Tissue Management With Tri-Staple Technology in Major and Minor Laparoscopic Liver Resections

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One of the most relevant technologic advancements in laparoscopic liver resection (LLR) is owing to the improved ability to safely secure and divide vascular and biliary structures and the liver parenchyma by the use of endostaplers. We compared, retrospectively, 35 LLRs with the Tri-Staple technology versus 57 LLRs without, during a 14-month period. Colorectal liver metastases were overall the main indication for LLR. Neither major hepatectomy nor left lateral sectionectomy was done in the nonstapled group. Mean surgical time and blood loss were similar, whereas the tumor number and size were significantly larger in the stapled group ($P \leq 0.01$). The conversion rate was 0% and 3.5% ($n = 2$); and the morbidity rate was 9% ($n = 3$) and 12% ($n = 7$), respectively, in the stapled and nonstapled group ($P = 0.8$). No overall 3-month mortality was recorded. Endo GIA Reloads with Tri-Staple technology allow a proper division of the intrahepatic vessels and biliary structure. These devices in LLRs are safe and feasible, allowing major hepatectomy and complex cases as 2-staged procedures and laparoscopic living donor liver resections.

Key words: Laparoscopic liver resection – Minimally invasive liver surgery – Endo-staplers – Tri-Staple technology – Laparoscopic living donor liver resection

There has been exponential growth of reported experiences of laparoscopic liver resection (LLR) since the first procedure was performed in 1992, with more than 3000 published procedures available worldwide today.^{1–7} Meticulous knowledge of surgical anatomy of the liver, improvements

in perioperative care, development of newer instruments, enhanced diagnostic imaging, and advancement in laparoscopic skills are considered the major advances that have been achieved in this field.

The indications for laparoscopic hepatic resection are usually the same as the standard approach, as

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Fig. 1 Dividing of the right HV.

previously advised by the Louisville Statement Consensus Conference.⁸ Although LLR was initially indicated for benign lesions, the recurrence pattern has been shown to be similar to that described for open resection of colorectal liver metastases (CRLM) and/or hepatocellular carcinoma, reporting outcomes at least as good as those reported for open surgery.^{9–14}

In addition, laparoscopic living liver donor hepatectomy has demonstrated its potential role especially in left lateral sectionectomy procurement, where it looks to be more appropriate compared with laparoscopic-assisted techniques in right-lobe living liver donation.^{15,16}

One of the most relevant technologic advancements in minimally invasive liver surgery is owing to the improved ability to safely secure and divide vascular and biliary structures and eventually the liver parenchyma. For this, endostaplers are playing a very important role.

The Endo GIA Reloads with Tri-Staple technology (Covidien Europa, Dublin, Ireland) were introduced in 2010 and have been utilized for LLR at Ghent University Hospital since April 2011 as part of standard of care.

The Department of General, Hepatobiliary, and Pancreatic Surgery at the Ghent University Hospital started a systematic program of laparoscopic liver surgery in 2004. Today, more than 60% of all resectional procedures are done by laparoscopy.

The purpose of this study is to analyze the personal experience and overall results in major and minor LLR comparing stapled versus nonstapled groups.

Material and Methods

Between April 2011 and May 2012, all LLRs requiring Endo GIAs were systematically performed with Covidien Tri-Staple technology devices. Following the center policy, hepatic resections requiring bile duct or vascular reconstruction or patients having focal lesions not amenable to a parenchyma-sparing technique were not considered for laparoscopic approach. During that period, a total of 153 liver resections were performed. The laparoscopic approach was done in 92 (60%) cases. The collected data were analyzed retrospectively after Institutional Review Board approval (B670201316662).

Surgical technique

LLR was performed with the patient in supine and 30° anti-Trendelenburg position with the surgeons between the patient's legs. An intermittent pneumatic compression device was applied to the lower extremities to minimize the risk of deep venous thrombosis. For lesions situated in S5 and S6, and for right hepatectomy, a wedge-shaped cushion was positioned under the patient's right flank with the table turned on the left side. For resection of lesions located in posterior-superior (P-S) segments (SI, SIVa, SVII, and SVIII), the patient was turned two-thirds on the left side with the right arm alongside the body; alternatively, with the right arm fixed above the head to avoid nerve lesions.

In brief, 4 to 6 port sites (one 5-mm; one 10-mm, and two to four 12-mm ports) were inserted in the upper abdominal quadrant: the 12-mm ports were placed to allow insertion of a 30° optical device and the linear stapler; the 10-mm port was for the surgical aspirator or harmonic scissors; and the 5-mm port was used mainly to allow irrigation and aspiration during surgery, and to retract the liver when necessary.

Carbon dioxide pressure for pneumoperitoneum was kept around 10 mmHg during hepatic parenchyma transection (mean central venous pressure 4–6 mmHg, while maintaining urinary output above 0.5 mL/kg/h). Assessment of liver surface and surgical margins was done by intraoperative ultrasonography guidance (Aloka Alpha 7, Tokyo, Japan).

Parenchyma division was almost exclusively performed with the surgical aspirator (SonoSurg-Olympus, Medical System Europe GmbH, Hamburg, Germany). Staplers were indicated to safely divide major intrahepatic vessels (*i.e.*, lobar pedicle or hepatic veins; Figs. 1 and 2) and, in some cases, to

Fig. 2 Stapling the MHV and the LHV.

divide the liver parenchyma. Bipolar coagulation was used for minor bleeding or oozing in combination with the argon beam. The Pringle maneuver was rarely applied. Larger vascular/biliary structures were controlled with endoclips (Hem-o-lock clips, TFX Medical Ltd, Research Triangle Park, North Carolina). Superficially located lesions were resected using the corkscrew technique.¹⁷

During left or right hepatectomy, before starting the parenchymal transection, the occlusion of the relative portal branch as well as loading the hepatic veins (HV) was performed. Particularly, in living donor liver resection [retrieval of the full left liver lobe including the middle hepatic vein (MHV)], the parenchyma division started after careful hilum dissection with complete isolation of the left hepatic artery and portal vein. No selective inflow occlusion was done.

When division of the left lobe was completed, the hepatic artery was secured and divided with 2 Hem-o-lock clips, the left portal branch was divided and secured by using a TA 30 vascular cartridge and the confluence of the MHV with the left hepatic vein (LHV) with an Endo GIA Reload 60-mm (tan, curved type). Finally, the specimen was extracted using a plastic bag through the Pfannenstiel incision, additional port-site enlargement, or by partial opening of a previous abdominal scar (especially for wedge resections).

Statistical analysis

Continuous data are reported as mean $\pm$ SD and were compared using the two-sided Student *t* test.

Table 1 Type of LLRs performed in stapled and nonstapled group

Type of LLR	Stapled LLR (N = 35)	Nonstapled LLR (N = 57)	P value
Major hepatectomy	10 (29%)	0	0.0001
Left hepatectomy	7 (70%)	0	-
Right hepatectomy	3 (30%)	0	-
Minor hepatectomy	25 (72%)	57 (100%)	0.0001
Wedge	8 (32%)	18 (31.5%)	1
Monosegmentectomy	9 (36%)	31 (54.5%)	0.15
Left lateral sectionectomy	6 (24%)	0	0.0005
Bisegmentectomy	2 (8%)	8 (14%)	0.71
Lesions in P-S segments (I; Iva; VII; VIII)	12/25 (48%)	10/57 (17.5%)	0.006

P value statistical significance <0.05.

Comparisons between groups for categorical variables were performed using the χ^2 test or Fisher exact test when appropriate. Statistical significance was set at $P < 0.05$. Statistical analysis was performed by IBM-SPSS Statistics 19.0 (SPSS Inc, Chicago, Illinois).

Results

Staplers were used in 35 of 92 LLR cases (38%). Thirty-three patients (mean age, 59 ± 18 years; male to female ratio, 21 to 12) who underwent 35 LLRs with staplers were compared with 52 patients (mean age, 61 ± 19 years; male to female ratio, 28 to 24) who underwent 57 LLRs without staplers (Table 1). Neither major hepatectomy nor left lateral sectionectomy was done in the nonstapled group. Lesions located in the P-S segments were performed more frequently in the first group. CRLM were overall the main indication for LLR in both groups, with the exception of living liver donation, peripheral cholangiocarcinomas, and a Caroli syndrome in the stapled group needing a major hepatectomy. In particular, 2 two-staged LLRs in 2 patients with CRLM with previous ligation and alcoholization of the right portal vein branches were performed in the stapled group (Table 2). Major hepatectomy rate in this subgroup was 29% (10/35): $n = 3$, right hepatectomy; and $n = 7$, left. The tan, mostly "curved" type Covidien Endo GIA Reloads (compressed tissue thickness range, 0.88–1.8 mm) were used. The median number of cartridges per patient was 2 (range, 1–9). Differences between the groups are depicted in Table 3. Pringle maneuver was used less frequently in the stapled group ($P = 0.58$). Because of the possibility of performing a major

Table 2 Indication for LLRs

Indication	Stapled LLR (N = 35)	Nonstapled LLR (N = 57)	P value
Colorectal liver metastases	17 (48%)	31 (54.5%)	0.66
HCC on cirrhosis	5 (14%)	3 (5.5%)	0.25
Living liver donation	4 (11%)	0	0.018
Liver cell adenoma	3 (9%)	14 (24.5%)	0.09
Peripheral cholangiocarcinoma	2 (6%)	0	0.14
Caroli	1 (3%)	0	0.38
Breast metastases	1 (3%)	2 (3.5%)	1
Hydatid cyst	1 (3%)	0	0.38
Focal nodular hyperplasia	1 (3%)	7 (12%)	0.14
Previous abdominal surgery	17 (49%)	32 (56%)	0.52
Two-staged hepatectomy	2 (6%)	0	0.14

HCC, hepatocellular carcinoma.

hepatectomy with the use of staplers, the tumor size and number were larger in the stapled group (Table 3). Conversion rate was 0% and 3.5% ($n = 2$) and the morbidity rate was 9% ($n = 3$) and 12% ($n = 7$), in the stapled and nonstapled group, respectively ($P = \text{ns}$). In the stapled group, 1 patient undergoing a bisegmentectomy V-VI for CRLM with severe chemotherapy-induced steatohepatitis of the underlying liver parenchyma developed a biliary fistula that was treated conservatively (grade 3 complication)¹⁸; a urinary tract infection (grade 1 complication)¹⁸ was recorded in 2 additional patients. In the second group, 2 urinary tract infections, 2 sterile fluid collections, 1 wound hematoma, 1 pneumothorax, and 1 episode of pneumonia were recorded. No 3-month mortality was recorded overall.

Median postoperative hospital stay was 4 days (range, 2–8) and 3.5 days (range, 1–7) for the stapled and nonstapled group, respectively. “R0” resection in patients with malignancy was achieved in 94% (33 of 35) of patients. Neo-adjuvant chemotherapy regimen was administered in all patients undergoing LLR for CRLM. In the nonstapled group, “R0” resection in patients with malignancy was achieved in 92% (52 of 57) of patients (Table 3). Recurrence occurred in 4 of 17 patients (23%) and in 15 of 57 patients (26.3%) in the first and in the second group, respectively, after an overall median time to recurrence of 7 months (range, 4.9–9.8 months).

Discussion

Although the development of laparoscopic liver resection has been limited over time, LLR is a well-established worldwide procedure,^{19,20} which is

Table 3 Perioperative data

Parameter	Stapled LLR (N = 35)	Nonstapled LLR (N = 57)	P value
Mean surgical time, (min) mean $\pm$ SD	310 $\pm$ 114	343 $\pm$ 122	0.2
Pringle maneuver (n)	5 (14%)	11 (19%)	0.58
Mean blood loss, SD (range, mL)	300 (50–2350)	250 (50–1900)	0.3
Tumor size, (cm) $\pm$ SD (range)	42 $\pm$ 31 (8–140)	29 $\pm$ 14 (5–65)	0.021
Tumor number, mean $\pm$ SD (range)	1.47 $\pm$ 0.9 (1–5)	1.28 $\pm$ 0.5 (1–3)	0.001
Median postoperative stay (range, days)	4 (2–8)	3.5 (1–12)	0.8

actually reported more for malignancies^{9–14} than for benign^{4,6,15,16,21} disease.

The present study shows that LLR is safe and feasible for different liver diseases, involves minimal blood loss and very few complications, and is characterized by a short hospital stay. The use of the stapler influences significantly the indications allowing for major hepatectomy, 2-staged hepatectomy, and living donor liver resections, which otherwise would be extremely difficult or unsafe to perform. Similarly, a larger number of tumors as well as lesions more than 10 cm in size can also be resected through a major hepatectomy. In the stapled group, almost 50% of wedge resections were performed in the P-S segments in a safe manner. These segments are usually more difficult because the angle of the instruments is limited by the costal margin, making bleeding control and also tumor margins more challenging.¹ The fact that fewer lesions were approached in the P-S segments in the second group can explain the trend toward less blood loss; however, it was statistically not significant.

Covidien Endo GIA Reloads with Tri-Staple technology allow safe division of the intrahepatic vessels together with biliary structure, owing to its stepped cartridge face, by facilitating the lateral diffusion of tissue during clamping and firing, and requiring less force to compress tissue. The vascular-medium reload (tan) is a good compromise for liver surgery. This is particularly interesting in 2-stage hepatectomy with previous ligation and embolization of sectorial portal vessels, a procedure that increases inflammation and fibrosis of such struc-

tures, making the sequential use of staplers challenging.

Indeed, stapler misfire is an event that may occur.^{5,22} The massive bleeding originated by stapler failure makes laparoscopic management very difficult, especially if it occurs at the level of major hepatic veins, which makes a reliable endostapler essential.

Moreover, the unique curved tip reload appears to be useful while introducing the device through the parenchyma as it enhances the visibility of the instrument and permits control of its position, and finally it allows for some retraction of the dividing vessels while firing. Altogether, the 45° angle of rotation, the lightness, and the intuitive enhanced articulation knob moving in the same direction as the articulation make this device particularly suitable for laparoscopic living donor liver surgery, where the optimal stapler position is to safely divide the hepatic veins without compromising the outflow of the remnant liver (which is absolutely mandatory).

No conversion to open surgery was recorded in the stapled group of LLR, whereas 48% of wedge resections were done in P-S segments (considered to be more complex than a straightforward right or left hepatectomy).^{1,23,24}

In conclusion, the Tri-Staple technology in laparoscopic liver resection is safe and feasible for the resection of liver segments. The contribution of this new technology and a completed learning curve account for a favorable outcome with minimal morbidity especially when approaching P-S segments and in complex cases of major hepatectomy.

Acknowledgments

This research was supported by Covidien AG in Switzerland.

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