Original Article

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Short- and long-term outcomes of hepatectomy with or without radiofrequency-assist for the treatment of hepatocellular carcinomas: a retrospective comparative cohort study

Rui Guo*, Xiaobin Feng*, Senlin Xiao, Jun Yan, Feng Xia, Kuansheng Ma, Xiaowu Li**

Institute of Hepatobiliary Surgery, Southwest Hospital, Third Military Medical University, Chongqing, China.

Summary **The objective of this study was to compare the short- and long-term outcomes of radiofrequency-assisted liver resection (RFLR) and conventional clamp-crushing liver resection (CCLR) and to evaluate the safety and efficiency of RFLR. Between January 2008 and December 2012, a total of 597 patients with hepatocellular carcinoma (HCC) who underwent curative hepatectomy were identified. A total of 272 patients underwent RFLR, and 325 patients received CCLR. The short- and long-term outcomes were compared. The patients in the RFLR and CCLR groups showed similar baseline characteristics. The RFLR group showed less intraoperative blood loss (485.5 *vs*. 763.2 mL, $p = 0.003$), a lower transfusion requirement rate (19.1 *vs*. 31.7%, $p \leq 0.01$), shorter surgery duration (211 *vs*. 296 min, $p \leq 0.01$) and a lower vascular inflow occlusion rate (25.7 *vs*. 33.8%, $p = 0.032$). No significant postoperative changes in bilirubin or liver enzymes were observed in the two groups. The degree of postoperative complications and morbidity did not significantly differ between the two groups. There were no significant differences in the 1-, 2- and 3-year overall survival rates (73.8%, 58.5%, and 55.7% *vs*. 80.8%, 65.8%, and 56.2%, respectively) or disease-free rates (51.9%, 47.2%, and 46.0% *vs*. 54.5%, 44.9%, and 38.5%, respectively) between the RFLR and CCLR groups. These results suggested RFLR was a safe and efficient method for patients with HCC. RFLR was associated with decreased blood loss, fewer blood transfusions, shorter surgery times and less vascular inflow occlusion application. The RFLR group did not show increased liver injury or postoperative morbidity or mortality.**

Keywords: Hepatocellular carcinoma, radiofrequency-assisted, hepatectomy, comparative study, blood loss

1. Introduction

Hepatocellular carcinoma (HCC) is the fifth most common primary malignant cancer of the liver and the third leading cause of cancer-related deaths worldwide (*1,2*). Curative liver resection is widely accepted as the initial and first-line therapeutic strategy for patients with early-stage and advanced-stage HCC (as defined in the Barcelona Clinic Liver Cancer (BCLC) staging system, according to the guidelines of the American Association for the Study of Liver Disease and European Association for the Study of the Liver) (*3*). Liver resection has been increasingly performed in most specialized centers and has undergone remarkable improvement over recent decades. This has resulted in improvements in diagnosis, surgical techniques, anesthetic management and postoperative care, thereby reducing morbidity and mortality following hepatic resection (*4*).

Despite improvements in the safety of liver resection, the procedure continues to present a risk of massive intraoperative bleeding. Recent technological innovations and improved techniques, including vascular control, low central venous pressure, various hemostatic agents and multiple parenchymal

*These authors contributed equally to this works.
***Address correspondence to:*
Dr. Xiaowu Li, Institute of Hepatobiliary Surgery, Southwest Hospital, Third Military Medical University, Chongqing 400038, China.
E-mail: lixw1966@163.com

transection techniques aimed at controlling and minimizing hemorrhaging during the transection of liver parenchyma in haptic resections have been applied in clinical practice (*5*). Radiofrequency (RF)-assisted liver resection devices have been developed that employ a bipolar needle and utilize the RF energy to pre-coagulate the liver transection plane. The heat produced by the microwaves seals the vessels and enables the bloodless resection of parenchyma transections. This method was first introduced by Habib's group at Hammersmith Hospital, London, UK and has been shown to effectively reduce intraoperative bleeding (*6*). Although this device is promising, severe adverse events have been reported, especially bile leakage and severe liver damage, which could increase postoperative morbidity and mortality (*7,8*).

Our study compared RF-assisted liver resection (RFLR) with conventional clamp-crushing liver resection (CCLR) in HCC patients and investigated whether RFLR could reduce intraoperative bleeding, vascular inflow occlusion and postoperative complications. Our study also analyzed RFLR damage to liver function and postoperative morbidity in HCC concomitant cirrhosis in the short-term and compared the long-term results with those of CCLR.

2. Methods

2.1. *Patients*

From January 2008 to December 2012, on a series of 597 patients diagnosed with HCC hepatectomy was performed at Institute of Hepatobiliary Surgery, Southwest Hospital. Patients who received CCLR or RFLR were identified. Data comprising demographic information, perioperative parameters and complications of all participants were prospectively collected and retrospectively analyzed from a review of medical charts and a computerized database. The study protocol was approved by the Clinical Trial Ethics Committee of Southwest Hospital, Third Military Medical University, and informed consent for the study was obtained from the participants prior to treatment.

Patients who fulfilled the following criteria were included in the study: *i*) a clinical diagnosis of resectable HCC; *ii*) 18 to 65 years of age; *iii*) preoperative liver function tests showing Child-Pugh Classification A or B with no encephalopathy or upper gastrointestinal bleeding history; *iv*) 15-min indocyanine green retention (ICG-R15) of < 30%; *v*) acceptable clotting profile [platelet count (PLT) > 50×10^9/L and a prolonged prothrombin time of < 5 seconds]; *vi*) sufficient relative residual liver volume (% RLV) ≥ 40%; *vii*) no tumor invasion in the primary branch of the portal vein, hepatic vein, or inferior vena cava; *viii*) no metastasis in lymph nodes or other organs; and *ix*) written informed consent.

2.2. *Diagnosis and definition*

The diagnosis of HCC was preoperatively confirmed based on the criteria of the practice guidelines of the American Association for the Study of Liver Disease (AASLD) and was confirmed *via* a pathological specimen test after surgery (*9*). Ultrasonic (US) contrast, tri-phasic abdominal contrast-enhanced spiral computed tomography (CT) scanning and abdominal magnetic resonance imaging (MRI) were applied to detect liver lesions. Either *i*) two imaging techniques showing typical HCC features or *ii*) positive findings on imaging together with or without an alpha-fetoprotein (AFP) level > 400 ng/mL was considered to indicate HCC.

Liver resection was classified based on Couinaud's classification system. Major liver resection was defined as the resection of three or more liver segments according to Couinaud's classification, whereas minor liver resection was defined as the resection of two segments or less (*10*). Operative mortality was defined as any death within 90 days after surgery or during the hospital stay. The severity of postoperative complications was estimated according to the Clavien-Dindo classification system (*11*). The postoperative peak of alanine aminotransferase (ALT) level and total bilirubin (TIBL) level were chosen to be accurate markers of hepatocellular injury and recovery following hepatic resection. Liver failure was diagnosed using the "50-50 criteria" (*12*). Bile leakage was defined as the drainage of 50 mL or more of bile from the surgical drain or drainage from an abdominal collection lasting 3 days or more (*13*).

2.3. *Preoperative management*

All patients underwent careful preoperative assessment, including laboratory tests (*e.g.*, blood biochemistry, alpha-fetoprotein assay, and hepatitis B virus DNA PCR test), chest X-ray, electrocardiogram (ECG), contrast enhanced ultrasonography (CEUS), tri-phasic abdominal contrast-enhanced spiral CT scanning and abdominal MRI. Liver function was assessed with Child-Pugh grading, indocyanine green retention at 15 minutes (ICG-R15) and/or an oral glucose tolerance test (OGTT). The indication for surgery for each patient was discussed at the Multi-Disciplinary Treatment and Pathway Meeting.

2.4. *Surgical procedure*

A team of four senior hepatobiliary surgeons who had more than 10 years of experience and had independently conducted standard anatomical hepatectomy in more than 100 patients performed all hepatic resections. The surgical procedures were selected according to a previously described algorithm (*14,15*). All hepatic resection surgeries were carried out under general anesthesia using a "J" right subcostal incision with a midline extension. Intraoperative ultrasound (IOUS) was routinely applied to confirm the tumor location and size. Then, the resection was delineated 1 cm from the edge of the tumor using an electrosurgical knife. RFLR was performed using a bipolar radiofrequency device (Habib™ 4X, Generator 1500X RITA Medical Systems, Inc., California, USA). The device consisted of two pairs of opposing electrodes with an active end which was 6-10 cm in length. RFLR was conducted by inserting the electrode into the liver parenchyma and parallel to the delineated line. Coagulation desiccation was performed and induced pale tissue coloration due to coagulation necrosis. The electrodes were withdrawn 1-2 cm in preparation for the next session. After the treatment, the liver parenchyma was dissected using a surgical scalpel along the desiccated line. Electric scalpel or water dissector (Jet2, Erbe Corp., Germany), together with a Kelly clamp were used to dissect the liver parenchyma in both RFLR and CCLR. After crush-clamping, small vessels (< 2 mm) were sealed and divided using the electric scalpel. Large vessels and major intrahepatic bile ducts were ligated and divided. In CCLR, the tumor was resected only using the clamp-crushing method without RFA pre-coagulation treatment. The Pringle maneuver (15 min of occlusion and 5 min of reperfusion) was applied in both groups to achieve intermittent inflow occlusion to control massive bleeding, if necessary.

2.5. Statistical methods

Statistical analyses were performed using the Statistical Package for the Social Sciences version 19.0 software (SPSS, Chicago, Illinois, USA). Continuous variables were expressed as the means ± standard deviation or median with interquartile range and compared using an independent sample *t* test and the Mann-Whitney U test. For categorical variables, comparisons were made using chi-square analysis and a Fisher's exact test. All differences were examined using a two-tailed test, and $p < 0.05$ was considered to be statistically significant.

3. Results

3.1. *Patient characteristics*

A total of 597 HCC patients (528 males and 69 females) who had surgical liver resection were enrolled and analyzed in this study. A total of 272 (45.6%) and 325 (54.4%) patients received RFLR and CCLR, respectively. The baseline characteristics of the patients receiving RFLR and CCLR are shown in Table 1. Most patients in both groups suffering from HCC were males (89.3% *vs*. 87.7%, respectively, $p = 0.531$). The mean age was 49.0 years in the RFLR group compared with 49.5 years in the CCLR group ($p = 0.568$). Hepatitis B viral infection was common in both groups (88.2% *vs*. 84.3%, respectively, $p = 0.167$). There were no significant differences between the two groups regarding age, gender, HBV infection, tumor size, tumor number, ICG-R15, TIBL, ALT, AST, platelet count, or perioperative AFP level. In both groups, most liver resections were carried out for HCC with Child-Pugh A.

Table 1. Baseline demographic in HCC patients undergoing RFLR or CCLR

Items	RFLR	CCLR	*p value*
No. of patients, *n* (%)	272 (45.6%)	325 (54.4%)	
Gender			0.531
Male	243 (89.30%)	285 (87.70%)	
Female	29 (10.80%)	40 (12.30%)	
Age (years)	48.98 ± 11.48	49.51 ± 10.99	0.568
HBsAg, n (%)			0.167
Positive	240 (88.24%)	274 (84.31%)	
Negative	32 (11.76%)	51 (15.69%)	
Serum Biochemistry			
PLT count(× 10^9/L)	135.92 ± 79.06	139.49 ± 78.97	0.583
ALT level	46.83 ± 38.16	56.64 ± 65.88	0.03
AST level	50.81 ± 34.51	64.53 ± 115.32	0.059
Total Bilirubin	18.08 ± 22.59	22.41 ± 37.62	0.097
Albumin	41.16 ± 8.89	40.30 ± 9.94	0.272
AFP level			0.831
≤ 400	192 (70.59%)	232 (71.38%)	
> 400	80 (29.41%)	93 (28.62)	
ICG-R15 (%)			1.000
≤ 20	259 (98.90%)	322 (99.07%)	
> 20	3 (1.10%)	3 (0.93%)	
Tumor Size max (cm)	6.09 ± 3.23	6.24 ± 3.63	0.583
Tumor Number, *n* (%)			0.604
Single	206 (75.74%)	252 (77.54%)	
Multiple	66 (24.26%)	73 (22.46%)	
Child-Pugh A/B/C	258/14/0	298/27/0	0.128

HBAg: hepatitis B virus surface antigen, PLT: platelet, ALT: alanine aminotransferase, AST: aspartate aminotransferase, ICG-R15: indocyanie green retention test at 15 min, AFP: alpha-fetoprotein.

3.2. *Intraoperative outcomes*

The surgical variables and perioperative outcomes for the 597 patients are shown in Table 2. The surgical procedures in the RFLR group comprised 108 (39.7%) major resections and 164 (60.3%) minor resections. There were 146 (44.9%) major resections and 179 (55.1%) minor resections in the CCLR group. There was no intraoperative death in either group. The average duration of the operation was significantly shorter in the RFLR group compared with the CCLR group (211 *vs*. 296 min, respectively, $p \leq 0.01$). Significantly reduced blood loss was observed in the RFLR group compared with the CCLR group (485.5 *vs*. 763.2 mL, respectively, $p = 0.003$). The RFLR group also required less operative blood transfusions than the CCLR group (128.8 *vs*. 312.1 mL, respectively, $p \leq 0.01$). The patient transfusion requirement was also significantly less in the RFLR group compared with the CCLR group (52 *vs*. 103, 19.1% *vs*. 31.7%, respectively, $p \leq 0.01$). Additionally, the Pringle maneuver was less frequently required in the RFLR group compared with the CCLR group (25.7% *vs*. 33.8%, respectively, $p = 0.032$). However, there were no significant differences in occlusion times between the two groups (30.3 *vs*.33.3min, respectively, $p = 0.303$).

3.3. *Postoperative morbidity and mortality*

The mean hospital stay time after surgery was 16.4 days in the RFLR group and 16.3 days in the CCLR group ($p = 0.838$). The length of ICU stay did not differ between the patients who underwent RFLR and those who underwent CCLR (1.6 ± 1.4 *vs*. 1.6 ± 1.7 days, respectively, $p = 0.808$).

Table 2. Comparison of intraoperative data of patients in RFLR and CCLR groups

Items	RFLR	CCLR	*p value*
Type of resection (%)			0.199
Major	108 (39.7%)	146 (44.9%)	
Minor	164 (60.3%)	179 (55.1%)	
Duration of operation (min)			0.000
Mean (S.D.)	211.2 (63.2)	295.9 (107.3)	
Median (range)	203 (85-532)	285 (120-738)	
Blood Loss (mL)			0.003
Mean (S.D.)	485.54 (465.8)	763.2 (1154.8)	
Median (range)	350 (50-4500)	400 (50-12000)	
Transfusion (mL)			0.000
Mean (S.D.)	128.8 (308.8)	312.1 (745.0)	
Median (range)	600 (0-2280)	540 (0-7000)	
No. of transfused patients	52 (19.1%)	103 (31.7%)	0.000
Pringle maneuver (%)	70 (25.7%)	110 (33.8%)	0.032
Pringle time (min)			0.303
Mean (S.D.)	30.33 (13.33)	33.25 (21.18)	
Median (range)	30 (0-60)	30 (0-123)	

S.D.: standard deviation.

Table 3. Baseline demographic in HCC patients undergoing RFLR or CCLR

Items	RFLR ($n = 272$)	CCLR ($n = 325$)	*p value*
Hospital Stay (days)	16.4 ± 8.4	16.3 ± 7.3	0.838
ICU stay (days)	1.6 ± 1.4	1.6 ± 1.7	0.808
Dindo-Clavien morbidity	83 (30.5%)	88 (27.1%)	0.355
Classification			
I	20 (7.4%)	11 (3.4%)	
II	16 (5.9%)	20 (6.2%)	
III	28 (10.3%)	37 (11.4%)	
IV	6 (2.2%)	12 (3.7%)	
V	13 (4.8%)	8 (2.5%)	
Type of complication			
Bile leakage	22 (8.1%)	21 (6.5%)	0.444
Gastrointestinal bleeding	0	1 (0.3%)	1.000
Abdominal bleeding	2 (0.7%)	1 (0.3%)	0.877
Portal vein thrombosis	2 (0.7%)	1 (0.3%)	0.877
Wound infection	10 (3.7%)	7 (2.2%)	0.265
Abdominal infection	8 (2.9%)	11 (3.4%)	0.942
Lung infection	11 (4.0%)	27 (8.3%)	0.759
Ileus	1 (0.4%)	0	0.929
Pleural effusion	13 (4.8%)	27 (8.3%)	0.086
Intra-abdominal abscess need tapping	20 (7.4%)	16 (4.9%)	0.214
Sepsis	2 (0.7%)	4 (1.2%)	0.847
Respiratory distress	3 (1.1%)	11 (3.4%)	0.118
Renal failure	4 (1.5%)	5 (1.5%)	1.000
Liver failure	16 (5.9%)	12 (3.7%)	0.286
MODS	6 (2.2%)	8 (2.5%)	1.000
Death	13 (4.8%)	8 (2.5%)	0.126

Postoperative complications are displayed in Table 3. The Clavien-Dindo Classification of Surgical Complications was used to evaluate the severity of postoperative complications (*11*). The mortality rate seemed to be higher in the RFLR group compared with the CCLR group (4.8% *vs*. 2.5%, respectively), however this difference was not significant ($p = 0.126$). The overall postoperative morbidity rate was 28.6% (171/597), and there was no significant difference between the two groups in postoperative morbidity (30.5% (83/272) in the RFLR group versus 27.1% (88/325) in the CCLR group ($p = 0.355$)). The most severe complications were liver failure, sepsis, MODS and portal vein thrombosis, which could result in death. A total of 16 (5.9%) patients who underwent RFLR and 8 (2.5%) patients who underwent CCLR suffered from liver failure; however, only 6 patients in the RFLR group and 4 patients in the CCLR group progressed to MODS and death and there was no significant difference ($p = 0.286$). The kinetics of postoperative ALT and TIBL in each group is shown in Figure 1. The ALT peak on postoperative day (POD) 1 in the RFLR group was not significantly different from that in the CCLR group (500.5 ± 429.7 *vs*. 490.3 ± 464.6 IU/L, $p = 0.317$) and had a tendency to return to normal values by POD 10. The TIBL was similar for both groups with an increase until POD 3 followed by a slow decrease to preoperative values on POD 7 ($p = 0.64$).

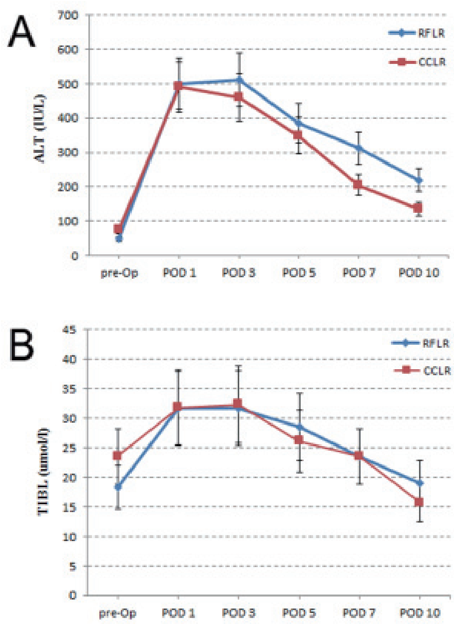

Figure 1. Postoperative liver injury and recovery assessed by serial measurement of (A) alanine aminotransferase (ALT) and (B) total bilirubin (TIBL) level in RFLR and CCLR groups.

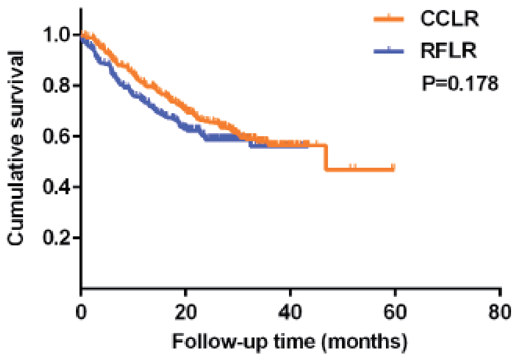

Figure 2. Overall survival for the patients in RFLR and CCLR groups.

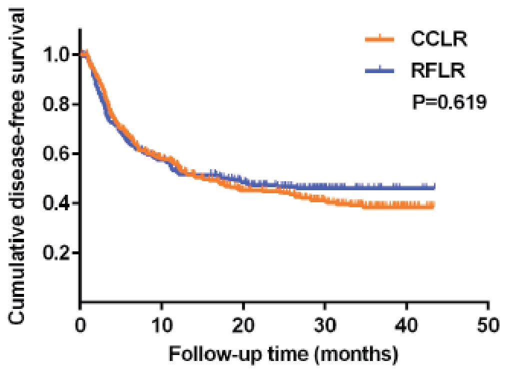

Figure 3. Recurrence-free survival for the patients in RFLR and CCLR groups.

3.4. *Disease-free survival and overall survival*

The median follow-up duration in the RFLR patients was 21.9 months (range 1-43 months) and 26.7 months (range 1-60 months) in the CCLR patients. The 1-, 2-, and 3-year overall survival rates were 73.8%, 58.5%, and 55.7% in the RFLR group and 80.8%, 65.8% and 56.2% in the CCLR group, respectively (Figure 2). There were no significant differences between the two groups (p = 0.178). The 1-, 2-, and 3-year disease-free survival rates were 51.9%, 47.2%, and 46.0% in the RFLR group, and 54.5%, 44.9% and 38.5% in the CCLR group, respectively (Figure 3). No significant differences between the two groups were observed (p = 0.619).

4. Discussion

The results of this retrospective study revealed that the efficacy of RFLR was superior to that of CCLR (without RF assistance) during operations for patients with HBV-related and cirrhotic HCC. The amount of blood loss, blood transfusion frequency, operation duration and vascular inflow occlusion were significantly reduced in the RFLR group compared with those in the CCLR group. Additionally, RFLR did not induce further damage or increase mortality/morbidity after hepatic resection compared with CCLR. The 1-, 2-, and 3-year overall survival and disease-free rates were similar between the two groups.

Controlling blood loss and minimizing bleeding during liver parenchyma transection are primary concerns of every hepatic surgeon (*16*). Previous studies have shown that increased intraoperative blood loss and increased blood transfusions are critical factors associated with perioperative morbidity, mortality and tumor recurrence for patients with HCC (*17-20*). Accordingly, efforts have been made to minimize intraoperative blood loss. A RF device for liver parenchyma transection has been recently introduced and has met with great interest due to its ability to minimize bleeding and reduce surgery duration (*6*). The central finding of this study included significantly reduced blood loss as well as a reduced need for blood transfusion in patients undergoing RFLR compared with those undergoing CCLR. These apparent benefits compensated for the RFA coagulate necrosis effect, which inhibited blood flow to small vessels and surrounding tissues during liver parenchyma transection. Our results were similar to those of Arita (*21*) and Li *et al*. (*22*) and showed RFLR achieved less blood loss. In this large-scale retrospective study, more than 90% of the patients had HBV-related cirrhosis concomitant with HCC. Liver tissue hardens and loses elasticity in these patients. This consequently adds difficulty in separating or dissecting the liver parenchyma and increases the risk of massive bleeding. Therefore, RFLR was an effective method to reduce blood loss and blood transfusion during liver parenchyma transection in HBV-related cirrhosis.

Another substantial advantage of the RFLR compared with CCLR is that RFLR reduced the frequency and duration of hepatic vascular inflow occlusion, which maximally protected hepatocellular function and reduced postoperative liver dysfunction or liver failure. The Pringle maneuver (PM) was the most commonly used and traditional hepatic vascular inflow occlusion technique to control massive bleeding in hepatic resection. However, recent studies have suggested that the Pringle maneuver may promote ischemia-reperfusion injury in the liver and induce postoperative liver dysfunction or liver failure (*23-25*). Our results demonstrated that the application of PM in RFLR patients was less than that in CCLR patients. We also observed a slightly higher postoperative ALT level, longer fall back in the RFLR group, and slightly higher postoperative liver failure in the RFLR group; however, these differences were not significant. This finding is important for HCC with cirrhosis because it is better to avoid unnecessary vascular inflow occlusion and maintain the vascular inflow stability of the liver during surgery. It has been known that RF coagulation induced necrosis of the tumor tissue and normal tissue of the remnant liver (*26*). Reducing the application of PM allows more remnant liver preservation and a lowered incidence of postoperative liver failure.

We also observed that the postoperative 90-day overall morbidity rate of 28.6% was in line with previously reported rates of 16.7% to 54%, and the overall mortality rate (within 30 days after operation) of 3.5% was consistent with previously reported rates of 8.9% to 19.6% for liver resection (*27-29*). The overall morbidity and mortality rates did not differ between the patients who underwent RFLR and those who underwent CCLR in this study. Bile leakage has been traditionally regarded as a major complication after hepatectomy. The incidence of postoperative bile leakage after RFLR was 7.2% in this study, which is consistent with or even better than in most reported series ranging from 0% to 12.5% (*30-32*). In the present study, the postoperative bile leakage rate in the RFLR group was comparable to that in the CCLR group (8.1% *vs*. 6.5%, $p = 0.444$). Our results were better than those of Li (*22*) and Lupo *et al*. (*33*), showing that RFLR did not cause additional bile leakage. This could be explained by the following: *i*) We started the RF device at 60 W for 10-30 sec per each coagulation and adjusted the power based on the severity of liver cirrhosis; and *ii*) We rarely exceeded 80 W, whereas Lupo's (*33*) group used 100 W for 3-6 min per application. More conservative energy use decreased damage to remnant liver parenchymal function, avoided necrosis on the surgical surface and decreased biliary damage (*26*). We noticed a gradual lowering of the incidence of bile leakage in the RFLR group during the study period (over a period of years) due to a thorough understanding of the RF device and improved knowledge of intrahepatic anatomy.

The overall survival and disease-free survival rates were comparable and did not significantly differ between the two groups. A previous study reported overall 3-year survival rates ranging from 30% to 63% and a 3-year disease-free survival range of 24%-54% (*29,34,35*). Our results are in line with their data. Prassas *et al*. (*36*) reported longer overall survival and longer disease-free survival rates for RFLR. They hypothesized that tissue ablation generated by the RF device induced tumor cell death beyond the histological margin and enabled a more complete R0 resection (*37*). However, our study did not provided robust evidence to support this. This could be because tumor prognosis is dependent on numerous factors including preoperative tumor stage and grade, intraoperative bleeding, postoperative complications, sample size and follow-up duration in selected patients (*38*). Thus, a longer follow-up is required to confirm the superiority of RFLR.

Although this report represents a large, single center comparative study to evaluate the effectiveness and safety of RFLR for the treatment of patients with HCC, it has some limitations. First, the retrospective, non-randomized, non-blinded nature of the study unavoidably induced bias in selecting patients to receive either RFLR or CCLR. However, the preoperative parameters or baselines of the two groups were comparable, the two groups of patients were well matched, and a large sample size was obtained. These may compensate for the aforementioned limitation. Second, different surgeons and surgical habits were possible confounders. However, the team consisted of four senior hepatobiliary surgeons who independently conducted standard anatomical hepatectomy in more than 100 patients in our unit performed the surgeries based on standard algorithms. Finally, fully understanding the long-term outcomes would require a longer follow-up. Our results could only report on the 1-, 2-, and 3-year overall survival and disease-free survival rates. The follow-up of some patients was limited and insufficient to estimate 5-year overall survival and disease-free survival. Therefore, a further randomized controlled trial comparing these two groups of patients is currently ongoing in our institute. This study has been registered on Clinicaltrials.gov (identifier: NCT 01992978), and we are recruiting patients. We look forward to the publication of this trial and others.

5. Conclusion

RFLR was shown to be a safe and effective method for selected patients undergoing liver resection. Compared with CCLR, RFLR is advantageous with reduced intraoperative bleeding, decreased operative duration, and resulted in fewer blood transfusions and less vascular inflow occlusion. RFLR did not either worsen liver function recovery or increase complications or mortality rates. However, RFLR should be performed by experienced hepatobiliary surgeons who have a thorough understanding of intrahepatic anatomy and are proficient with the RF device. Further large-sample, multicenter, randomized and controlled studies are necessary to assess the long-term effects of RFLR and determine the most suitable method for patients with cirrhosis and HCC.

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