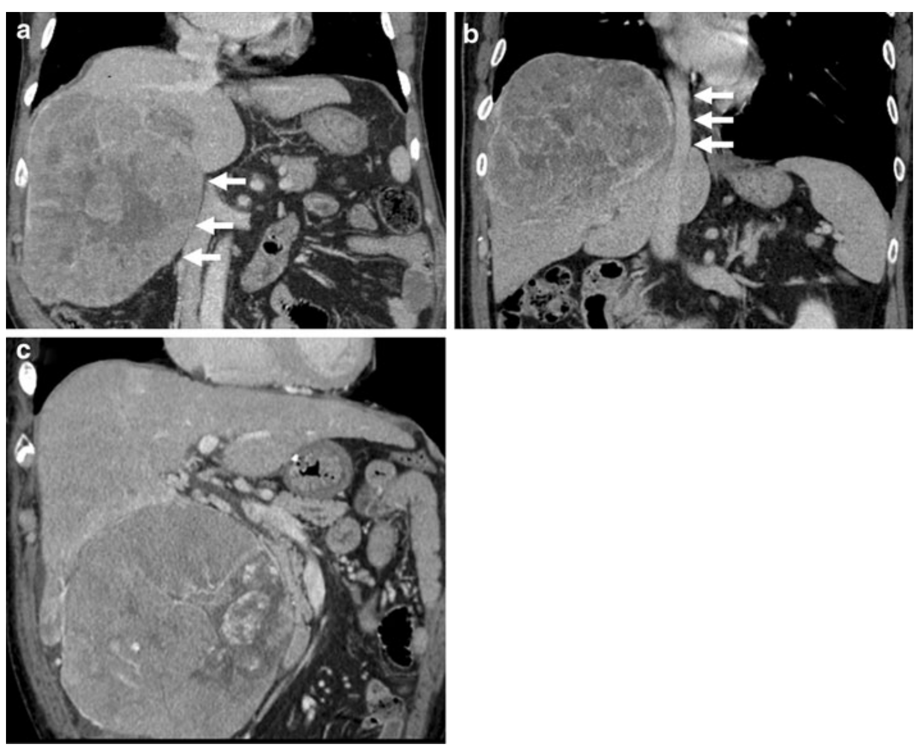

Fig. 2 **a** Computed tomography of a huge hepatocellular carcinoma compressing the IVC (case 11 in Table 4). Because of the huge tumor, an approach to the infrahepatic IVC was impossible. The tumor was located on the IVC inferior to the renal vein. The estimated blood loss was 6070 ml. **b** Computed tomography of a huge hepatocellular carcinoma (case 5 in Table 4). No direct compression of the IVC was observed. The liver-hanging maneuver was performed and the estimated blood loss was 1800 ml. **c** Computed tomography of a huge hepatocellular carcinoma extending inferiorly (case 8 in Table 4). An approach to the infrahepatic IVC was impossible. The estimated blood loss was 17,000 ml

Statistical analysis

We analyzed the associations between the continuous and categorical clinicopathologic variables using Student's *t* test and χ^2 test, respectively. A *P* value of less than 0.05 was considered statistically significant.

Results

The EBL according to the type of hepatic resection is shown in Fig. 3. The data for the 10 patients (2.8%) who experienced EBL > 3000-5000 ml and the 5 patients (1.4%) who experienced massive EBL of more than 5000 ml are given in Table 1. The body weight according to the EBL was examined. The body weight of patients with massive bleeding (61 ± 7 kg) tended to be greater than that of those without massive bleeding (57 ± 11 kg) but the difference did not reach statistical significance ($P = 0.4333$).

A blood transfusion was performed in 14 of 270 patients (5%) who experienced less than 1000-ml EBL and in 33 of 68 (49%) who experienced no less than 1000-3000-ml EBL. A blood transfusion was performed in all 15 patients (100%) who experienced a greater than 3000-ml EBL ($P = 0.0001$).

Ten patients with EBL > 3000-5000 ml

The causes of the blood loss in the ten patients with EBL > 3000-5000 ml seemed to be miscellaneous. Three patients had central bisegmentectomy. Three patients had no more than subsegmentectomy and all the tumors were located in the paracaval portion of the caudate lobe. Of the two patients who had right major hepatectomy, one had a huge right adrenal cancer with an IVC thrombus and significant bleeding was seen during the IVC thrombectomy, and the other had extended right lobectomy with portal vein resection and reconstruction for advanced hilar cholangiocarcinoma. Of the two patients who had left major hepatectomy, significant bleeding was seen during portal vein thrombectomy in one patient, and the other patient had left trisegmentectomy for advanced intrahepatic cholangiocarcinoma invading the hepatic hilus.

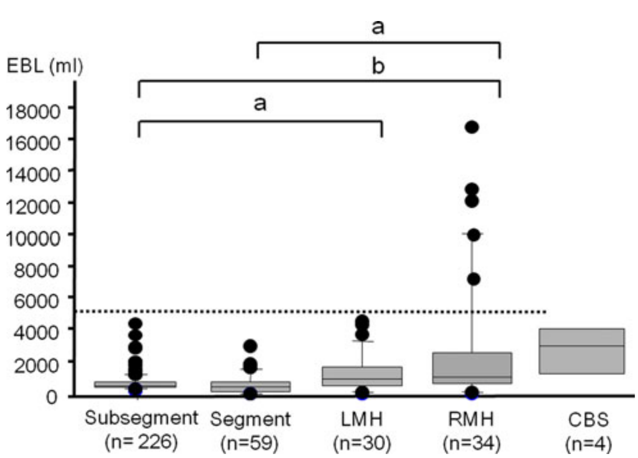

Fig. 3 Estimated blood loss (EBL) according to the type of hepatic resection. The mean EBL in subsegmentectomy, segmentectomy, left major hepatectomy, and right major hepatectomy is 493 ± 587, 637 ± 614, 1360 ± 1220, and 1360 ± 1220 ml, respectively. (*a*) *P*= 0 0.0001; (*b*) $P = 0.0003$. Subsegment, no more than subsegmentectomy; segment, segmentectomy; LMH, left major hepatectomy; RMH, right major hepatectomy; CBS, central bisegmentectomy

Table 1 Causes of estimated blood losses of more than 3000 ml during surgery

Case	Resection	EBL (ml)	Disease	Cause of blood loss
1	Partial (CL)	3100	MLT	Tumor location (paracaval)
2	CBS	3100	MLT	Type of resection
3	CBS	3275	EBC	Type of resection
4	RMH	3555	Others	IVC thrombectomy
5	LMH	3756	EBC	PV resection and reconstruction
6	LMH	3800	PLC	Left trisegmentectomy
7	Partial (CL)	3982	PLC	Tumor location (paracaval)
8	LMH	4500	PLC	PV thrombectomy
9	CBS	4636	MLC	Type of resection
10	RMH	4800	PLC	PV thrombectomy
11	RMH	6070	PLC	Huge tumor, compressing IVC
12	RMH	10,000	PLC	Huge tumor, compressing IVC
13	RMH	12,200	PLC	Huge tumor, compressing IVC
14	RMH	13,000	PLC	Huge tumor, compressing IVC
15	RMH	17,000	PLC	Huge tumor, compressing IVC

RMH right major hepatectomy, *LMH* left major hepatectomy, *CL* caudate lobe, *CBS* central bisegmentectomy, *PV* portal vein, *PLC* primary liver cancer, *IVC* inferior vena cava

Clinical factors for massive bleeding

All the patients with massive EBL of more than 5000 ml had a huge PLC located in the right lobe of the liver that compressed the IVC (Table 1). The preoperative clinical factors of the two groups are compared in Table 2. The patients in group I were significantly younger than those in group II ($P = 0$ .0265). In the evaluation of preoperative liver function, the serum albumin level was significantly lower in group II than in group I ($P = 0.0422$). There were

Table 2 Comparison of the clinicopathological data of the two groups

Characteristics	Group I EBL < 5000 ml ($n = 19$)	Group II EBL > 5000 ml ($n = 5$)	P value
Age	63 + 13	77 + 5	0.0265
Male	16 (84%)	5 (100%)	0.9999
Female	3 (16%)	0 (0%)	
Viral status			0.0648
HBV	9 (47%)	0 (0%)	
HCV	3 (16%)	3 (60%)	
None	7 (37%)	2 (40%)	
HBV + HCV	0 (0%)	0 (0%)	
Mean ICGR15 (%)	16.6 ± 10.9	20.9 ± 7.1	0.4195
Albumin (g/dl)	3.8 ± 0.5	3.3 ± 0.4	0.0422
Total bilirubin (mg/dl)	0.8 ± 0.4	0.7 ± 0.2	0.5439
Prothrombin time (%)	100 ± 14	109 ± 9	0.2369
Tumor size (cm)	7.9 ± 4.7	15.1 ± 2.2	0.0034
Whole-liver volume[a] (ml)	1484 ± 594	2589 ± 482	0.0009
Resected liver volume[a] (ml)	890 ± 482	1972 ± 498	0.0002
Distance to IVC (cm)	1.4 ± 1.4	0	0.0034
IVC compression (Yes/No)	0/19 (0%)	5/0 (100%)	0.0001
MHV compression (Yes/No)	1/18 (6%)	3/2 (60%)	0.0988
Extrahepatic feeder (Yes/No)	2/17 (11%)	2/3 (40%)	0.1739
PV invasion (Yes/No)	9/10 (47%)	5/0 (100%)	0.1181
Re-resection (Yes/No)	2/17 (11%)	0/5 (0%)	0.9999
Hepatitis activity (A1/A2)	10/9	3/2	0.9999
Hepatic fibrosis (F1 + 2/3 + 4)	12/7	4/1	0.6311
Steatosis (0/1)	12/7	4/1	0.6311

HBV hepatitis B antigen-positive, *HCV* hepatitis C antibody-positive, *IVC* inferior vena cava, *MHV* middle hepatic vein, *PV invasion* portal vein invasion to the first branch or main trunks of the portal vein

no significant differences between the two groups for the other parameters, including the ICGR15 test values, serum bilirubin levels, and prothrombin times.

The tumor size, estimated whole-liver volume, and estimated resected liver volume were significantly larger in group II than in group I ($P = 0.0034$, $P = 0.0009$. and $P = 0.0002$, respectively). The distance from the tumor edge to the IVC was 1.4 ± 1.4 cm in group I and 0 cm in all patients in group II. This difference was statistically significant ($P = 0.0034$). IVC compression by the tumor was observed in none of the group I patients and in all of the group II patients; this difference was also statistically significant ($P = 0.0001$). There were no statistically significant differences in the other findings from preoperative radiographic examinations, such as the presence of an extrahepatic tumor feeder and portal vein invasion.

Intraoperative data

Intraoperative data of the two groups are compared in Table 3. The type of vascular control did not differ between the two groups. The LHM was used in 14 patients in group I (74%) but in no patients in group II. In two patients in group II, significant bleeding was observed during blind retrohepatic dissection between the anterior surface of the IVC and the liver for passing a tape. In three patients in group II, the infrahepatic IVC could not be exposed because of the large size of the tumor. In groups I and II, there were no intraoperative episodes of severe hypotension (systolic blood pressure <50 mmHg) lasting more than 5 min and severe metabolic acidosis (pH < 7.0) or air embolism.

Table 4 gives the profiles of the patients with PLC larger than 10 cm in diameter. The results suggest that IVC compression by the tumor and hepatectomy with an anterior approach and without the LHM may be causes of massive bleeding in patients with tumors larger than 10 cm.

Histological examinations

There were no differences in the histological parameters, such as the extent of hepatitis and fibrosis of the liver,

Table 3 Comparison of the intraoperative data of the two groups

Characteristics	Group I EBL < 5000 ml ($n = 19$)	Group II EBL > 5000 ml ($n = 5$)	*P* value
Vascular control			0.4772
Pringle maneuver	3 (%)	2 (40%)	
SHVE	4 (51%)	1 (20%)	
IVC clamp	12 (28%)	2 (40%)	
LHM (Yes/No)	14/5 (74%)	0/5 (0%)	0.0059
AP (Yes/No)	7/12 (37%)	4/1 (80%)	0.0787
AP with/without LMH	6/1	0/4	0.0152

SHVE selective hepatic vascular exclusion method, *IVC clamping* clamping of the inferior vena cava below the liver, *LHM* liver hanging maneuver, *AP* anterior approach

Table 4 Profiles of the patients with primary liver cancers larger than 10 cm in diameter

Patient	Age	Size (cm)	PV	IVC (cm)	AP/LHM	EBL (ml)
1(G-I)	39	12.0	+	2.8 (−)	+/+	1860
2(G-I)	47	12.5	+	0 (−)	−/−	500
3(G-I)	58	14.0	−	0.9 (−)	−/−	1100
4(G-I)	59	14.2	+	0 (−)	+/+	2790
5(G-I)	54	16.0	+	0 (−)	+/+	1800
6(G-I)	58	17.0	−	2.0 (−)	+/+	1670
7(G-II)	86	12.4	−	0 (+)	+/−	10,000
8(G-II)	74	13.7, 7.0, 3.0	−	0 (+)	+/−	17,000
9(G-II)	72	14.8	−	0 (+)	+/−	12,260
10(G-II)	76	17.0	−	0 (+)	+/−	13,000
11(G-II)	77	17.8, 4.0	−	0 (+)	−/−	6070

G-I group I, *G-II* group II, *PV* portal vein thrombus invading the first branch or main trunk of the portal vein, *IVC* distance from the tumor edge to the inferior vena cava, measured on CT scans, *IVC (+)* IVC compression (+), *AP* anterior approach, *LHM* liver hanging maneuver, *EBL* estimated blood loss

between the two groups. In all of the patients, the extent of steatosis of the liver was none or mild (Table 2). No patients had moderate or severe steatosis of the liver and there were no significant differences in the steatosis of the liver between the two groups.

Postoperative outcomes

No operative mortalities and in-hospital deaths after 30 days were observed in the patients with EBL > 3000-5000 ml. In two patients, bile leakage from a hepaticojejunal anastomosis was encountered as a postoperative complication. None of the other patients experienced any postoperative complications.

The postoperative outcomes in the right major hepatectomy patients are compared in Table 5. One postoperative death occurred in group I but no such deaths occurred in group II. No in-hospital deaths (after 30 postoperative days) occurred in either group. The postoperative death was caused by liver failure secondary to a portal vein thrombus. There were no significant differences in the morbidities between the two groups. No reoperations were performed in either group.

Discussion

The amounts of blood loss and blood transfusion during hepatectomy impact postoperative morbidity and mortality [1–5]. Reducing operative bleeding is an important goal, and hepatic surgeons have worked hard to achieve this goal during hepatectomy [14]. Nevertheless, only a few published studies have examined the predictors for massive bleeding during hepatectomy. Helling et al. [1] reported that in 115 major hepatectomies, massive bleeding of no less than 5000 ml occurred in 39 patients. Based on their operative notes, one possible reason for the massive bleeding was the presence of a tumor near the IVC and major hepatic veins, especially the middle hepatic vein. In our study, 15 patients (4.2%) experienced EBL of more than 3000 ml.

The causes of EBL > 3000-5000 ml seemed to be miscellaneous. Partial resection for a tumor located in the paracaval portion of the caudate lobe of the liver and central bisegmentectomy seemed to be risks. In addition to hepatic resection, thrombectomy from the IVC and portal vein appeared to be another risk. For massive EBL > 5000 ml, right major hepatectomy for a huge PLC compressing the IVC was a clear risk.

An important component for reducing intraoperative blood loss is controlling the hepatic inflow. Liver resection using the Pringle maneuver results in a decrease in portal vein and hepatic artery bleeding and better visualization of the operative field. Hepatectomies using hepatic pedicle clamping have resulted in fewer transfusions [15]. We employed the Pringle maneuver in all cases in this series. Alternative routes for hepatic inflow can exist in large

Table 5 Comparison of the postoperative outcomes of the two groups

Characteristics	Group I EBL < 5000 ml (*n* = 19)	Group II EBL > 5000 ml (*n* = 5)	*P* value
Postoperative mortality	1	0	0.9999
In-hospital mortality	0	0	
Postoperative complication	7 (26%)	3 (22%)	0.5615
Liver dysfunction	0	1	
Liver failure	1	0	
Bile leakage	1	1	
Ascites	2	1	
Wound infection	2	0	
Depression	1	0	
Reoperations	0	0	

protruded hepatocellular carcinomas on the surface of the liver. For example, diaphragmatic arteries and arterial branches derived from the superior mesenteric artery can act as extrahepatic feeders of the tumor and provide hepatic inflow. We examined the presence of these extrahepatic feeders by preoperative angiography, and their presence was not found to be a significant risk for massive bleeding. Therefore, the causes of the massive bleeding in this series do not appear to be related to hepatic inflow.

The tumor size, estimated whole-liver volume, and estimated liver volume to be resected were significant risk factors for massive bleeding. The estimated whole-liver volume and estimated liver volume to be resected depended on the tumor size, except in cases of multiple tumors. The mean tumor size in group I was 15.5 cm and the smallest size was 12.4 cm. For such large tumors, in which mobilization is difficult and even hazardous, an anterior approach for hepatectomy has been described [16, 17]. This technique is performed without mobilization of the right lobe and intrahepatic control of the right hepatic pedicle and major hepatic veins. The LHM is a technique in which a tape is passed between the anterior surface of the IVC and the liver is suspended during hepatic parenchymal transection [11]. Ogata et al. [11] demonstrated that this maneuver can facilitate major hepatectomies with an anterior approach and offers several advantages, including the following: (1) it facilitates the control of bleeding at the deeper parenchymal plane and (2) it guides the direction of the anatomic parenchymal transection. We used an anterior approach for hepatectomy in 11 cases and the LHM in 14 cases. The anterior approach was applied in four of five patients with massive EBL (i.e., group II), but the LHM could not be applied in any of the group II patients. These results suggest that the anterior approach without the LHM seems to be a risk factor for massive bleeding. The reasons for abandoning the LHM were bleeding during blind retrohepatic dissection (2 cases) and inability to expose the infrahepatic IVC because of the large size of the tumor (3 cases). Ogata et al. [11] demonstrated that a tumor larger than 10 cm in diameter did not affect the feasibility of the LHM. In the patients in our series with large tumors but no compression of the IVC, the LHM could be performed without bleeding. However, further research is necessary to clarify whether the LHM can be applied without bleeding in large tumors that compress the IVC. Another reason for avoiding the LHM is the inability to detect an appropriate approach to the infrahepatic IVC on a preoperative CT scan.

The most important predictor for massive bleeding was the location of a large tumor. Among the patients who underwent no more than subsegmentectomy, three patients experienced EBL > 3000 ml and their tumors were located in the paracaval portion of the caudate lobe of the liver. The approach to this location has been reported to be difficult. For large PLCs in particular, the location of the tumor relative to the IVC is important. The distance between the tumor and the IVC measured on preoperative CT scans was significantly shorter in group II than in group I. Furthermore, in all the patients in group II, preoperative CT scans showed that the IVC was compressed by a large tumor. Several tumors in group I were adjacent to the IVC, but none compressed the IVC. These results suggest that bleeding from the IVC and backflow from the hepatic veins may be the most important causes of massive bleeding, especially in cases with an anterior approach and without the LHM. There were no differences between the groups with respect to other aspects of the operative procedures, such as selective vascular exclusion and clamping of the infrahepatic IVC. The IVC clamping method for lowering the central venous pressure [9] did not work well in preventing massive bleeding. Another technique to reduce bleeding, when a suprahepatic or infrahepatic approach to the IVC is possible, may be the total vascular exclusion method. When the suprahepatic or infrahepatic IVC cannot be exposed because of a large tumor, the total vascular exclusion method cannot be used. In fact, some surgeons have found that the Pringle maneuver was superior to the total vascular exclusion method for reducing blood loss [18]. Still, the question remains as to whether the total vascular exclusion method works well.

Helling et al. [1] demonstrated that bleeding from the middle hepatic vein was one cause of massive bleeding. In our series, a tumor adjacent to the middle hepatic vein was not a significant risk factor for massive bleeding. The taping and clamping of the extrahepatic common trunk of the middle and left hepatic veins were easily performed without mobilization of the liver [19]. We could perform the selective vascular exclusion method for the middle and left hepatic veins. This may have been possible because the proximity of the tumor to the middle hepatic vein was not a predictor for massive bleeding.

Recently, two studies from independent institutes have demonstrated that the histological grade of hepatic steatosis predicts the amount of blood loss [20, 21]. Nevertheless, we failed to detect any differences in the incidence of hepatic steatosis in the present study. In the two previous studies, the subjects were living donors and patients without cirrhosis. Therefore, the backgrounds of these patients are totally different from those of the patients in this study.

During massive bleeding, the avoidance of serious intraoperative or postoperative complications may be attributed to the ability of anesthesiologists to rapidly infuse large volumes of warm blood and other volume expanders via a rapid infusion system. Maintaining perfusion and euthermia and avoiding metabolic acidosis can therefore provide protection against the lethal effects of acidosis, hypotension, coagulopathy, and prolonged hemorrhagic shock. In our series, despite massive bleeding, prolonged hypotension, metabolic acidosis, and air embolism were not observed. These factors may contribute to the absence of postoperative and in-hospital mortalities in group II. Therefore, in patients with tumors larger than 12 cm in diameter that compress the IVC, a rapid infusion system and blood for transfusion should be prepared in case of massive bleeding during hepatectomy.

In conclusion, right major lobectomy for larger PLCs that compress the IVC is a predictor of massive EBL during hepatectomy. Preparation of rapid infusion devices for patients with these risk factors is necessary to avoid prolonged hypotension during the surgery.

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