Ultrasound-guided radiofrequency ablation of the segmental Glissonian pedicle: A new technique for anatomic liver resection

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Background. *Anatomic liver resection is widely accepted as the optimal surgical treatment for hepatocellular carcinoma (HCC); however, the complexity of conventional operative methods limits their use. To explore the possibility of using modern techniques to achieve a simpler approach, we have evaluated ultrasound-guided segmental radiofrequency ablation (RFA) of the Glissonian pedicle before liver resection in a porcine model and in HCC patients.*
Methods. *This study had 2 stages. First, we piloted anatomic liver resection using ultrasound-guided RFA of the segmental Glissonian pedicle in 6 Bama miniature pigs. Having found this technique safe and effective, we selected 21 HCC patients to treat with the same approach.*
Results. *The pigs had no postoperative mortality or morbidity. Demarcation areas were apparent in all targeted segments. The mean length of segmental portal, arterial, and biliary tract branches ablated was 1.7, 1.4, and 1.6 cm, respectively. Human HCC operations consisted of 8 subsegmentectomies, 8 segmentectomies, and 5 multisegmentectomies. The procedure was feasible in all patients, with no mortality, morbidity, or need for blood transfusions. A demarcation area was apparent in all patients within 157 seconds of RF application for each target feeding vessel. The mean number of target feeding vessels was 2 (range, 1–7).*
Conclusion. *Our study demonstrates that ultrasound-guided RFA ablation of the segmental Glissonian pedicle is expedient, safe, and effective, and is suitable for resection of any hepatic segments or subsegments, from segments 2 to 8. (Surgery 2016;159:802-9.)*

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Hepatocellular carcinoma (HCC) with cirrhosis is the fifth most common cancer and the third most common cause for cancer-related death worldwide; particularly in China, more than one-half of HCC is diagnosed and 70% is attributable to chronic hepatitis B virus infection.[1] Liver resection is considered among the most potentially curative therapy for HCC. Because HCC has a propensity for vascular invasion and metastasizes via the portal venous system, Makuuchi et al proposed anatomic resection, which involved the removal of a hepatic segment or subsegment confined by tumor-bearing portal venous territories to pursue the ideals of completely removing lesions, with maximal preservation of liver function and minimal blood loss and invasive trauma.[2-9]

Several techniques are used to demarcate the relevant segments before hepatic resection. The most common is the puncture technique, which consists of intraoperative ultrasound (IOUS)-guided injection of indigo carmine into the vessel, which delineates the margin of the area to be resected at the liver surface.[3] Demarcation can also be achieved by the use of balloon catheters inserted

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transhepatically or through the mesenteric vein, to occlude the feeding portal branch.[10,11] However, this technique has the major limitation of requiring great skill in puncturing or occluding small vessels, a challenge to most surgeons. An alternative method is an intrahepatic Glissonian approach,[12-15] consisting of isolating and ligating the hepatic pedicle of the target segment. Furthermore, excessive intraoperative blood loss and prolonged operation time have deterred the use of this procedure. Torzilli et al[16] proposed using ultrasound-guided manual compression of the target segment hepatic pedicle, which revealed the segment by causing segmental ischemia; however, a major shortcoming of this technique is that it is unsuitable for direct application to segments 4, 5, and 8. Navarra et al[17,18] recently reported on ultrasound-guided radiofrequency ablation (RFA) of the segmental Glissonian pedicle with use of a Habib sealer (Rita Medical Systems, Inc Fremont, CA), which has 2 rows of RFA probes. The Navarra technique also has limitations: it does not allow surgeons identify precise location of target vessels and may risk inadvertent damage of nontarget structures.[19]

We have modified the Navarre procedure, using a single cooled-tip radiofrequency (RF) electrode, under IOUS guidance, which enables precise targeting of segmental vessels. This technique has potential advantages. First, it can readily performed by hepatobiliary pancreatic surgeons or radiologists familiar with IOUS and liver anatomy. Second, occlusion of segmental vessels before parenchymal resection may reduce the possibility of disseminating tumor cells through the portal venous system. We have evaluated this technique in Bama miniature pigs, because their livers are anatomically and physiologically comparable with the human liver.[20] In pigs, we found ultrasound-guided RFA of the segmental Glissonian pedicle preceding parenchymal transection, to be safe, effective, and rapid.[21] The purpose of this study, was to evaluate the clinical feasibility and safety of this technique for resection of hepatic segments or subsegments, from segments 2 through 8, with temporary hepatic artery occlusion.

METHODS

Animal model. We used 6 Bama miniature pigs (3 female, 3 male), 6–8 months old and weighing 15–20 kg. The Animal Ethics Committee of the Chinese PLA General Hospital, Beijing, China, approved the protocols. A veterinarian specializing in animal studies managed the pigs according to the Regulations on the Management of Laboratory Animals, China (1988).

The piglets were placed supine and anesthetized with combined intravenous anesthetic and inhaled ether. Liver segments 3, 5, and 6[20] were selected. We made a J-shaped right subcostal incision and performed cholecystectomy to eliminate the potential for RF-induced injury to the gall bladder. We scanned the intrahepatic vascular structure by IOUS to identify the arterial and portal branches of the target segment. A cooled-tip RF electrode, with a 500-kHz generator (Valleylab, Boulder, CO), was applied to achieve coagulative destruction of the feeding vessels. We selected a segmental portal branch target ablating position $\geq$2.0 cm distant from the segmental bifurcation, and then placed the electrode closely next to the segmental hepatic pedicle under IOUS guide groove. In a modification of our previous protocol,[21] we temporarily isolated and clamped the hepatic artery during ablation. We delivered RF energy according to these steps: (1) after baseline impedance was stabilized, RF output was increased gradually to 1,400 mA; (2) 1,400 mA impedance was increased to 10 ohms above baseline; (3) energy output was modulated periodically to avoid charring; and (4) RF was stopped after the ischemic area was demarcated. The duration of RFA was documented.

We resected the liver parenchyma by use of the clamp–crush method, without occlusion of hepatic inflow. No drains were placed. At 14 days postoperatively, we performed a laparotomy to evaluate the intraperitoneal situation and harvest the entire liver, then humanely killed the piglets. All specimens, including the target segments and the remnant liver parenchyma, were sliced into 0.5-cm sections perpendicular to the Glissonian pedicle's long axis. Hematoxylin and eosin–stained sections were examined microscopically for pathologic changes to segmental arterial, portal, and biliary tract branches and to surrounding tissues.

HCC patients. Between October 2012 and September 2013, we prospectively enrolled 21 HCC patients admitted for anatomic hepatectomy to the PLA General Hospital, Beijing, China. The Human Ethics Committee of the Chinese PLA General Hospital, Beijing, China, approved the protocols, and all patients gave written informed consent for the surgical procedures. All had tumors from 2.0 to 5.0 cm, but were without any thrombotic complications that necessitated extensive hepatectomy. We assessed preoperative hepatic function with liver function tests and the indocyanine green retention rate at 15 minutes.[2,22] All patients underwent 3-phase contrast-enhanced computed