HPB, 2008; 10: 225–228

informa
healthcare

REVIEW ARTICLE

Laparoscopic liver surgery: parenchymal transection using saline-enhanced electrosurgery

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Abstract
Minimally invasive liver resection (MILR) has evolved considerably in the past decade. Safe hepatic parenchymal transection, has been one of the technical hurdles that has become evident during the growth of MILR. Advances in technology have now made safe liver transection a reality allowing resections of greater magnitude. In this review, the precoagulation approach is described in both methodology and technique. Using this method of liver transection, we have been able to perform MILR of all varieties and magnitudes, with favorable patient outcomes. A detailed description of one particular device will be highlighted to disseminate our experience and thus broaden the technical options for hepatobiliary surgeons wishing to offer their patients a minimally invasive therapy.

Key Words: *laparoscopy, liver resection, parenchymal transection*

Introduction

Liver surgery has evolved considerably in the past decade. Advances in surgical strategy and intraoperative patient management, combined with focused hepatobiliary experience and training, have made technical feats possible, including: extended and ex situ/ex vivo resections, complex vascular and biliary reconstruction, and live-donor hepatectomy for liver transplantation. While improved methods of parenchymal transection may have a factor in reduction of patient morbidity and mortality, no one method has been found to be superior in terms of patient outcome [1–6].

More recently, minimally invasive liver resection (MILR) has become a reality. It is now recognized that MILR can be performed for both benign and malignant conditions, for major resections, with safety and outcomes comparable to the open approach [7]. In contrast to open surgery, MILR relies heavily on the methods and devices for parenchymal transection, given the inherent need for preemptive and/or rapid hemostasis. This is particularly true for MILR of large magnitudes (hemihepatectomy) where large intrahepatic vessels are encountered. In this scenario, reliable coagulation of parenchyma and small vessels is paramount to a safe and precise resection. Currently there are several devices designed for precoagulation of the liver, using radiofrequency-based technology. One such device is the TissueLink Endo SH2.0™ Sealing Hook (SH) (TissueLink Medical Inc., Dover, NH). When used correctly, the SH allows almost bloodless transection. This method not only allows the hepatobiliary surgeon to offer MILR to patients, but also makes major hepatectomy a possibility in selected cases.

This review will focus on one method of liver parenchymal transection during MILR. We will outline the device, methods of use, and review our experience using this method for MILR to provide surgeons with technical options when performing minimally invasive hepatibiliary surgery.

Materials and methods

The following methods are based on recommended device usage guidelines combined with our group's experience using this method in over 500 MILR. This clinical experience includes over 150 hemihepatectomies, and resection of livers varying in parenchymal character.

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ISSN 1365-182X print/ISSN 1477-2574 online
DOI: 10.1080/13651820802166864

The TissueLink Endo SH2.0™ SH is designed to pre-coagulate the liver parenchyma prior to transection (see Figure 1). Physically, the unit consists of an elongated diathermy unit, married to a saline infusion system. Ergonomically, the activation button is placed so the surgeon can activate the device and simultaneously manipulate the distal hook during treatment.

This device centers on monopolar, saline-enhanced radiofrequency (RF) technology to treat, seal, and bluntly dissect liver tissue on a small scale for progressive transection. As the tissue is gently heated, this causes the tissue collagen to contract and essentially "strangle" vascular structures and stroma while simultaneously coagulating the hepatocyte/sinusoid substance. Prior to the procedure, the device is prepared by wire connection to a standard electrocautery unit (with patient grounding pad) and IV tubing to a bag of 0.9 normal saline. In most instances the electrocautery unit is set to 120 watts (coagulation), and saline drip rate to 1 drop/second. Choreography of the liver parenchymal transection includes: scoring the liver capsule, superficial parenchymal transection, deep dissection and transection, and finally cut surface hemostasis.

Liver capsule

Once the liver is inspected with ultrasound, the neoplasm of interest mapped, and the target lobe is mobilized, the transection line is demarcated. The saline is turned off temporarily rendering the device similar to standard electrocautery. The line of transection is scored as in the open surgical approach.

Superficial parenchymal transection

Once the capsule is scored the superficial transection is performed. Using the "heel" of the device (see Figure 1) activate the device (button) with light, constant pressure on the tissue combined with intermittent pushing (aka "stomping") motions. The desired effect is to have boiling of the saline, coagulation of the tissue, and gentle blunt separation of the treated region. The motion of the device and/or drip rate made need to be titrated to achieve this effect. With ample saline and motion, excessive steam, or the opposite effect, electrical arcing, is avoided. Nonethe-less it is important to have a suction apparatus closely associated with the SH to scavenge steam (see Figure 2). We prefer to use these two items in combination: while the SH is activated the suction apparatus is retracting the specimen side of the transection plane, simultaneously scavenging steam.

As the device precoagulates the superficial parenchyma, tactile feedback will indicate the presence either stromal or small vascular structures. Because the device (if activated and in constant contact with the tissue) precoagulates the tissue several millimeters deep to the actual divided liver, small vessels are being treated and secured prior to their visualization. These structures are then hooked with the "toe" of the device (see Figure 1), further coagulated briefly, and then divided by pulling the device, similar to the action of the hook cautery during laparoscopic cholecystectomy. Larger vessels are managed by prolonging the coagulation step with a side-to-side motion for added contraction and extended lateral sealing prior to division. In the case where either the parenchyma or small vessels are incompletely sealed (hemorrhage), coagulating the site with a brief circular motion completes tissue contraction hemostasis in almost all circumstances. Avoid over treating the tissue as progressive collagen contraction will diminish tactile feedback and also inhibit retraction of the transected liver diminishing exposure.

Deep dissection and transection

Naturally, as the transection proceeds deeper into the liver substance, larger vessels will be encountered. The technique is then altered to allow dissection of those larger elements which require adjunctive devices for sealing due to caliber. In our experience, the SH is

Figure 1. TissueLink Endo SH2.0™ Sealing Hook (SH). Note similarity to laparoscopic hook cautery with added cable, IV tubing, and activation button on handpiece. Inset: hook tip with "toe" and "heel". (Picture reproduced with permission from TissueLink Medical).

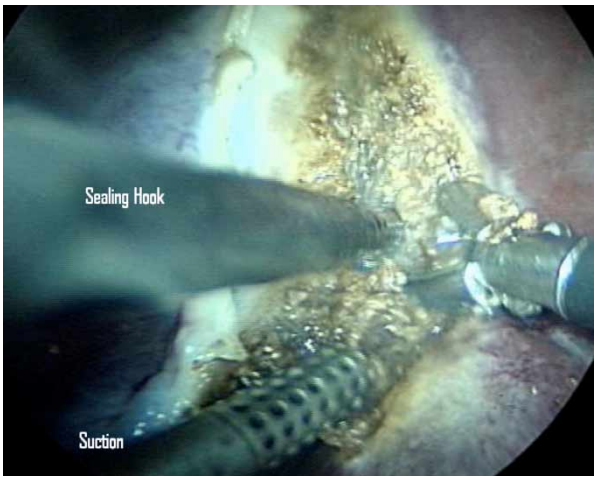

Figure 2. Sealing Hook and suction during transection. Notice close proximity of the SH and suction apparatus.

able to seal up to 8mm vascular structures, but this is dependent on treatment time, vessel nature (thickness), and liver collagen content. While continuously activated, the heel of the device is progressively "stomped" lightly on the tissue. This action gently divides the intervening parenchyma, and allows detection of oncoming vessels, which are then isolated by dissecting the liver tissue above and below (see Figure 3).

Once an intrahepatic vessel is identified and isolated, it may be treated using the SH until visibly coagulated, or, when appropriate, sealed and divided using a coaptive device of choice. In the case where a vessel is treated and breached, continued treatment, if not sealing the vessel, will cause contraction and therefore diminished hemorrhage (and theoretically lessen the risk of gas embolus), promoting rapid suture control of the site.

Cut surface hemostasis

Once transection is completed, the SH can be used to achieve hemostasis on the cut surface using again a circular motion. In our experience this provides reliable hemostasis and removes the need for adjunctive topical hemostatic agents or postoperative drainage.

Special device nuances

Of special note is the mechanical behavior of the SH. Since this device uses heat to function, logically the surgeon must avoid causing bystander tissue damage. The device should be used with caution near any biliary structures, the diaphragm, or metal objects which may cause conduction and arcing. Secondly, steatotic livers, having a smaller proportion of tissue collagen require prolonged treatment with the electrocautery placed on a lower power setting (typically 90 Watts). In contrast, fibrotic/cirrhotic livers require less device treatment but more meticulous dissection as the tactile feedback is diminished by the inherent tissue turgor. Lastly, swifter motions, in combination with adequate saline flow, allow the device to coagulate most effectively, reduce tissue hardening, and provide blunt separation of coagulated liver tissue surrounding intrahepatic structures. These nuances in the use of this device constitute what many surgeons consider pitfalls early in their experience.

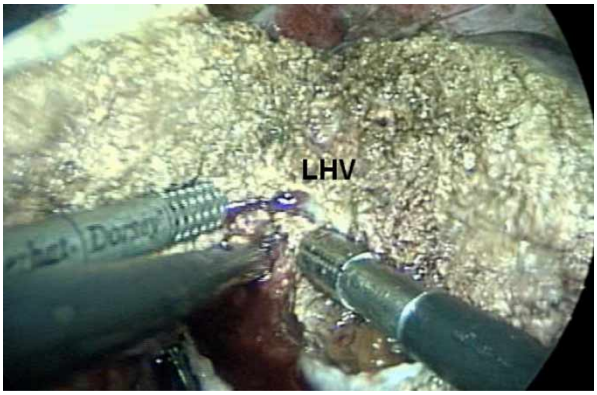

Figure 3. Sealing Hook isolating the intrahepatic left hepatic vein (LHV). Note the smooth transection plane, exposure, and lack of hemorrhage.

Results

Our center has performed over 500 MILR using the SH, with acceptable patient outcomes. In our recent report of 300 cases, we found, using the pre-coagulation method of transection, an advantage of MILR over open resection in terms of operating time, blood loss, length of stay, and overall complications [7]. Furthermore, inflow occlusion was not necessary using this approach, and no patient required reoperation for hemorrhage. Biliary complications were infrequent and no patient required surgical intervention. Our subsequent cases have had similar clinical results regardless of resection magnitude and the incorporation of less experienced surgeons or trainees into these procedures.

Discussion

Technological innovation and advancement are a hallmark of contemporary surgical practice. Moreover, development of devices designed to divide solid organs, have been pivotal in the transition to the minimally invasive approach to liver surgery. During the genesis of MILR, mobilization and vascular dissection were perfected based largely on technical experience gained in other clinical scenarios (gastrointestinal, renal, endocrine procedures). In contrast, the laparoscopic division of the highly vascularized liver was thought to be virtually insurmountable even in the face of advances in open liver surgery.

As various devices were introduced and applied to this unique surgical dilemma, we have seen a steady clinical progression from the minimally invasive treatment of liver cysts [8], to peripheral wedge resections [9], major hepatectomy [7,10], and recently donor hepatectomy [11,12]. Such a progression, in our opinion, is largely due to experience combined with improvements in parenchymal transection technologies. Many centers embarking upon MILR have seen a similar progression. In our center we began with peripheral resections using coaptive devices such as Harmonic Scalpel (Ethicon Endo-Surgery, Cincinnati, OH) and LigaSure (ValleyLab, Tyco Healthcare, Boulder, CO) with excellent results. Later, preparing for hemihepatectomy, we and others have utilized laparoscopic ultrasonic dissection (CUSA, Tyco Healthcare, Mansfield, MA) with improved ability to visualize intrahepatic vessels. Endostaplers, while swift and able to transect both parenchyma and vessels of any caliber, require

adjunctive hemostatic devices and agents to achieve hemostasis following liver division. With the advent of devices designed for precoagulation of the liver tissue, we and others have been able to perform the full gamut of resection magnitudes [7,13], while diminishing surgical field device "traffic" during procedures, without compromising clinical outcomes.

The SH, using the methods described above, is an example of one such technological advancement. It affords rapid transection of superficial hepatic parenchyma, without the need for inflow occlusion. More importantly, deeper dissection of vascular structures is possible, allowing their subsequent management with a technique or device of choice. Our preferred method is SH, followed by coaptive sealing device, and lastly endostapling for inflow pedicles and proper heptic veins. Cut surface hemostasis is achieved as the transection proceeds, lending to shortened procedure times, avoidance of adjuvant hemostatic agents and surgical drains, reduced inpatient stays, and therefore reduced operating costs [7].

While the SH is a simple device with logical applications and usage, we have noticed several phenomena which deserve discussion. First, the device relies on ample saline to avoid charring and arcing. When this occurs, the device becomes, in essence, electrocautery, and therefore the surgeon cannot take advantage of the precoagulation abilities intended in the device's design. Second, we have noticed that surgeons unfamiliar with the SH tend to overcoagulate the liver tissue. Logically, this should be avoided as with any monopolar device, to reduce bystander parenchymal or biliary necrosis. Furthermore, since heating the liver causes collagen contraction, over-treatment results in loss of cut surface mobility and exposure, which is naturally deleterious when attempting hemostatic technical maneuvers. Surgeons inexperienced with the proper use of this device may not appreciate the benefits of precoagulation until the learning curve has been surpassed. In our center, during educational procedures, the trainee is reminded of the low risk of encountering large vessels during superficial transection. This in turn allows a more aggressive use of the device initially, providing a sense familiarity and confidence, resulting in less over-treatment of the tissue. Lastly, the technique described enables the surgeon to identify and localize intrahepatic vessels as tactile feedback and experience progresses. It is our opinion that this is a major advantage of this method. While the SH may not be able to seal vessels of any caliber, gentle treatment of vessels also causes contraction, and if not completely sealed, the vessel is then more easily managed by another approach or device.

In our group's clinical series, the pre-coagulation approach to liver transection affords safe management of this pivotal step in MILR. Through this methodology, resections of a variety of magnitudes can be performed safely and efficiently, once the surgical learning curve is passed. The SH is one device which, when used properly, achieves the goals of deliberate transection in combination with hemorrhage reduction. While no single device (as with open transection methods) is best in all circumstances, familiarity, experience, and surgeon comfort with such devices will provide the best possible patient outcomes in MILR. It is our hope that promotion and description of these novel devices and their use will promote the advancement of hepatobiliary surgery as the technology and discipline continue to evolve.

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