Bloodless Liver Resection Using Radiofrequency Energy

Ahmet Ayav Long R. Jiao Nagy A. Habib

Department of Surgical Oncology, Imperial College London, Faculty of Medicine, Hammersmith Campus, London, UK

Key Words

Bloodless liver resection • Radiofrequency energy •
Radiofrequency-assisted liver resection technique

Abstract

Background: Liver surgery carries the risk of intraoperative bleeding. In order to avoid bleeding, transection of the liver can be performed after coagulating the parenchyma by using monopolar or bipolar radiofrequency energy. **Methods:** 236 consecutive patients underwent liver resection with the radiofrequency-assisted technique using either a monopolar or a bipolar device. Data were collected prospectively to assess the outcome including, intraoperative blood loss, blood transfusion requirement, morbidity and mortality rates. **Results:** There were 41 major hepatectomies and 195 minor resections. Overall mean intraoperative blood loss was 157 ± 240 ml, while mean blood loss during liver transection was 90 ± 105 ml. 10 patients (4%) received blood transfusion. 50 patients (21%) developed postoperative complications including 5 bile leaks (2%). The mortality rate was 2.1%. No patient was reoperated for postoperative haemorrhage or bile leak. The mean postoperative stay was 11 ± 10 days. **Conclusion:** The radiofrequency-assisted liver resection technique offers hepatobiliary surgeons an additional method for performing liver resections with minimal blood loss, low transfusion requirement, and low morbidity and mortality rates.

Copyright © 2007 S. Karger AG, Basel

Introduction

Liver resection remains a major procedure carrying a significant risk of intraoperative bleeding leading to blood transfusion which has been shown to affect post-operative morbidity, mortality and long-term survival [1–4]. With improvements in surgical and anaesthetic techniques, and the development of new surgical tools, liver resection can now be performed in most centres with minimal blood loss [5–12]. However, these techniques for liver resection often require hepatic inflow occlusion (Pringle's manoeuvre) during transection of liver parenchyma. Furthermore, clamping of hepatic pedicles increases the potential risk of liver dysfunction from ischaemia-reperfusion injury particularly in patients with underlying chronic liver disease [13, 14].

Intraoperative manoeuvres are commonly used to minimise the risk of intraoperative bleeding including hypotensive anaesthetics, hepatic pedicle clamping, and total vascular exclusion [7–12]. None of them are completely effective, and each adds a potential risk of causing liver dysfunction in patients with chronic liver disease [14]. In recent years, several techniques have been developed to reduce blood loss during transection of liver parenchyma without vascular clamping [14–16]. The main problems related to these methods are that although small vessels can be coagulated during transection, large vessels are usually left intact or injured, which can result in con-

siderable blood loss during the operation and which require tedious clipping and tying to achieve haemostasis.

In the last few years, the advent of new energy sources, such as radiofrequency (RF), has had an increasing impact on surgical practice, notably in the field of liver tumours. The role of RF in liver surgery has been expanded from simple tumour ablation to embrace routine hepatic resection by using an RF probe to develop a plane of coagulative necrosis along the intended line of parenchymal transection [15, 16]. This technique was used for all hepatic resections performed in our department (either by the open approach or by a laparoscopic approach) in order to avoid intraoperative haemorrhage and the need for routine postoperative admission to the intensive care unit [17, 18].

The aim of the current study was to report the impact of this technique on the reduction of blood loss during liver resection without vascular clamping.

Patients and Methods

Between January 2000 and March 2006, 236 consecutive patients underwent RF-assisted liver resection for tumours in our department. All patients underwent careful preoperative assessment of their disease including either spiral computed tomography or magnetic resonance imaging. Patient data were collected prospectively, including demographic details, nature and number of tumours, operative procedure, operating time, blood loss, blood transfusion requirement, morbidity, mortality and length of hospital stay. Operative time was defined as the overall time of the surgical procedure from skin to skin, while the resection time was defined as the time from the start of RF ablation to completion of parenchymal transection. Every patient presenting with grade II (or higher) complications according to Dindo et al. [19] classification were recorded as having postoperative complication. Blood loss was recorded as the combination of the weight of the surgical swabs and the amount of blood in the suction system for the whole operation. Postoperatively, intra-abdominal collection was defined as any presence of intra-abdominal fluid around the resection margin on postoperative computed tomography scan.

The surgical resection was performed according to the previously described technique [16–18]. Minor hepatectomy was defined as either tumorectomy, segmentectomy or bi-segmentectomy. Major hepatectomy included resection of more than three segments based on Couinaud's classification.

Results

A total of 417 tumours were resected in 236 patients. Clinical details of these patients are summarised in table 1. The resection was performed using the monopolar RF probe in 174 cases (156 by an open surgical approach and 18 by a laparoscopic approach), and a bipolar RF device

Table 1. Patients' characteristics: diagnosis, number and size of tumours (values are mean $\pm$ SD)

Clinical details	
Mean age, years	58 $\pm$ 12
Males/females	127/109
Diagnosis	
Metastases	170 (72%)
Hepatocellular carcinoma	37 (15%)
Cholangiocarcinoma	9 (4%)
Gallbladder carcinoma	5 (2%)
Adenoma	3 (1.2%)
Focal nodular hyperplasia	4 (1.6%)
Haemangioma	4 (1.6%)
Mean tumour size, mm	43 $\pm$ 29
Mean number of lesions	1.9 $\pm$ 1.4

(Habib 4X, Rita Medical Systems Inc.) in 62 cases. Surgical procedures ranged from single tumorectomy to right hepatectomy. There were 154 cases of tumorectomies or segmentectomy, 14 multiple segmentectomies, 27 left lateral segmentectomies, 11 left hepatectomies, and 30 right hepatectomies. Thus, major hepatectomy was performed in 41 cases (17%) and minor hepatectomies in 195 cases (83%). All the procedures were achieved according to the previously described technique. None of the patients had vascular inflow occlusion (Pringle's manoeuvre).

Mean intraoperative blood loss was 157 $\pm$ 240 ml (range 10–1,100). Mean blood loss during parenchymal transection was 90 $\pm$ 105 ml (range 10–590). Ten patients (4%) received intraoperative blood transfusion, with a mean of 2.5 units of red blood cells per patient. No patients required fresh-frozen plasma or postoperative blood transfusion. The mean overall operative time was 215 $\pm$ 88 min, while the mean resection time was 66 $\pm$ 46 min.

Five patients were admitted to the intensive care unit postoperatively because of associated co-morbidities ($n = 3$) and long operative time ($n = 2$). Fifty patients (21%) developed postoperative complications. The complications included pleural effusion ($n = 26$), intra-abdominal collection ($n = 20$), biliary leak ($n = 5$), postoperative liver failure ($n = 2$) and hepatic ischaemia ($n = 1$). This patient required a reoperation because of a tear in the hepatic artery. Otherwise, none of the patients underwent reoperation. The diagnosis of biliary leak was evident in 4 cases from wound drains, and were managed conservatively. In 1 case, the leak was revealed by a biloma on CT scan and required percutaneous drainage.

There were no intraoperative deaths, but 5 patients died postoperatively (2.1%). Two developed postoperative liver failure, 1 after an extended right hepatectomy with hepaticojejunostomy for hilar cholangiocarcinoma, and 1 after resection of a 79-mm hepatocarcinoma from segment VII in a cirrhotic liver. For the remaining 3 cases, the cause of death was multifactorial with multiorgan failure and systemic sepsis secondary to chest infection and cardiac failure, but in none of these cases was multiorgan failure as a result of liver failure. The overall mean postoperative stay was 11 ± 10 days.

Discussion

Using a RF-assisted technique, liver resection can be performed with minimal blood loss and low transfusion rate without dissection or clamping of the hepatic pedicle. In our experience, the mean blood loss is 157 ml and the transfusion rate is 4%, which is lower than most of previously published series [1, 4–7, 9, 11, 20–23].

Concern has been expressed about the low rate of major hepatectomy undertaken in our centre. We believe, like others, that even if segmental and non-anatomical resections are commonly classified as minor hepatectomies, they can be more challenging and technically more demanding than a classical lobar resection [1]. The low rate of major hepatectomy (17%) we report is because we can easily perform nearly bloodless non-anatomical resections in order to spare liver parenchyma using the RF-assisted technique. Furthermore, we have never had to apply Pringle's manoeuvre to complete a resection and therefore we experienced a very low rate of postoperative liver failure (2 patients). However, we do observe routinely a transient increase in transaminase and bilirubin levels following liver resection, with a peak at day 1 and normalisation at day 7. This transient abnormality in the liver function tests was probably related to the zone of coagulative necrosis left behind along the resection margins. To avoid leaving too much coagulated tissue behind,

<1 cm of tissue is now left at the margin, which is sufficient to ensure vascular and biliary occlusion for haemostasis and biliary control. These abnormalities are very different from ischaemia-reperfusion injury to the liver which can occur during hepatic inflow occlusion (continuous or intermittent), and which is known to predispose to postoperative liver failure [2, 24–27].

The overall postoperative complication rate was 21% in this series, consistent with or better than most reported large series ranging from 16 to 45% [1, 4–6, 9, 20–23]. However, none of the complications was directly related to the resection technique. Pleural effusion was the most common postoperative complication in line with other series that used different parenchymal transection techniques [5, 11, 13, 28]. Postoperative intra-abdominal collection was observed in 20 patients (8%), but only 5 had proven abscesses which needed radiological drainage, the others were treated conservatively, and none of them had any sign of biloma.

There is no requirement to tie blood vessels or bile ducts with the RF-assisted resection technique and there has been concern about the risk of postoperative haemorrhage or bile leak. However, in our experience, no patient bled postoperatively, and the rate of biliary complication was also low (2.1%). These figures indicate that biliary control and blood vessel control were effective with RF energy.

Although the technique of liver resection with monopolar or bipolar RF for liver resection is safe to apply, a detailed knowledge of liver anatomy plus excellent surgical skills remain crucial. The RF energy cannot be applied close to the hilum or hepatic veins, and dissection of these regions has to be performed by trained hepatobiliary surgeons. RF is a tool to help surgeons divide the liver parenchyma safely and with minimal blood loss.

In conclusion, the RF-assisted liver resection technique offers hepatobiliary surgeons an additional method for performing liver resection with minor intraoperative blood loss, a low transfusion requirement, low mortality and low morbidity.

References

- 1 Gozzetti G, Mazziotti A, Grazi GL, Jovine E, Galluci A, Gruttadauria S, Frena A, Morganti M, Ercolani G, Masetti M, Pierangeli F: Liver resection without blood transfusion. *Br J Surg* 1995;82:1105–1110.
- 2 Bismuth H, Castaing D, Garden J: Major hepatic resection under total vascular exclusion. *Ann Surg* 1989;210:13–19.
- 3 Kooby DA, Stockman J, Ben-Porat L: Influence of transfusion on perioperative and long-term outcome in patients following hepatic resection for colorectal metastases. *Ann Surg* 2003;237:860–869.
- 4 Makuuchi M, Takayama T, Gunvèn P, Kosuge T, Yamazaki S, Hasegawa H: Restrictive versus liberal blood transfusion policy for hepatectomies in cirrhotic patients. *World J Surg* 1989;13:644–648.

- 5 Man K, Fan ST, Ng IOL, Lo CM, Liu CL, Wong J: Prospective evaluation of Pringle maneuver in hepatectomy for liver tumors by a randomized study. *Ann Surg* 1997;226:704–713.
- 6 Jones R, Moulton CE, Hardy KJ: Central venous pressure and its effect on blood loss during liver resection. *Br J Surg* 1998;85:1058–1060.
- 7 Romano F, Franciosi C, Caprotti R, Uggieri F, Uggeri F: Hepatic surgery using the Ligasure vessel sealing system. *World J Surg* 2005;29:110–112.
- 8 Sugo H, Mikami Y, Matsumoto F, Tsumura H, Watanabe Y, Kojima K, Futagawa S: Hepatic resection using the harmonic scalpel. *Surg Today* 2000;30:959–962.
- 9 Sakamoto Y, Yamamoto J, Kokudo N, Seki M, Kosuge T, Yamaguchi T, Muto T, Makuuchi M: Bloodless liver resection using the monopolar floating ball plus Ligasure diathermy: preliminary results of 16 liver resections. *World J Surg* 2004;28:166–172.
- 10 Takayama T, Makuuchi M, Kubota K, Harihara Y, Hui AM, Sano K, Ijichi M, Hasegawa K: Randomized comparison of ultrasonic vs. clamp transection of the liver. *Arch Surg* 2001;136:922–928.
- 11 Yamada T, Sasaki Y, Yokoyama S, Miyashiro I, Murata K, Doki Y, Kameyama M, Ohigashi H, Hiratsuka M, Ishikawa O, Imaoka S: Practical usefulness of bipolar scissors in hepatectomy. *Hepatogastroenterology* 2002;49:597–600.
- 12 Rau HG, Schardey HM, Buttler E, Reuter C, Cohnert TU, Schildberg FW: A comparison of different techniques for liver resection: blunt dissection, ultrasonic aspirator and jet-cutter. *Eur J Surg Oncol* 1995;21:183–187.
- 13 Serracino-Inglott F, Habib NA, Mathie RT: Hepatic ischemia-reperfusion injury. *Am J Surg* 2001;181:160–166.
- 14 Farges O, Malassagne B, Flejou JF: Risk of major liver resection in patients with underlying chronic liver disease: a reappraisal. *Ann Surg* 1999;229:210–215.
- 15 Navara G, Ayav A, Weber JC, et al: Short- and long-term results of intraoperative radiofrequency ablation of liver metastases. *Int J Colorectal Dis* 2005;20:521–528.
- 16 Weber JC, Navarra G, Jiao LR, et al: New technique for liver resection using heat coagulative necrosis. *Ann Surg* 2002;236:560–563.
- 17 Ayav A, Bachellier P, Habib NA, et al: Impact of radiofrequency-assisted hepatectomy for reduction of transfusion requirement. *Am J Surg*, in press.
- 18 Bachellier P, Ayav A, Pai M, et al: Result of radiofrequency-assisted laparoscopic liver resection. *Am J Surg* 2007;193:143–148.
- 19 Dindo D, Demartines N, Clavien PA: Classification of surgical complications. A new proposal with evaluation in a cohort of 6,336 patients and results of a survey. *Ann Surg* 2004;240:205–213.
- 20 Scatton O, Massault JP, Dousset B, et al: Major liver resection without clamping: a prospective reappraisal in the era of modern surgical tools. *J Am Coll Surg* 2004;199:702–708.
- 21 Adam R, Pascal G, Azoulay D, et al: Liver resection for colorectal metastases. The third hepatectomy. *Ann Surg* 2003;238:871–884.
- 22 Imamura H, Seyama Y, Kokudo N, et al: One thousand fifty-six hepatectomies without mortality in 8 years. *Arch Surg* 2003;138:1198–1206.
- 23 Weber JC, Bachellier P, Oussoultzoglou E, Jaeck D: Simultaneous resection of colorectal primary tumour and synchronous liver metastases. *Br J Surg* 2003;90:956–962.
- 24 Delva E, Calmus Y, Nordlinger B, et al: Vascular occlusions for liver resections: operative management and tolerance to hepatic ischemia: 142 cases. *Ann Surg* 1989;209:211–218.
- 25 Huguet C, Nordlinger B, Galopin JJ, et al: Normothermic hepatic vascular exclusion for extensive hepatectomy. *Surg Gynecol Obstet* 1978;147:689–693.
- 26 Huguet C, Gavelli A, Bona S: Hepatic resection with ischemia of the liver exceeding one hour. *J Am Coll Surg* 1994;178:454–458.
- 27 Elias D, Lasser P, Debaene B, et al: Intermittent vascular exclusion of the liver (without vena cava clamping) during major hepatectomy. *Br J Surg* 1995;82:1535–1539.
- 28 Torzilli G, Makuuchi M, Midorikawa Y, et al: Liver resection without total vascular exclusion: hazardous or beneficial? An analysis of our experience. *Ann Surg* 2001;233:167–175.