Intraoperative cell salvage with autologous transfusion in elective right or repeat hepatectomy: a propensity-score–matched case–control analysis

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Background: Liver resection may be associated with substantial blood loss, and cell saver use has been recommended for patients at high risk. We performed a study to compare the allogenic erythrocyte transfusion rate after liver resection between patients who had intraoperative cell salvage with a cell saver device versus patients who did not. Our hypothesis was that cell salvage with autologous transfusion would reduce the allogenic blood transfusion rate.

Methods: Cell salvage was used selectively in patients at high risk for intraoperative blood loss based on preoperatively known predictors: right and repeat hepatectomy. Patients who underwent elective right or repeat hepatectomy between Nov. 9, 2007, and Jan. 27, 2016 were considered for the study. Data were retrieved from a liver resection database and were analyzed retrospectively. Patients with cell saver use (since January 2013) constituted the experimental group, and those without cell salvage (2007–2012), the control group. To reduce selection bias, we matched propensity scores. The primary outcome was the allogenic blood transfusion rate within 90 days postoperatively. Secondary outcomes were the number of transfused erythrocyte units, and rates of overall and infectious complications.

Results: Ninety-six patients were included in the study, 41 in the cell saver group and 55 in the control group. Of the 96, 64 (67%) could be matched, 32 in either group. The 2 groups were balanced for demographic and clinical variables. The allogenic blood transfusion rate was 28% (95% confidence interval [CI] 12.5%–43.7%) in the cell saver group versus 72% (95% CI 56.3%–87.5%) in the control group ($p < 0.001$). The overall and infectious complication rates were not significantly different between the 2 groups.

Conclusion: Intraoperative cell salvage with autologous transfusion in elective right or repeat hepatectomy reduced the allogenic blood transfusion rate.

Contexte : La résection hépatique peut s'accompagner de pertes sanguines importantes et l'utilisation d'un système de récupération de sang autologue est recommandée chez les patients à risque élevé. Nous avons procédé à une étude pour comparer le taux de transfusion de sang allogénique après la résection hépatique selon que les patients avaient ou non été soumis à une intervention de récupération de sang autologue. Notre hypothèse est que la récupération de sang autologue peropératoire pourrait réduire le taux de transfusion de sang allogénique.

Méthodes : La récupération de sang autologue a été utilisée sélectivement chez des patients exposés à un risque élevé à l'égard de pertes sanguines peropératoires, en fonction de facteurs prédictifs préopératoires connus : hépatectomie droite et reprise de l'hépatectomie. Les patients ayant subi une intervention chirurgicale non urgente pour hépatectomie droite ou reprise d'hépatectomie entre le 9 novembre 2007 et le 27 janvier 2016 ont été considérés comme admissibles à l'étude. Les données ont été récupérées à partir d'une base de données sur la résection hépatique et analysées de manière rétrospective. Les patients soumis à la récupération de sang autologue (à partir de janvier 2013) ont constitué le groupe expérimental, et les autres (2007–2012) ont constitué le groupe témoin. Pour réduire le risque de biais de sélection, nous avons apparié les scores de propension. Le paramètre principal était le taux de transfusion de sang allogénique dans les 90 jours suivant l'opération. Les paramètres secondaires étaient le nombre d'unités transfusées, le taux de complications infectieuses et le taux global de complications.

Résultats : Quatre-vingt-seize patients ont pris part à l'étude, 41 dans le groupe soumis à la récupération de sang autologue et 55 dans le groupe témoin. Parmi les 96 patients de l'étude, 64 (67 %) ont pu être assortis, 32 dans chaque groupe. Les 2 groupes étaient équilibrés aux plans des variables démographiques et cliniques. Le taux d'allotransfusions a été de 28 % (intervalle de confiance [IC] de 95 % 12,5 %–43,7 %) dans le groupe soumis à la récupération de sang autologue, contre 72 % (IC de 95 % 56,3 %–87,5 %) dans le groupe témoin (p < 0,001). Le taux de complications infectieuses et le taux global de complications n'ont pas été significativement différents entre les 2 groupes.

Conclusion : La récupération de sang autologue peropératoire dans les cas d'hépatectomie droite ou d'hépatectomie répétée a réduit le taux de transfusion de sang allogénique.

Perioperative blood loss[1,2] and transfusion[2,3] affect the outcome after liver resection. A perioperative allogeneic blood transfusion rate of 17%[4] to 64%[5] has been reported after hepatectomy. Reported risk factors for blood transfusion include preoperative anemia (hemoglobin level < 125 g/L), extrahepatic procedure, caval exposure, major hepatectomy, tumour diameter, thrombopenia, cirrhosis and repeat liver resection.[4,6,7] It has been shown that perioperative allogeneic blood transfusion is a risk factor for complications and death[2,3,8,9] and may reduce disease-free survival after resection of hepatocellular carcinoma[10] and colorectal liver metastases.[11,12] Consequently, a reduction of the allogeneic blood transfusion rate would be welcome.

Intraoperative cell salvage with autologous transfusion has been widely used in orthopedic, urologic and cardiac surgery.[13] Several studies of intraoperative cell salvage in hepatobiliary-pancreatic surgery[14–17] and liver transplantation[18–21] showed the feasibility of the procedure. The "historical" safety concerns regarding cell salvage in oncological surgery[22] were not confirmed by recent studies[14–21,23,24] and systematic reviews.[13,25,26] Cell salvage has been shown to be safe in oncological surgery.[13–21,23–26] Therefore, its use has been recommended for interventions with expected high blood loss.[13,25,26]

The aim of the present study was to compare the allogenic erythrocyte transfusion rate after liver resection between patients who had intraoperative cell salvage with a cell saver device versus patients without cell saver use. Cell salvage was used selectively in patients with a high risk of intraoperative blood loss based on preoperatively known predictors: right and repeat hepatectomy. We hypothesized that cell salvage with autologous transfusion after right or repeat hepatectomy would reduce the allogeneic blood transfusion rate.

Methods

According to French legislation for the regulation of clinical research, requirements for the provision of informed consent concerning the study were waived because of the retrospective monocentric study design and local data analysis without data transmission.[27] However, patients gave informed written consent for surgery, data collection and cell salvage.

Predictors of blood loss

We performed analysis of predictors of intraoperative blood loss in a data set of 133 liver resection procedures performed between Nov. 9, 2007, and Nov. 2, 2011, in our institution.[28] Right hepatectomy (odds ratio [OR] 7.8, 95% confidence interval [CI] 2.8–21.2) and repeat hepatectomy (OR 6.1, 95% CI 1.7–21.6) were identified as predictors of blood loss greater than 500 mL in multivariate analysis. For blood loss greater than 1000 mL, only right hepatectomy was a significant risk factor in multivariate analysis (OR 5.6, 95% CI 1.8–16.9). Based on this analysis, intraoperative cell salvage was considered for patients undergoing right or repeat hepatectomy since 2013.

Patients

We reviewed all cases of liver resection performed between Nov. 9, 2007, and Jan. 27, 2016 in our institution. Exclusion criteria were emergency liver resection and liver procedures other than right or repeat hepatectomy. Patients who required extrahepatic procedures such as simultaneous colorectal resection were included in the study.

The data were retrieved from a liver resection database and were analyzed retrospectively. Patients with cell saver use (since January 2013) constituted the experimental group, and those without cell salvage (2007–2012), the control group.

Perioperative and anesthetic management and surgical technique

Standard preoperative investigation included blood analysis and computed tomography scanning or magnetic resonance imaging in all patients. Contraindications for liver resection were liver cirrhosis (Child–Pugh class B or C), insufficient volume of the future liver remnant, technical impossibility to obtain complete resection of liver tumours and nonresectable extrahepatic disease.

Anesthesia was induced with propofol, 2 mg/kg. Adequate analgesia was given, according to the preference of the anesthesiologist, with sufentanil (administered continuously at 20 mg/h after an induction dose of 0.3 mg/kg) or remifentanil (given by target controlled infusion with target blood concentration 3–8 ng/mL). Tracheal intubation was facilitated with cisatracurium, 0.2 mg/kg. Additional neuromuscular blocking agents were given during the procedure, guided by neuromuscular monitoring. Anesthesia was maintained with desflurane. Volume-controlled mechanical ventilation (tidal volume 6–8 mL/kg) with a mixture of oxygen and air (fraction of inspired oxygen 0.5) and desflurane was done in all patients. Invasive arterial blood pressure monitoring was used continuously, and the mean arterial pressure was maintained above 80 mm Hg. Central venous pressure monitoring was used selectively, mainly in right hepatectomy. We used epidural blockade and avoidance of fluid overload to achieve and maintain a low central venous pressure.[29]

After a bilateral subcostal incision, liver parenchyma transection was performed by the clamp crushing technique under intermittent portal triad (Pringle) clamping. Inferior vena cava clamping was not used.[29] Ultrasonography and a bile leakage test were performed routinely. Intraoperatively, allogenic blood transfusion was considered according to the preoperative hemoglobin level, blood loss and hemodynamic tolerance. Postoperatively, allogenic transfusion was given according to tolerance when the hemoglobin level dropped below 80 g/L and until a target hemoglobin level of 100 g/L was achieved.

Pharmacological interventions to decrease blood loss such as tranexamic acid were not used. Antibiotics were given perioperatively according to guidelines.[30]

Postoperatively, patients were monitored in the intensive care unit for at least 24 hours. An enhanced recovery after surgery protocol was not used during the study period. Patient-controlled epidural or intravenous (morphine) administration of analgesics was used according to the preference of the anesthesiologist. All patients had thromboprophylaxis with low–molecular-weight heparin.[31]

Intraoperative cell salvage with the Dideco Electa Essential Concept cell saver (Sorin Group) was used between 2013 and 2016. A third-generation leukocyte depletion filter (Imugard III-RC [Terumo]) was routinely used for autologous transfusion of cell-salvaged blood.[13,19,32] Cell salvage was stopped when the tumour capsule was exposed during parenchymal transection, and a standard aspiration device was used further to minimize shedding of tumour cell into the cell saver reservoir.[19] Cell salvage was used only during liver resection and not for extrahepatic procedures. Cell salvage was stopped if biliary or other contamination occurred.

Blood loss in the control group was measured with a standard aspiration device with an accuracy of 50 mL. In the cell saver group, blood loss was measured with the cell saver device with an accuracy of 1 mL and with a standard aspiration device. Volume of blood loss aspirated with the cell saver was given in a printed protocol by the device. Both volumes were added to obtain the estimated total blood loss.

Definitions

We defined major hepatectomy as the resection of 3 or more liver segments. The Brisbane terminology was used for classification of the type of liver resection.[33] We defined extrahepatic procedures as partial or total resection of other organs (colon, rectum, stomach, diaphragm, adrenal gland) and biliodigestive anastomosis. Cholecystectomy, liver biopsy and lymph node sampling or dissection were not considered as extrahepatic procedures.

Overall complications were defined as any deviation from an uneventful postoperative course within 90 days after surgery. We defined the severity of complications according to the Clavien–Dindo classification.[34] The diagnosis of an infectious complication was based on clinical, biological and radiological data and included catheter, surgical site, and pulmonary and urinary infections. We defined infectious complications according to the criteria established by the Centers for Disease Control and Prevention and the 1991 Consensus Conference;[35] such complications were treated adequately with antibiotics, percutaneous drainage or surgical revision. Wound infection was classified as surgical site infection. Hospital stay was defined as postoperative hospital stay.

Outcomes

The primary outcome was the perioperative allogeneic transfusion rate within 90 days after liver resection. Secondary outcomes were the number of transfused erythrocyte units, overall and infectious complications, and hospital stay. We did not perform a power analysis owing to the retrospective study design.[36]

Statistical analysis

We reported continuous variables as mean with standard deviation (SD) or as median with range and compared them using a nonparametric Mann–Whitney test. We reported dichotomous variables as counts with proportions and compared them using the Pearson χ^2 or Fisher exact test, as appropriate. For paired variables (after matching), we used the McNemar test for dichotomous variables and the Wilcoxon signed-rank test for continuous variables. All statistical tests were 2-sided, and $p < 0.05$ was considered significant. To correct for baseline selection bias, we performed propensity score matching.[37] To predict the probability of cell saver use, we constructed a propensity score using logistic regression analysis for each patient using

8 preoperatively known covariates: age 70 years or more, hemoglobin level less than 125 g/L, prothrombin time less than 80%, colorectal metastases, presence of more than 1 tumour, right hepatectomy, associated procedures and preoperative chemotherapy. We did not use any postbaseline covariates to construct the propensity score.[37] We performed one-to-one greedy, nearest-neighbour matching without replacement on the logit of the propensity score and using a caliper distance equal to 0.25 of the standard deviation of the logit of the propensity score[37] to form pairs of subjects with and without cell saver use. We performed balance diagnostics for comparing the distribution of baseline covariates between the control and cell saver groups in the unmatched and matched samples using standardized differences.[38]

Results

A total of 294 liver resection procedures were performed between Nov. 9, 2007, and Jan. 27, 2016, in our institution. Nine cases were emergency procedures, and 189 were liver procedures other than right or repeat hepatectomy. Therefore, 96 elective right or repeat hepatectomy procedures were included in the study. Patients were followed for at least 3 months. No patient was lost during follow-up.

Baseline demographic and clinical characteristics of the 96 patients are shown in Table 1. There were significant covariate imbalances between the 2 groups: compared to the control group, patients in the cell saver group were older, more had hepatocellular carcinoma, and fewer had colorectal liver metastases (Fig. 1).

Matched sample

We were able to match 64 patients (67%) on propensity score. Baseline data are shown in Table 2. The cell saver and control groups were balanced for age, cancer, hemoglobin level, American Society of Anesthesiologists score of 3 or greater, steatosis, hepatocellular carcinoma, more than 1 liver tumour, largest tumour diameter 50 mm or greater, right hepatectomy, associated procedures and preoperative chemotherapy (standardized differences below or near 0.1). For sex distribution, Charlson Comorbidity Index score, colorectal metastasis and other diagnosis, standardized differences were between 0.1 and 0.16 (Fig. 1). The extent of liver resection, simultaneous extrahepatic procedures and perioperative data are shown in Table 3. The mean blood loss was 914 mL (SD 699 mL) and was not significantly different between the 2 groups. The mean operative time was shorter in the cell saver group than in the control group (238 [SD 65] min v. 284 [SD 75] min, $p = 0.04$), and the frequency of Pringle clamping was lower ($p = 0.006$).

Allogenic and autologous transfusion

The perioperative allogenic blood transfusion rate was 28% (95% CI 12.5%–43.7%) in the cell saver group versus 72% (95% CI 56.3%–87.5%) in the control group ($p < 0.001$) (Table 4). The corresponding values for mean number of

Table 1. Baseline demographic and clinical characteristics before propensity score matching of 96 patients who underwent right or repeat liver resection, by group

Characteristic	Group; no. (%) of patients*		*p* value†	Standardized difference‡
	Control *n* = 55	Cell saver *n* = 41		
Female sex	18 (33)	11 (27)	0.8	0.075
Age, mean ± SD, yr	63.5 ± 13.5	66.6 ± 12.6	0.4	0.243
Cancer	52 (94)	34 (83)	0.7	0.076
Charlson Comorbidity Index score, mean ± SD	5.8 ± 1.6	5.7 ± 2.1	1.0	0.052
Hemoglobin level, mean ± SD, g/L	132 ± 20	131 ± 22	0.3	0.044
ASA score ≥ 3	22 (40)	15 (37)	1.0	0.029
Steatosis	31 (56)	17 (41)	0.4	0.103
Colorectal metastases	42 (76)	19 (46)	0.02	0.490
Hepatocellular carcinoma	4 (7)	8 (20)	0.06	0.425
Other diagnosis	9 (16)	10 (24)	0.3	0.200
> 1 liver tumour	28 (51)	25 (61)	0.1	0.359
Largest tumour diameter ≥ 50 mm	19 (34)	15 (37)	0.7	0.143
Right hepatectomy	31 (56)	21 (51)	0.7	0.103
Associated procedure	15 (27)	10 (24)	0.8	0.065
Preoperative chemotherapy	25 (45)	13 (32)	0.4	0.181

ASA = American Society of Anesthesiologists; SD = standard deviation.

*Except where noted otherwise.

†Continuous variables were compared by means of the Mann–Whitney test; dichotomous variables were compared by means of the Fisher exact test.

‡Calculated according to reference 38.

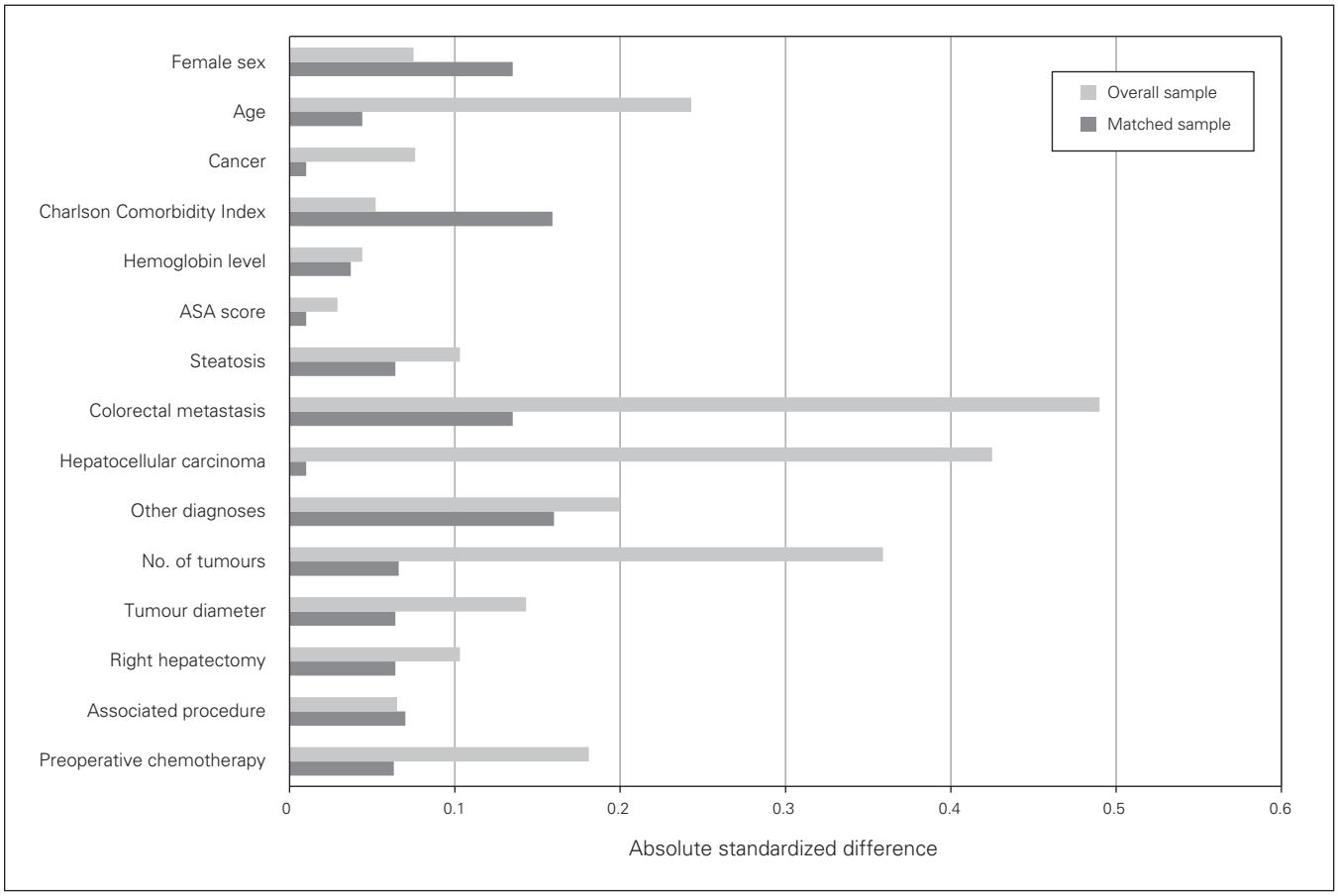

Fig. 1. Absolute standardized differences for baseline covariates, comparing cell saver to control group in the overall sample (96 patients) and the matched sample (64 patients) for right and repeat hepatectomy. ASA = American Society of Anesthesiologists.

Table 2. Baseline demographic and clinical characteristics of the 2 groups after propensity score matching

Characteristic	Group; no. (%) of patients*		*p* value†	Standardized difference
	Control *n* = 32	Cell saver *n* = 32		
Female sex	11 (34)	9 (28)	0.8	0.135
Age, mean ± SD, yr	65.9 ± 13.3	66.5 ± 12.3	0.8	0.044
Cancer	30 (94)	30 (94)	1.0	0.0
Charlson Comorbidity Index score, mean ± SD	5.6 ± 1.6	5.9 ± 1.9	0.4	0.159
Hemoglobin level, mean ± SD, g/L	131 ± 22	132 ± 22	0.6	0.037
ASA score ≥ 3	14 (44)	14 (44)	1.0	0.0
Steatosis	20 (62)	19 (59)	1.0	0.064
Colorectal metastases	23 (72)	21 (66)	0.7	0.135
Hepatocellular carcinoma	4 (12)	4 (12)	1.0	0.0
Other diagnosis	5 (16)	7 (22)	0.7	0.160
> 1 liver tumour	22 (69)	21 (66)	1.0	0.066
Largest tumour diameter ≥ 50 mm	12 (38)	13 (41)	1.0	0.064
Right hepatectomy	18 (56)	17 (53)	1.0	0.064
Associated procedure	7 (22)	8 (25)	1.0	0.070
Preoperative chemotherapy	15 (47)	14 (44)	1.0	0.063

ASA = American Society of Anesthesiologists; SD = standard deviation.

*Except where noted otherwise.

†Continuous variables were compared by means of the Wilcoxon signed-rank test; dichotomous variables were compared by means of the McNemar test.

Table 3. Perioperative data for the 2 groups for the matched sample

Variable	Group; no. (%) of patients* Control *n* = 32	Cell saver *n* = 32	*p* value†
Repeat hepatectomy	21 (66)	16 (50)	0.3
Extension of hepatectomy			
Minor (1–2 segments)	11 (34)	11 (34)	1.0
Major (3–4 segments)	15 (47)	16 (50)	1.0
Extended (≥ 5 segments)	6 (19)	5 (16)	1.0
Extrahepatic procedure	7 (22)	8 (25)	1.0
Biliodigestive anastomosis	1 (3)	1 (3)	1.0
Colorectal resection	2 (6)	2 (6)	1.0
Other‡	4 (12)	5 (16)	1.0
Operative time, mean ± SD, min	284 ± 75	238 ± 65	0.04
Pringle clamping	30 (94)	22 (69)	0.006
Blood loss, mean ± SD, mL	751± 545	1077 ± 802	0.1

SD = standard deviation.

*Except where noted otherwise.

†Continuous variables were compared by means of the Wicoxon signed-rank test; dichotomous variables were compared by means of the McNemar test.

‡Partial resection of right hemidiaphragm (*n* = 4), partial resection of small intestine (*n* = 5).

transfused erythrocyte units per patient who received an allogenic transfusion were 3.8 (SD 2.5) and 5.4 (SD 4.4). Twenty patients (62%) in the cell saver group had an intraoperative autologous erythrocyte transfusion of salvaged blood. The mean volume of autologous blood transfused was 458 (SD 347) mL. The mean hematocrit of transfused autologous blood was 34% (SD 13).

Postoperative complications

There were no intraoperative deaths. Two patients (3%) died within 90 days; the causes were septic shock with multiorgan failure due to anastomotic fistula after right hepatectomy with ileostomy closure in 1 patient and liver failure in the other. Complications were recorded in 38 patients (59%) (Table 5). Five patients (8%) required reoperation. Major complications (Clavien–Dindo class ≥ III) were recorded in 16 patients (25%) and infectious complications in 20 (31%). There were no significant differences between the cell saver and control groups in complications or mortality.

Table 4. Perioperative allogenic transfusion within 90 days postoperatively in the 2 groups for the matched sample

Variable	Group Control *n* = 32	Cell saver *n* = 32	*p* value*
No. (%) of procedures with allogenic transfusion			
Total†	23 (72)	9 (28)	< 0.001
Intraoperative	19 (59)	4 (12)	< 0.001
Postoperative	13 (41)	5 (16)	0.008
Total no. of erythrocyte units transfused	125	34	0.002
No. of erythrocyte units per patient, mean ± SD	5.4 ± 4.4	3.8 ± 2.5	–
Hemoglobin level at discharge, mean ± SD, g/L	114 ± 16	110 ± 17	0.2

SD = standard deviation.

*Continuous variables were compared by means of the Wilcoxon signed-rank test; dichotomous variables were compared by means of the McNemar test.

†Nine patients had both intra- and postoperative transfusion.

Table 5. Postoperative complications, severity of complications according to Clavien–Dindo classification[34] and hospital length of stay in the 2 groups for the matched sample

Variable	Group; no. (%) of patients* Control *n* = 32	Cell saver *n* = 32	*p* value†
Complication(s)	22 (69)	16 (50)	0.3
Infectious complication(s)‡	12 (38)	8 (25)	0.4
Pulmonary	7 (22)	4 (12)	0.5
Venous catheter	2 (6)	1 (3)	1.0
Urinary tract	3 (9)	0 (0)	0.2
Surgical site	6 (19)	4 (12)	0.7
Clavien–Dindo grade			
I	5 (16)	2 (6)	0.4
II	9 (28)	6 (19)	0.5
III	1 (3)	6 (19)	0.1
IV	5 (16)	2 (6)	0.4
V	2 (6)	0 (0)	0.5
Reoperation	3 (9)	2 (6)	1.0
Hospital length of stay, mean ± SD, d	17.6 ± 17.0	11.4 ± 6.7	0.08

SD = standard deviation.

*Except where noted otherwise.

†Continuous variables were compared by means of the Wilcoxon signed-rank test; dichotomous variables were compared by means of the McNemar test.

‡Some patients had more than 1 infectious complication.

Discussion

In the present case–control study comparing the perioperative allogenic blood transfusion rate within 90 days after right or repeat hepatectomy between patients who had intraoperative cell salvage with a cell saver versus those who did not, the transfusion rate was significantly lower in the cell saver group than in the control group (28% v. 72%). The number of allogenic erythrocyte units transfused was significantly lower in the cell saver group. The data did not permit demonstration of an impact of cell saver use on postoperative complications.

Autologous transfusion with a cell saver was used by Zulim and colleagues[14] in 39 patients undergoing liver resection; all patients received an autologous transfusion, with a mean volume of 1511 mL (range 200–6250 mL). Fujimoto and colleagues[15] used autologous transfusion with cell salvage in patients undergoing liver resection for hepatocellular carcinoma and transfused a mean volume of 439 mL of salvaged blood. Bui and colleagues[16] used a cell saver in 21 patients undergoing liver resection and were

able to decrease blood loss and transfusion requirements. More recently, Bower and colleagues[17] studied cell salvage for major oncologic procedures in 92 patients, 32 (35%) of whom received an autologous transfusion of salvaged blood. Forty-three patients underwent liver resection (14 with autologous transfusion), with a mean volume of 255 mL (range 117–1499 mL) of autologous blood transfused. The recurrence rate was not increased among patients with cell salvage in these studies.[14,15,17]

Several investigators have reported cell salvage with autologous transfusion in patients undergoing liver transplantation for hepatocellular carcinoma.[18–21] In those studies, a reduced allogenic transfusion rate and no increase in hepatocellular carcinoma recurrence was registered.[18,20,21] Liang and colleagues[19] reported use of a leukocyte depletion filter for removal of tumour cells after cell salvage in patients with hepatocellular carcinoma undergoing liver transplantation; the filter was effective except in 2 patients with ruptured tumours.

Cell salvage with autologous transfusion has been used in urologic and gynecologic surgery for malignant disease.[23,24] The mean volume of autologous blood transfused was 506 mL and 400 mL, respectively.

Our study confirms the efficacy of cell salvage for reducing allogenic transfusion requirements.[13,15,23] The mean volume of autologous blood transfused, 458 mL, is within the range reported by other authors.[15,17,23,24]

The present study also confirms the safety of cell salvage with autologous transfusion with regard to postoperative complications.[14–21,23,24] The shorter hospital stay in the cell saver group reflects the general trend of a shorter hospital stay in more recent years, although a formalized enhanced recovery after surgery protocol was not used during the study period.

In the present study, cell salvage was selectively used in patients at high risk for intraoperative blood loss, based on preoperatively known predictors: right and repeat hepatectomy. McNally and colleagues[39] reported major liver resection and increased operative time as predictors of intraoperative blood loss. In their study, a median blood loss of 782 mL (range 25–5000 mL) was registered. Other authors confirmed longer operative time as a risk factor for increased blood loss in hepatectomy.[40] However, operative time was not known preoperatively. In our experience, selective use of cell salvage in patients undergoing liver resection was feasible. However, the external validity of predictive factors for blood loss (or blood transfusion) remained a problem, as varied case-mix, different surgical techniques and skills, and varied transfusion practices are likely to affect the outcome.[41]

Recently, Lemke and colleagues[42] reported that cell saver use in patients undergoing liver resection would be cost-efficient in those with a transfusion risk greater than 25%. The patients in the present study were within the criteria for cell saver use in liver resection proposed by those authors.

Our study could be criticized for the rather high transfusion rate in the control group, 72%. However, this finding is explained mainly by patient selection, as the study population was limited to patients who had undergone right or repeat hepatectomy. For comparison, the perioperative transfusion rate in 133 consecutive liver resection procedures (all types) performed between Nov. 9, 2007, and Nov. 2, 2011, in our institution was 43%.[28] Furthermore, the mean blood loss of 914 mL in the present study is within the range reported by other authors.[16,39,40]

Limitations

The main limitation of the present study is the retrospective and nonrandomized study design. However, data about cell salvage in liver resection[14–17] and surgery for malignant disease[13] from randomized trials are scarce. To the best of our knowledge, no randomized study of cell saver use has been reported in liver resection. Therefore, we performed propensity score matching to reduce baseline covariate imbalances between groups. Significant covariate imbalances between groups in the unmatched sample were reduced in the matched sample, as all standardized differences were 0.16 or less. The remaining covariate imbalances after matching are explained by the rather small number of patients (n = 96), which limited the possibilities of matching. Furthermore, propensity score matching will, on average, result in measured baseline covariates' being balanced between groups.[37] Unmeasured covariates can be balanced between groups only by randomization.

Furthermore, the small number of patients available for analysis limits the statistical value of our findings. Type II error is a possible explanation for the absence of impact of cell salvage on the observed overall complication rate.

The present study was not designed to detect differences in survival after liver resection for malignant disease between the cell saver and control group. However, previous reports did not show an increased rate of recurrence with cell saver use in patients with malignant disease.[13–21,23–26]

Possible biases are the shorter mean operative time and slightly higher blood loss in the cell saver group. The mean operative time was 46 minutes longer in the control group than in the cell saver group. Intuitively, a longer operative time may have increased the perioperative risk. Tzeng and colleagues[43] reported that a shorter operative time was associated with a reduced complication rate and that a longer operative time was associated with a higher complication rate. The slightly higher blood loss in the cell saver group may have been influenced by a reporting bias due to the retrospective study design. Surgical swabs were wrung out in the cell saver group before they were taken out of the surgical site. Blood loss to swabs may represent about 30% of the total surgical blood loss.[44] This may contribute to the observed difference in blood loss, as swabs

were not wrung out in the control group. The duration of the operation and intraoperative blood loss were not included in the propensity score model, as only variables that are measured at baseline (before treatment) should be included in the model.[37]

Another limitation of our study was the nonstandardized allogenic erythrocyte transfusion based on individual tolerance of the patient, a postoperative hemoglobin level trigger of 79 g/dL and the clinical judgment of the surgeon. We cannot exclude the possibility that some patients had an allogenic transfusion outside the criteria (overtransfusion) or that an allogenic transfusion was not given in a patient within the criteria. However, the overall clinical practice for allogenic erythrocyte transfusion was not changed during the study period in our institution. This is confirmed by a mean hemoglobin level at hospital discharge of 114 g/L for the control group versus 110 g/L for the cell saver group.

A further limitation of autologous transfusion of salvaged blood is the processing time of the cell saver and the use of filtration, which limits the flow of autologous blood transfused. In selected patients with high blood loss during liver transection, allogenic erythrocyte transfusion was required, as salvaged blood was not available in time. In these cases, the dynamics of blood loss influenced the decision to transfuse allogenic erythrocytes to maintain hemodynamic stability.

Conclusion

In this case–control study, intraoperative cell salvage with autologous transfusion in patients who underwent elective right or repeat hepatectomy reduced the allogenic blood transfusion rate.

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