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TECHNICAL REPORT

Use of radiofrequency hepatic parenchymal transection device in hepatic hemangioma resection: early experience and lessons learned

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Abstract

Background. Control of intraoperative hemorrhage represents a significant challenge in hepatic surgery, particularly during resection of large, hypervascular hepatic hemangiomata (HH). Various devices to minimize blood loss from hepatic parenchymal transection are currently under investigation. Herein, we present our experience with a radiofrequency (RF)-powered multiarray for resection of HH. *Patients and methods.* From September 2005 to January 2006, we conducted a retrospective review of our hepatobiliary database to identify patients with symptomatic giant cavernous HH undergoing resection with a RF multiarray device. The purpose of this review was to assess the technical aspects of using RF energy to assist in the resection of HH. *Results.* The extent of operation varied depending on the size and location of the tumor. Two patients underwent two atypical subsectionectomies and two underwent trisectionectomies. The Habib™ sealer provided a safe and effective method for hepatic parenchymal transaction. No patients required blood transfusion, and no injuries to major biliary or vascular strictures were observed at 1 year follow-up. A seroma developed in one patient 6 months postoperatively, but was drained percutaneously. *Conclusions.* Hepatic parenchymal transection with the Habib sealer device is a feasible approach to resect HH. Further study is needed to objectively compare the efficacy of RF-assisted parenchymal transection with that of traditional parenchymal transection techniques.

Key Words: *hepatic hemangioma, liver resection, RFA, Habib™ sealer*

Introduction

Hepatic surgery has undergone a dramatic evolution in the past quarter century. Once burdened with prohibitively high morbidity and mortality, hepatic resection is now considered a safe standard of care in appropriately selected patients with hepatic tumors. Advances in surgical technique, anesthesia, and critical care have reduced operative mortality to $<5\%$ in most major academic centers [1]. While several less invasive liver-directed therapies have emerged, hepatic resection is the only potentially curative treatment option in patients with malignant or symptomatic benign hepatic tumors. Nevertheless, liver surgery remains a potentially high-risk procedure requiring a great deal of operative experience and technical expertise.

Of chief concern among hepatic surgeons is the potential for intraoperative blood loss associated with liver resection. According to a recent review, the average estimated blood loss from hepatic resection in high volume centers approached as much as 500 ml [2]. Several strategies – including low CVP anesthesia, the Pringle maneuver, and total hepatic vascular exclusion – are presently employed to minimize hemorrhage during hepatic resection. In addition, specialized hepatic parenchymal transection devices such as the ultrasonic aspirator, jet dissector, ultrasonic shears, bipolar vessel sealer, linear endocutter, and saline-enhanced radiofrequency (RF) dissecting sealer have been developed to promote hemostasis during resection.

Recently, another device called the Habib™ sealer was introduced as a potentially useful tool to minimize blood loss during hepatic resection. This RF sealer employs RF energy to facilitate relatively ‘bloodless’ parenchymal dissection. Habib et al. first described its use in 2001 [3]; they showed that by creating a 2–3 cm wide zone of coagulative necrosis, RF energy provided a charred, avascular bed that could be sharply divided with minimal blood loss during parenchymal dissection. While previous

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studies demonstrate the utility of the Habib™ sealer for resection of malignant hepatic tumors, no reports exist on the potential role of the device in resection of benign vascular liver lesions. Herein, we present four patients with symptomatic hepatic hemangioma (HH) who underwent RF-assisted parenchymal transection with an RF-powered parenchymal transection device.

Surgical technique

Initial exposure and mobilization of the liver were performed in standard fashion. Briefly, the abdomen was entered using a right subcostal 'hockey stick' incision. The falciform ligament was divided and ligated. A self-retaining retractor was placed to retract the costal margin to provide optimal exposure. The ligamentous attachments to the right and left liver lobes were divided as needed, and the triangular ligament was released, exposing the ipsilateral hepatic veins.

The gastrohepatic ligament was then incised and the portal region explored. All visible arteries supplying the lobe that contained the hemangioma were ligated with suture, resulting in dermacation and reduction in the size of the hemangioma. A vessel loop was placed around the porta hepatic to facilitate a Pringle maneuver. Further mobilization of the liver was performed posteriorly off the retroperitoneum to expose the vena cava. After exposure, mobilization, and vascular control of the liver were complete, a cholecystectomy was performed in top-down fashion.

While the preceding operative steps were unchanged from our standard approach to hepatectomy, the next stage in the operation – parenchymal transection – differed substantially. After mapping the course of hepatic veins and margins of the hemangioma with intraoperative ultrasound, we used the Habib™ RF device to create a coagulative plane just outside the hemangioma. The RF generator was set to an energy setting of 70 W and the electrode was applied to the hepatic parenchyma, delivering current to the tissue to induce coagulation necrosis. Once the plane of coagulation was created, the parenchyma was cut with a straight scalpel. During the course of transection, careful attention was paid to the hepatic vasculature and biliary ducts encountered in the field of resection. All hepatic veins >3 mm and suspected biliary structures at the plane of transection were suture ligated. Minor bleeding from the cut surface of the parenchyma was coagulated with an argon beam. The transection plane was then closely inspected for biliary leaks. A clean white laparotomy sponge was applied to the cut surface. The cystic duct was cannulated with a catheter and the distal porta hepatic occluded while methylene blue dye was injected to assess for the presence of bile leak. After hemostasis was assured, the abdomen was closed in standard fashion.

Results

Four patients with symptomatic (pain, gastric compression) giant cavernous HH underwent RF parenchymal transection using the Habib™ sealer device. The extent of resection varied among the patients, with two patients undergoing atypical subsectionectomies, one undergoing lobectomy, and one trisectionectomy. Standard mobilization of the liver and control of inflow and outflow vessels were required for the treatment of these large hemangiomas. (See Figures 1–3 and Table I.)

Several technical principles were rigorously adhered to during parenchymal transection with the RF device. Before entering parenchyma feeding arteries were ligated. First, all hepatic veins >3 mm in diameter in the plane of transection were suture ligated. This minimized the 'heat sink' effect of blood flow, resulting in optimal delivery of energy to the tissue. Second, all biliary structures >2 mm in diameter were suture ligated. Strict adherence to this criterion resulted in no observed biliary leaks either intraoperatively or postoperatively. In addition, we performed the majority of our ablations at a power setting of 70 W. Early on in our experience, we used

Figure 1. Giant cavernous hepatic hemangioma in right hepatic lobe.

Figure 2. Parenchymal transection using the Habib™ needle.

Figure 3. Cut surface of the transected parenchyma shows coagulation necrosis. Hepatic veins are suture ligated.

power settings in excess of 100 W. This level of energy was associated with 'superheating' and sudden explosions of the liver tissue, which could potentially cause cracking and massive hemorrhage from the parenchyma if a hepatic or portal vein was in close proximity. Therefore, all subsequent ablations were performed at a power setting of 70 W. This energy level resulted in an effective and safe ablation of hepatic parenchyma.

Hepatic veins >3 mm in diameter were not sealed with this device in the coagulated plane of transection, necessitating suture ligation. The coagulative necrosis of the parenchyma resulted in very firm, noncompressible liver tissue, which held sutures very well. However, the firmness of the coagulated tissue plane prevents easy and safe passage of a linear endocutter or clamp, thus making division of larger hepatic veins potentially problematic and dangerous. For this reason, it is essential that the surgeon knows the exact course and location of major hepatic veins that require transection by using intraoperative ultrasound before applying the RF current. We purposely created a shallower plane of precoagulation that was superficial to the major hepatic veins as they converged with the vena cava in the most cephalad portion of the parenchymal transection, so that we could more safely and carefully isolate them for clamping and division.

In summary, the RF device facilitated expedient hepatic parenchymal transection. The estimated overall operative time did not differ from historical controls. Further, the Habib™ sealer demonstrated an excellent overall safety profile in these four patients. The use of a 70 W power setting, coupled with careful hepatic venous and biliary radical ligation, resulted in safe and effective parenchymal transection. No injuries to major biliary or vascular structures were observed. Estimated blood loss was similar to historical controls, and no incidences of postoperative bleeding requiring transfusion were noted; two patients required intraoperative transfusion. In addition, we observed no clinically evident bile leaks postoperatively. There was one seroma necessitating percutaneous drainage at 6 months.

Discussion

HHs are the most common benign vascular tumor of the liver [4]. Originating as abnormalities of the hepatic sinusoidal vascular endothelium, hemangiomas grow by progressive vascular ectasia rather than infiltration and angiogenesis. Several definitions exist in the literature for giant hepatic hemangioma.

Adam et al. in 1970 described giant HHs as >4 cm in diameter [5], although in 1982, in *Diseases of the Liver* the definition of 10–12 cm was used [6]. Regardless of their size, hemangiomas are typically asymptomatic, presenting as incidental findings during radiologic work-up of an unrelated illness. These lesions may produce symptoms, the most common being vague abdominal pain or discomfort. Rarely, hemangiomas may rupture, leading to potentially life-threatening intraparenchymal or intraperitoneal hemorrhage.

Hemangiomas are typically distinguished from other hepatic lesions on the basis of their radiologic appearance. Ultrasound, contrast-enhanced CT, and MRI are the three most common imaging modalities used to confirm the diagnosis of hemangioma. Ultrasound shows either a hyperechoic lesion with no posterior shadowing or a hypoechoic or isoechoic lesion with a hyperechoic rim [4]. Contrast-enhanced CT typically demonstrates three distinct findings, based on the contrast phase. Precontrast images show a well-circumscribed hypodense lesion; contrast infusion results in peripheral nodular enhancement of the lesion. On delayed images, the tumor centripetally enhances and ultimately appears as an isodense lesion [4]. When ultrasound or CT fails to elucidate the diagnosis, MRI is performed. MRI is considered the best imaging study as it provides for superior lesion detection and characterization. Hemangiomas appear as low density lesions on T1-weighted images and high density lesions on T2-weighted images;

Table I. Patient characteristics.

Gender	Age (years)	Tumor size (cm)	Location	Indication	EBL (ml)	Transfusion (units)
F	50	15 × 10 × 13	Left trisegmentectomy	Pain, early satiety	1000	2
F	44	27 × 20 × 14	Right trisegmentectomy	Nausea, early satiety	1500	2
F	63	10 × 8 × 12	Segment 3	Back pain, nausea	50	0
F	67	2 × 5	Segments 5 and 6	Pain	750	0

gadolinium contrast induces peripheral enhancement of the tumor [7].

While most hemangiomas are asymptomatic and need only to be observed, hemangiomas that produce intractable symptoms should be treated. Reported indications for resection include pain, rapid growth, intraperitoneal bleeding, thrombocytopenia (i.e. Kasabach-Merritt syndrome) and involvement in contact sports [8]. Before initiating treatment, all other possible etiologies for the patient's symptoms must be ruled out. Treatment of hemangioma varies based on the patient's presentation and underlying medical condition. At present, no effective medical therapy exists for hemangioma. The only available therapies for HH are transcatheter ablation [9], irradiation [10], or surgical resection. The first two are generally reserved for patients who are poor operative candidates. Transcatheter arterial embolization may also be used to achieve temporary hemostasis of ruptured hemangiomas.

At present, the only definitive therapy for HH is surgical resection. Several approaches to resection are available and should be tailored to the tumor's location and characteristics as well as the patient's overall health. Wedge resection and anatomical lobectomy were first reported in the late 1800s and remained the standard surgical approach to hemangioma resection. Another surgical option for hemangioma is enucleation [11]. HHs often develop a fibrous pseudocapsule that separates them from normal liver parenchyma; this pseudocapsule provides a bloodless plane for dissection, allowing enucleation of the lesion. Regardless of the operation, most hemangiomas are approached by an open laparotomy. Laparoscopy has a limited role in hemangioma resection, although a few case reports exist in the literature [12,13].

Due to their large size and generous blood supply, hemangiomas are particularly susceptible to hemorrhage during resection. In particular, tumors larger than 10 cm were found to be associated with increased intraoperative blood loss [14]. This is of particular concern because it has been reported that intraoperative blood loss requiring blood transfusion positively correlates with morbidity and mortality [15]. For this reason, several techniques are employed to minimize the risk of hemorrhage, including the Pringle maneuver and ligation of any hepatic arterial branches that feed the lobe containing the tumor. Given the generally recognized large blood loss during hemangioma resection, new parenchymal transection devices such as the Habib™ sealer may have the potential to reduce blood loss for hepatic resection with this indication, given the observations from other indications for hepatic resection. In the present series, it was not our observation that the blood loss was reduced compared to our general previous experience; however, from this limited initial experience no comparison on this parameter would be appropriate. It should be noted that hepatic resections with the indication of symptomatic hemangioma constitute between 8% and 10% of our annual hepatic resection experience.

RF ablation (RFA) involves the use of a high frequency current delivered to tissues through an electrode. Alternating current causes the ions in the vicinity of the electrode to rapidly change direction (ionic agitation), leading to frictional heating and coagulative necrosis of tissue. Cell death occurs at 49°C after 4–9 min [16]. Laparoscopic RFA, without resection, has been used to treat HH. Fan et al. reported 27 patients treated with laparoscopic RFA with no recurrence at a mean of 21 months [17]. Still, the authors recommend that tumors larger than 10 cm be treated open with resection to prevent risk of massive bleeding. In a series from Penn State and UCLA on giant cavernous liver hemangiomas, multiple techniques were employed, including lobectomy with use of ultrasonic sealers and enucleation [18]. Their reported transfusions were a mean of 3.3 U for enucleation and 4.4 U for lobectomy. No data on blood loss were given.

Classic liver surgery techniques still apply when using this RFA device. Knowledge of hepatic vein orientation is essential. Hepatic veins >3 mm that are located within the plane of transection require independent ligation, either because there is inadequate shrinkage of the parenchyma to compress vessels of this size or due to the heat sink effect that causes inadequate energy deposition due to convective heat transfer by rapid blood flow in these vessels causing incomplete coagulation. Similarly, biliary structures >2 mm also require suture ligation. We have found that large biliary channels will leak upon methylene blue injection if not independently ligated. Although a heat sink is likely not responsible, knowledge of anatomy and attention to biliary size is required to avoid postoperative leak.

Theoretically, the potential large amount of coagulation necrosis along the plane of transection poses a risk for postoperative infection; however, in the present experience no hepatic abscess or subhepatic collections were observed.

Another interesting observation from this experience was the occurrence of a 'superheating' phenomenon of the parenchyma with resultant parenchymal fracture ('sudden popping') occurring. This event was associated with the use of the device at the power setting of 100 W. This can be alarming given the sudden cracking and explosion of the tissue that likely results from the rapid rise of intracellular temperatures to >100°C. Parenchymal ablation is achieved in about 4–7 seconds with a setting of 70 W. Therefore we have subsequently used the device at this setting, without further events. Interestingly, the senior author's personal communication with the company revealed the present day general recommendation for power setting to be in the area of 70–90 W.

As would be expected, the RFA-associated phenomenon of 'outgassing' was also observed by intraoperative ultrasound of the liver parenchyma undergoing heating. As the parenchyma is heated, the solubility of dissolved nitrogen is decreased, resulting in microbubble formation [19]. We did not observe any correlation between outgassing and the power setting used.

The Habib™ RF device adds to the armamentarium of transection devices available to the hepatic surgeon. When used properly and with intraoperative ultrasound, RFA may be suitable for parenchyma-sparing hepatectomy, as long as the principles of standard hepatic resection are employed [20]. Our early experience with this RF parenchymal ablation device did not result in bile leak or postoperative bleeding. While there is a quick learning curve associated with the technical aspects of this device, we recommend careful attention to the principles of standard hepatic surgery in its use even by experienced liver surgeons.

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