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A prospective study of in-line radiofrequency ablation in hepatic parenchymal transection – its efficacy and complications

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Abstract

Background. Bleeding during liver transection remains a potential hazard. This study aims to report the efficacy and complications of in-line radiofrequency ablation (ILRFA)-assisted liver resection. *Patients and methods*. The blood loss of 25 consecutive patients who underwent ILRFA-assisted liver resection was obtained by weighing swabs and measuring suction jar contents during liver resection and calculated in ml per cm^2 of the transection surface area. Postoperative complications were recorded. Five clinical variables, which might affect blood loss, were analyzed. *Results*. The mean blood loss during parenchymal dissection for the ILRFA group was 3.4 ± 3.2 ml/cm^2. Three patients had intra-abdominal collections, including one patient with bile leakage after ILRFA-assisted liver resection. Age, gender, extent of liver resection, liver quality and Pringle maneuver did not demonstrate significant impact on blood loss. *Conclusions*. This study showed that ILRFA-assisted liver resection was associated with very low blood loss. This is likely to improve the operative safety of liver resection for hepatic tumors. There were no significant postoperative sequelae.

Key Words: *liver resection, blood loss, bile leak, radiofrequency ablation*

Introduction

Blood loss during liver resection remains a potential problem. It has been shown to have a deleterious impact on both short- and long-term outcomes of the surgery [1,2]. Median blood loss is reported as 450–1500 ml following liver resection, depending on the extent of resection and the normality of the liver parenchyma [3–7]. Perioperative transfusion for major blood loss is also associated with adverse prognosis in patients who undergo liver resection [8].

Radiofrequency ablation (RFA) has now been widely used for *in situ* destruction of liver tumors. RF electrical current produces heat, coagulation, and local tissue necrosis. Some surgeons have described use of an original RFA needle to create an avascular area through which the division of the hepatic parenchyma can be achieved with minimal blood loss [9,10]. The recently designed in-line radiofrequency ablation (ILRFA) probe consists of a plastic body with six deployable electrodes in one line, which can produce a precise avascular section up to 5 cm long, 6 cm deep and 1 cm wide. This transection plane can then be dissected almost bloodlessly with only a few large vessels and biliary structures requiring ligation or application of clips [11,12].

Some other techniques of hepatic resection, such as microwave coagulation and harmonic scalpel, have been shown to cause more bile leakage than the conventional clamp crushing method [9,13]. It is unknown if the area of necrosis created with ILRFA would result in a higher incidence of postoperative bile leakage. With our previous pilot study design, it was not possible to report on the postoperative complications associated with ILRFA-assisted liver resection [12]. In this article, we report the efficacy and complications of ILRFA-assisted liver resection in the next 25 consecutive patients with primary or metastatic liver tumors.

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Patients and methods

The Ethics Committee of SESAHS approved this study (Approval No: 03/172).

Materials

The ILRFA probe is a 5 cm long plastic device with six electrodes, spaced along the probe in one line, each 6 cm long, which can be deployed to varying depths in the hepatic parenchyma (Figure 1). The probe is connected to a standard RFA generator (1500 RITA generator, Sunnyvale, CA, USA). Each ablation was performed strictly according to the ILRFA protocol and each ablation cycle was 3 min.

Patient selection

The inclusion criteria for ILRFA-assisted liver resection were: (1) patients with radiologically or histologically proven primary or secondary hepatic tumors; (2) hepatic disease suitable for liver resection; (3) signed informed consent for ILRFA; (4) age between 18 and 85 years. The exclusion criteria were: (1) previous hepatic operations; (2) bleeding diathesis (prothrombin time >1.5 and platelets $<100 \times 10^9$); (3) additional procedures planned to the liver, e.g. cryoablation. A total of 51 patients underwent liver surgery during the study period; 25 patients who satisfied both the inclusion and exclusion criteria underwent ILRFA-assisted liver resection.

Operative procedures

All operations were performed under general anesthesia without central venous pressure (CVP) reduction. After liver mobilization, intraoperative ultrasound (IOUS) was performed to confirm the size, number and location of the hepatic tumors in relation to the major hepatic veins and the portal sheaths. The plane of transection was marked with a diathermy on the surface of the liver.

Figure 1. In-line radiofrequency ablation (ILRFA) probe.

The IOUS was also used to identify the relationship of the hepatic veins and the portal sheaths to the intended transection plane. Under IOUS guidance, these intraparenchymal structures were avoided during the deployment of the ILRFA electrodes, as each electrode can be independently deployed to varying depths. All the intended transection planes were ablated with ILRFA and then transected using an ultrasonic aspirator (Selector, Integra Neurosciences, UK). Blood loss during transection was calculated in ml/cm^2, where the amount of blood loss was measured in milliliters by weighing the sponges and counting the volume in the suction system, and the transection area was measured on the specimen in cm^2. In some of the patients, the Pringle maneuver was applied during the liver resection. The larger vessels and bile ducts were cauterized, clipped or ligated according to our routine practice.

All procedures were performed by D.L.M., an experienced liver surgeon. The clinical information in this study was collected prospectively by completing a standardized data sheet for each patient. Patients were followed at monthly intervals for the first 6 months and then at 3-monthly intervals thereafter. The assessments included clinical examination, liver function tests, tumor marker analysis and abdominal computed tomography (CT).

Statistical analysis

Statistical analysis was performed on the prospectively collected clinical data. The efficacy of ILRFA in blood loss was studied. The postoperative complications were recorded. Wilcoxon rank test was used for the comparison of difference in means of continuous factors. The statistical analyses were performed using SPSS for Windows (Version 11.5; SPSS GmbH, Munich, Germany). A significant difference was assumed for p values <0.05.

Results

All operations proceeded as planned. The demographics of these patients are shown in Table I. There was no hospital mortality. The mean volume of blood loss during the liver transection was 273 ± 325 ml. Twelve patients had less extensive liver resection (<3 segments); their absolute volume of blood loss during liver transection was 35, 50, 50, 50, 87, 150, 205, 245, 295, 300, 305 and 445 ml, respectively; and their mean volume of blood loss during liver transection was 185 ± 135 ml. The remaining 13 patients had more extensive liver transection (≥ 3 segments); their absolute volume of blood loss during liver transection was 50, 60, 80, 95, 100, 105, 200, 210, 350, 350, 605, 895 and 1500 ml, respectively; and their mean volume of blood loss was 354 ± 425 ml ($p=0.300$, vs <3 segments). The mean volume of blood loss per cm^2 was 3.4 ± 3.2. Seven patients (28%) had at least

Table I. Patient characteristics ($n = 25$).

Clinical factor	No. of patients	%
Overall	25	100
Gender	–	–
Male	16	64
Female	9	36
Age (years)	–	–
<60	10	40
≥60	15	60
Liver quality	–	–
Normal	15	60
Steatotic	8	32
Cirrhotic	2	8
Resection type*	–	–
Right hepatectomy	8	32
Left hepatectomy	2	8
Extended left hepatectomy	1	4
Left lobectomy	5	20
Segmental resection	9	36
In-flow occlusion	–	–
No	14	56
Yes	11	44
Blood transfusion	–	–
No	18	72
Yes	7	28

*Terminology of Couinaud, 1957.

Table II. Five factors that potentially affect blood loss during ILRFA-assisted liver transection.

		Blood loss (ml/cm^2)	
Clinical factor	No.	Mean ± SD	p value*
Overall	25	3.4 ± 3.2	–
Gender	–	–	0.379
Male	16	3.9 ± 3.7	–
Female	9	2.5 ± 2.0	–
Age (years)	–	–	0.739
<60	10	4.0 ± 4.4	–
≥ 60	15	3.0 ± 2.2	–
Liver quality	–	–	0.523
Normal	15	3.4 ± 2.5	–
Steatotic/cirrhotic	10	3.4 ± 4.3	–
Extent of resection	–	–	0.531
<3 segments	12	3.4 ± 2.7	–
≥3 segments	13	3.4 ± 3.7	–
In-flow occlusion	–	–	0.632
No	14	3.7 ± 2.5	–
Yes	11	3.0 ± 4.0	–

*Wilcoxon rank test for the comparison of difference in means of blood loss.

one unit of intraoperative blood transfusion and the average unit of transfusion given was 0.6 units per patient. There were 15 patients (60%) with normal liver, 8 patients (32%) with steatotic liver and 2 patients (8%) with cirrhotic livers. The blood loss of the two cirrhotic patients was 2.5 and 3.3 ml/cm^2, respectively. The blood loss of the eight steatotic patients was 1, 1.2, 1.2, 1.3, 1.7, 2.0, 5.0, and 15.0 ml/cm^2, respectively. The mean operative time was 169 ± 58 min. The mean postoperative stay was 7 ± 4 days. The median follow-up was 4 months (range 1–11 months).

The impact of five variables that might potentially affect blood loss during ILRFA-assisted liver transection is demonstrated in Table II. They are gender, age (<60 vs ≥60 years), liver quality (normal vs steatotic and cirrhotic), extent of resection (<3 segments vs ≥ 3 segments), and Pringle maneuver application. None of the five factors demonstrated any significant impact on blood loss during ILRFA-assisted liver transection. Eleven patients (44%) had the Pringle maneuver applied during the liver resection, but it was used only selectively in difficult cases. The average duration of clamping was 19 min. This maneuver failed to show statistically significant impact on blood loss ($p = 0.632$).

Three patients had postoperative intra-abdominal collections; including one patient who had a bile collection. All these patients were managed with CT-guided drain insertion. The median interval between the operation and the complication was 5 days (range 2–20 days). There were no other postoperative complications detected at the last follow-up.

Discussion

Studies show that 20–60% of patients undergoing liver resection require blood transfusion [6,14]. In patients with cirrhotic livers, bleeding is a more significant issue. Both short- and long-term morbidity and mortality correlate with intraoperative blood loss [1,2]. The more recent study from the Memorial Sloan-Kettering group reported an estimated blood loss of 871 ± 24 ml, a transfusion rate of 49%, a mean in-flow occlusion time of 31 min, and a mean transfusion of four units. Blood loss in patients who died was nearly three times greater [4].

Over the years, different techniques have been described to minimize blood loss during the transection phase. Surgeons use low CVP anesthesia, continuous or intermittent Pringle maneuver or total vascular exclusion in trying to achieve better operative results. Parenchymal transection can be performed with finger fracture, a scalpel or the more refined ultrasonic aspirator, which disaggregates and sucks away the soft hepatic parenchymal tissues, leaving the larger and tougher vessels and ductal structures behind for ligation or clipping. Rau et al. reported a blood loss of 24.3 ml/cm^2 of resection surface using the ultrasonic aspirator [15]. In cirrhotic livers, due to dense fibrosis, the ultrasonic aspirators are less effective in dividing the parenchymal tissue without bleeding [15]. Water-jet cutters (hydrodissectors) have also been used and 17.7 ml/cm^2 of blood loss has been reported [15]. However, early postoperative bleeding and bile leakage still exist, probably because of inadequate ligation of small vessels or bile ducts after segregation of the plane with these devices.

Habib and co-workers first described the use of an unmodified RFA probe to create a 2 cm zone of necrosis by repeatedly ablating tissue in the transec-

tion plane, followed by parenchymal dissection with a surgical scalpel [9]. They showed very encouraging results. The mean blood loss was 30 ± 10 ml and no morbidity or mortality was observed [9]. However, the major concern with this approach is that it is relatively slow, requiring many ablations to cover the intended transection plane, and the spherical ablations are not ideal for developing a coagulative transection plane. Multiple independent ablations have to be used, and this can be time-consuming. In addition, to achieve an adequate transection plane with this unmodified RFA probe, surgeons sometimes have to sacrifice more normal liver tissue, which can be problematic in cirrhotics and in complex liver resections [10].

This study reports the preliminary results of an innovative procedure using ILRFA to assist liver resection. In a sheep model, we have demonstrated that ILRFA could produce an avascular plane up to 6 cm deep and 5 cm long [11]. Dissection or cutting through this area was then achieved with minimal, if any, blood loss. We have also demonstrated a significant difference in blood loss ($p = 0.004$) in a pilot study of eight patients, who had ILRFA for half of the transection plane and the other half was transected using a conventional ultrasonic aspirator alone [12].

The major advantages of ILRFA are that it is very precise and rapid. Each ILRFA electrode should be deployed individually, under the guidance of intraoperative ultrasound, to avoid penetrating any major vessels (Figure 2). The RF field created between electrodes of alternating polarity results in localized heating and coagulation of tissue including blood vessels up to approximately 3 mm. The ILRFA probe can be withdrawn and re-applied along the intended transection plane (Figure 3). Each RF ablation requires only 3 min to achieve a complete coagulative ablation. This ablated plane can then be dissected almost bloodlessly with an ultrasonic aspirator (Figure 4). The small blood vessels and biliary structures are

Figure 3. In-line radiofrequency ablation (ILRFA) creating a coagulated section up to 5 cm long, 6 cm deep and 1 cm wide prior to liver resection.

coagulated in the process and the larger ones are ligated or clipped.

In this study, the mean blood loss was 3.4 ± 3.2 ml/cm^2. The results are lower than those in our previous pilot study, perhaps due to our increased experience [12]. The blood loss of the two cirrhotic patients was 2.5 and 3.3 ml/cm^2, respectively, and there were another two cirrhotics in our pilot study [12]. It is difficult to draw conclusions from such a small number of patients, but it is most encouraging that ILRFA appears to work very effectively in this difficult group of patients.

Some other techniques of hepatic resection, such as microwave coagulation and harmonic scalpel, have been shown to cause more bile leakage than the conventional clamp crushing method [9,13]. One of the concerns, however, which our previous study was unable to address, was the incidence of bile leakage after ILRFA [12]. In the present study, one patient had biliary leakage and there was no other significant postoperative sequela.

Figure 2. In-line radiofrequency ablation (ILRFA) probe deployment prior to ablation.

Figure 4. Avascular transection surface after in-line radiofrequency ablation (ILRFA)-assisted liver resection.

This procedure is easy to learn and surgeons with a good knowledge of liver anatomy can apply it to both segmental and formal resections. We have used this technique in both major and minor liver resections. The extent of liver transection did not affect blood loss in this study ($p = 0.531$). However, its most important limitation is that the radiofrequency energy will ablate any tissue that it is deployed through. Therefore it is of great importance not to damage hepatic veins or portal sheaths to the liver, which are to be retained. To avoid this, we recommend the use of intraoperative ultrasound during the electrode deployment.

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