

Segmentectomy: is minimally invasive surgery going to change a liver dogma?

Fulvio Calise¹ · Antonio Giuliani¹ · Loredana Sodano¹ · Enrico Crolla¹ · Paolo Bianco¹ · Aldo Rocca¹ · Antonio Ceriello¹

Received: 24 June 2015 / Accepted: 26 June 2015 / Published online: 22 July 2015
© Italian Society of Surgery (SIC) 2015

Abstract Nowadays, the respective approach to hepatic resections (for malignant or benign liver lesions) is oriented toward minimal parenchymal resection. This surgical behavior is sustained by several observations that surgical margin width is not correlated with recurrence of malignancies. Parenchymal-sparing resection reduces morbidity without changing long-term results and allows the possibility of re-do liver resection in case of recurrence. Minimally invasive liver surgery (MILS) is performed worldwide and is considered a standard of care for many surgical procedures. MILS is associated with less blood loss, less analgesic requirements, and shorter length of hospital with a better quality of life. One of the more frequent criticisms to MILS is that it represents a more challenging approach for anatomical segmentectomies and that in most cases a non-anatomical resection could be performed with thinner resection margins compared with open surgery. But even in the presence of reduced surgical margins, oncological results in the short- and long-term follow-up seem to be the same such as open surgery. The purpose of this review is to try to understand whether chasing at any cost laparoscopic anatomical segmentectomies is still necessary whereas non-anatomical resections, with a parenchymal-sparing behavior, are feasible and overall recommended also in a laparoscopic approach. The message coming from this review is that MILS is opening more and more new frontiers that are still need to be supported by further experience.

Keywords Laparoscopic liver resection · Laparoscopic surgery · Hepatocellular carcinoma · Liver colorectal metastasis · Segmentectomy

Introduction

Minimally invasive liver surgery (MILS) is now performed worldwide and is considered a standard of care for some surgical procedures such as left lobectomy [1, 2]. MILS is associated with less blood loss, less analgesic requirements, and shorter length of hospital stay with similar oncological outcomes as compared with open hepatectomy and a better quality of life in the first year after surgery [2–5].

In the review by Nguyen, minor hepatectomies, including segmentectomies and wedge resections, were the most commonly performed procedures (45 %) whereas major hepatectomies accounted for only 16 % of the entire group of laparoscopic hepatectomies [2]. These findings were also confirmed by Aldrighetti in a large national survey regarding minimally invasive liver resections and collecting data from thirty-nine centers in Italy: indeed, out of 1391 laparoscopic liver resections (excluding conversions) 1269 cases (69.1 %) of minor liver resections were recorded excluding 23.8 % of left lateral sectionectomies [6].

However, there are few reports in the literature clearly explaining how a laparoscopic segmentectomy is performed “anatomically” with a complete tributary inflow and outflow control. Probably, in reality the more frequently performed procedures are sub-segmentectomies with intra-parenchymal control of post segmental pedicle branches.

At the beginning of the era MILS, one of the more frequent criticisms was that, because of a more challenging

✉ Fulvio Calise
fulvio.calise@acocardarelli.it

¹ Unit of Hepatobiliary Surgery and Liver Transplant Center, “Cardarelli” Hospital, Naples, Italy

approach for anatomical segmentectomies, in most cases a non-anatomical resection is performed with thinner resection margins compared with open surgery.

However, even in the presence of reduced surgical margins, oncological results in the short- and long-term follow-up are the same such as open surgery [7, 8].

Similar observation are made for open surgery: a non-anatomical approach seems to have the same oncological results compared with anatomic resections but with better postoperative course due to the parenchymal sparing [9]. In a very recent paper Marubashi analyzed some 1102 patients with HCC, 577 in the anatomical, and 525 in the non-anatomical resection group. By propensity score matching, 329 patients were selected into each group. No statistically significant difference between the two groups was found concerning overall survival and early recurrence [10].

So, the question is: nowadays is it still necessary to chase at any cost the laparoscopic anatomical segmentectomies? Or, viceversa, non-anatomical resections are feasible and overall recommended?

MILS and segmentectomies

In the era of MILS segmentectomy as a surgical technique seems to have fallen into oblivion.

In 1957, Couinaud published his fundamental paper on the surgical anatomy of the liver, describing the eight segments, everyone with its pedicle: artery, portal vein, and bile duct [11]. Since then, every liver surgeon has referred to it as a Bible to be followed during routine surgical practice.

Since the rapid spread of liver surgery in the 1970s, several authors have suggested the technical tricks to remove the entire segment by sectioning the tributary pedicle [12–14]. Moreover, in 2012 Yoshida et al. published an editorial accurately describing the technique of segmentectomy by ultrasonically guided staining of the tributary portal branch and injecting a dye. But the described technique regards open surgery, underlying major differences between segmentectomy of the left (sg 2–4) and right (5–8) hemiliver [15]. This beautiful paper seems to have come from another world. The only published article resuming this old technique and modifying it for a laparoscopic approach is the outstanding paper by Ishizawa. The authors state that this staining technique is simple and useful for open surgery but it is much more difficult to reproduce laparoscopically the demarcation of the hepatic segment on the monitor visually [16].

They have therefore developed a laparoscopic fluorescent imaging system that allows visualization of indocyanine green (ICG) fluorescence to identify the biliary tract

and liver cancer intraoperatively, either by direct injection into the portal branch (positive staining) or by intravenous injection of ICG dye by clamping the segmental portal branch (negative staining) [16].

In the following article in *Annals of Surgery* they published their experience in laparoscopic segmentectomy correctly defined as complete removal of the Couinaud's segment, in which the corresponding hepatic veins are exposed on the raw surface. The laparoscopic approach was facilitated using intraoperative ultrasonography for each segment and by placing intercostal trocars to expose the root of the right hepatic vein for segmentectomy 7 and 8. But out of a series of 342 patients undergoing consecutive laparoscopic treatment, laparoscopic segmentectomy was completed in only 62 patients (19 %) with 10 subsegmentectomies and 16 bisegmentectomies performed [17].

We have extensively analyzed these two papers because the authors are the only ones, to our knowledge, to precisely describe the technique of laparoscopic segmentectomy when reported in the surgical series. Segmentectomy usually appears in the table of the types of liver resections performed as one of the techniques: but figures are disappointing as concerning the magnitude.

In another paper Kim et al. performed 10 anatomical s4 resection for hepatocellular carcinoma (HCC) with a Glissonian approach but with a worst postoperative course compared with other laparoscopic series with a postoperative hospital stay of 7.7 days (range 3–13 days) and 20 % of patients requiring intraoperative blood transfusion and a mean estimated blood loss of 592 ml (range 175–1600 ml) [18].

In the Survey of MILS carried out in 39 surgical centers in Italy in the years from January 1995 to February 2012 and published in this number, Aldrighetti et al. report an 86.9 % of segmentectomies and wedge resections performed in the overall series with only 13 % of major hepatectomies. The paper, the first to comprehensively analyze the laparoscopic liver surgery (LLS) in a western country, shows that MILS is not confined to dedicated centers of hepatobiliary surgery accounting, the latest, for almost 30 % of the entire surgical activity. Similarly the French Hepato-bilio-pancreatic Surgery Association, analyzing the LLS in the past 6 years, report a proportion of multiple intermediate liver resections (tumorectomies, uni/bisegmentectomies) of 13.3 %, a percentage not increasing after 2010 [19].

In a recent large 14-year series from a single center, Cai et al. report only 35 segmentectomies out of 365 cases with a relevant number of non-anatomic resections ($n = 68$) and left lateral sectionectomy ($n = 112$) [20]. Interestingly though, they analyze several factors concerning the accomplishment of segmentectomy: conversion to open

surgery, complications rate, mean operating time, blood loss, and hospitalization concluding that in order to perform a laparoscopic liver segmentectomy a surgeon needs an average of 28 cases for training [20].

In a paper published by Viganò et al. in 2009 Authors state that the learning curve for major resections was 60 cases [21], but in an another paper of the same year, by Viganò et al. presenting a systematic review of laparoscopic resections, it stated that non-anatomical resections are commonly reported in literature referred to the so called “laparoscopic liver segments” as defined in the crucial paper of the Louisville Statement [1, 22].

In the two Consensus Conferences on LLS held in Louisville (2008) and Morioka (2014) segmentectomy is considered as a minor resection if referred to anterior and therefore “easy” to perform segments from 2 to 6. This finding and recommendation of the jury under the term “minor” are based on the literature and not involving posterior–superior segments. But in the paper of Morioka “anatomical resections, including sectionectomy, segmentectomy and sub-segmentectomy, meant as parenchymal preserving resections of portal territories are considered complex procedures requiring identification of anatomical boundaries [1, 23].” This surgery must rely on advanced intraoperative ultrasound, pedicle vascular control through a Glissonian approach.

At this point the crucial question: is it therefore mandatory, thanks to progress in US-guided liver resections, to resect the entire segment in order to be oncologically correct? Several reports [24, 25] show that the minimal margin for metastasis may go from the traditional 1 cm to 1 mm, or even predicting, as with Torzilli et al., R1 for metastasis lying on a major vein [26, 27]. The question is different for HCC due to frequent satellite nodules; however, according to several reports, it seems there are no differences in oncological outcome between regulated (segmentectomy) and unregulated resection [28–30].

Okamura et al. compared two groups of HCC patients divided into anatomic ($n = 139$) and non-anatomic ($n = 97$) resections with a propensity score matching. At both uni- and multivariate analyses operative procedure was not a significant risk factor for recurrence that, however, did not differ in the two groups [9].

More recently, similar results are shown by Hirokawa who analyzed 330 patients with HCC with a propensity score model showing for non-anatomic resections better short-term outcomes in terms of reduced operation time ($P = .02$), blood loss ($P = .01$), blood transfusion ($P < .01$), complications (particularly bile leakage and abdominal abscess) ($P = .04$), and postoperative hospital stay ($P < .01$). They conclude that anatomic resection was not superior to non-anatomic resection in survival

outcomes. Rather, postoperative short-term outcomes were more favorable with non-anatomic resection [31].

All these experiences are about solitary small (<5 cm) HCC but as stated by the Louisville and Morioka consensus, the main indication for LLR are exactly small single nodules [1, 23].

Recently Rao et al. have published an extensive meta-analysis comparing 296 laparoscopic hepatic resections to 404 ones. The number of positive resection margins was reduced in the laparoscopic group as well as transfused blood, duration of portal clamping, and hospital stay [32]. In the largest review of LLR series, reported by Nguyen et al. [2], the most common type of liver resection (45 %) is wedge resection or segmentectomy (1258/2804). LLS achieves adequate oncologic treatment and does not seem unequivocal to affect resection margins. Warning should though be emphasized for parenchymal transection by stapler which may modify, at the transection line, the evaluation of adequate oncological margin by destroying the perilesional parenchyma through the compression caused by the device [33, 34].

Similar observation was made by Postriganova et al. that reported how dissection devices can narrow the resection margin due to thermal necrosis [7]. This seems to be an isolated report from the literature; indeed this observation did not lead to a higher rate of tumor-involved resection margins, to a higher rate of recurrence within the liver, or to a poorer survival.

Other papers compare anatomic and non-anatomic LLR. Abu Hilal et al. [35] focused on left lateral sectionectomy, showing that there was no difference in resection margin between the laparoscopic (11 mm; 1.5–30 mm) and open (12 mm; 4–40 mm) approaches. Aldrighetti et al. [36] show that the resection margin of laparoscopic left lateral sectionectomy (1.1 ± 0.3 cm) is comparable with the open approach (1.3 ± 0.5 cm). McPhail et al. [37], in a collective review of five case–control series on laparoscopic versus open left lateral sectionectomy suggest that the laparoscopic approach do not compromise margin status. Kazaryan et al. [38] report a comparative evaluation of 75 segmental LLR performed for malignant tumors localized in posterosuperior (1, 7, 8, 4a: 28 procedures) and antero-lateral (2, 3, 4b, 5, 6: 47 procedures) segments showing only a 5.3 % of infiltrated margin in both groups.

In our series of 156 laparoscopic liver resections, segmentectomies account for 50 % ($n = 78$) of the total; the identification of the portal pedicle was made by ultrasound guidance but no dying procedures were ever used. A light and temporary devascularization of the resection margins, in case of uncompleted sectioning of the tributary pedicle, neither impacted the resection margin always superior to 5 mm nor the favorable outcome of the patient (0 % mortality) (unpublished data).

Conclusion

“The actual resective approach to hepatic cancer (primary or secondary) is oriented toward minimal parenchymal resection. This methodology is sustained by observation that surgical margin width is not correlated with cancer recurrence. Parenchymal-sparing resection reduces morbidity without changing long-term results and allows the possibility of re-do liver resection in case of recurrence. With regard to segmentectomies MILS has opened new frontiers that yet need to be supported by years and years of experience: however, our impression is that we are rediscovering a dogma that dominated liver surgery for more than 30 years [39]”.

These words, written 3 years ago have received a further clinical validation in the elapsed time. In the era of MILS segmentectomy that meant as an anatomic resection runs a high risk of disappearing as a standard procedure useful for our patients, Anatomical segmentectomy is undoubtedly more difficult in laparoscopic than in open surgery; but complete resection of the whole segmental territory does not seem to modify the fate of the patient. Other and major problems are still need to be solved concerning quality of liver, extension of disease, and response to systemic chemotherapy.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Standard All procedure performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Research involving human participants and/or animals No research on humans nor animals was made.

Informed consent Informed consent is not required for review type of articles.

References

- Buell JF, Cherqui D, Geller DA, O'Rourke N, Iannitti D, Dagher I, Koffron AJ, Thomas M, Gayet B, Han HS, Wakabayashi G, Belli G, Kaneko H, Ker CG, Scatton O, Laurent A, Abdalla EK, Chaudhury P, Dutson E, Gamblin C, D'Angelica M, Nagorney D, Testa G, Labow D, Manas D, Poon RT, Nelson H, Martin R, Clary B, Pinson WC, Martinie J, Vauthey JN, Goldstein R, Roayaie S, Barlet D, Espat J, Abecassis M, Rees M, Fong Y, McMasters KM, Broelsch C, Busuttil R, Belghiti J, Strasberg S, Chari RS, World Consensus Conference on Laparoscopic Surgery (2009) The international position on laparoscopic liver surgery: The Louisville Statement, 2008. *Ann Surg* 250:825–830
- Nguyen KT, Gamblin TC, Geller DA (2009) World review of laparoscopic liver resection—2,804 patients. *Ann Surg* 250:831–841
- Abu Hilal M, Di Fabio F, Abu Salameh M, Pearce NW (2012) Oncological efficiency analysis of laparoscopic liver resection for primary and metastatic cancer: a single-center UK experience. *Arch Surg* 147:42–48
- Giuliani A, Migliaccio C, Ceriello A, Aragiusto G, La Manna G, Calise F (2014) Laparoscopic vs. open surgery for treating benign liver lesions: assessing quality of life in the first year after surgery. *Updates Surg* 66:127–133
- Giuliani A, Migliaccio C, Surfaro G, Ceriello A, Defez M (2012) Short-and long-term follow-up. In: Calise F, Casciola L (eds) Minimally, surgery of the liver. Springer, Milan, pp 167–173
- Aldrighetti L, Cipriani F, Ratti F, Casciola L, Calise F (2012) The Italian experience in minimally invasive surgery of the liver: a national survey. In: Calise F, Casciola L (eds) Minimally, surgery of the liver. Springer, Milan, pp 295–312
- Postrganova N, Kazaryan AM, Røsok BI, Fretland Å, Barkhatov L, Edwin B (2014) Margin status after laparoscopic resection of colorectal liver metastases: does a narrow resection margin have an influence on survival and local recurrence? *HPB (Oxford)* 16:822–829
- Nguyen KT, Laurent A, Dagher I, Geller DA, Steel J, Thomas MT, Marvin M, Ravindra KV, Mejia A, Lainas P, Franco D, Cherqui D, Buell JF, Gamblin TC (2009) Minimally invasive liver resections for metastatic colorectal cancer. A multi-institutional, international report of safety, feasibility and early outcome. *Ann Surg* 250:842–848
- Okamura Y, Ito T, Sugiura T, Mori K, Uesaka K (2014) Anatomical versus nonanatomic hepatectomy for a solitary hepatocellular carcinoma: a case-controlled study with propensity score matching. *J Gastrointest Surg* 18:1994–2002
- Marubashi S, Gotoh K, Akita H, Takahashi H, Ito Y, Yano M, Ishikawa O, Sakon M (2015) Anatomical versus non-anatomical resection for hepatocellular carcinoma. *Br J Surg* 102:776–784
- Le foie Coinaud C (1957) études anatomiques et chirurgicales. Masson, Paris
- Iwamoto S, Sanefuji H, Okuda K (2003) Angiographic subsegmentectomy for the treatment of patients with small hepatocellular carcinoma. *Cancer* 97(4):1051–1056
- Tanaka K, Shimada H, Matsumoto C et al (2008) Anatomic versus limited non-anatomic resection for solitary hepatocellular carcinoma. *Surgery* 143(5):607–615
- Torzilli G, Procopio F, Cimino M et al (2010) Anatomical segmental and subsegmental resection of the liver for hepatocellular carcinoma: a new approach by means of ultrasound-guided vessel compression. *Ann Surg* 251:229–235
- Yoshida H, Katayose Y, Rikiyama T, Motoi F, Onogawa T, Egawa S, Unno M (2012) Segmentectomy of the liver. *J Hepatobiliary Pancreat Sci* 19:67–71
- Ishizawa T, Zuker NB, Kokudo N, Gayet B (2012) Positive and negative staining of hepatic segments by use of fluorescent imaging techniques during laparoscopic hepatectomy. *Arch Surg* 147:393–394
- Ishizawa T, Gumbs AA, Kokudo N, Gayet B (2012) Laparoscopic segmentectomy of the liver: from segment I to VIII. *Ann Surg* 256:959–964
- Kim YK, Han HS, Yoon YS, Cho JY, Lee W (2015) Total anatomical laparoscopic liver resection of segment 4 (s4), extended s4, and subsegments s4a and s4b for hepatocellular carcinoma. *J Laparoendosc Adv Surg Tech* 25:375–379
- Goumard C, Farges O, Laurent A, Cherqui D, Soubrane O, Gayet B, Pessaux P, Pruvot FR, Scatton O (2015) An update on laparoscopic liver resection: The French Hepato-Bilio-Pancreatic Surgery Association statement. *J Visc Surg* 152:107–112
- Cai X, Li Z, Zhang Y, Yu H, Liang X, Jin R, Luo F (2014) Laparoscopic liver resection and the learning curve: a 14-year, single-center experience. *Surg Endosc* 28:1334–1341

21. Viganò L, Laurent A, Tayar C, Tomatis M, Ponti A, Cherqui D (2009) The learning curve in laparoscopic liver resection: improved feasibility and reproducibility. *Ann Surg* 250:772–782
22. Viganò L, Tayar C, Laurent A, Cherqui D (2009) Laparoscopic liver resection: a systematic review. *J Hepatobiliary Pancreat Surg* 16:410–421
23. Wakabayashi G, Cherqui D, Geller DA, Buell JF, Kaneko H, Han HS, Asbun H, O'Rourke N, Tanabe M, Koffron AJ, Tsung A, Soubrane O, Machado MA, Gayet B, Troisi RI, Pessaux P, Van Dam RM, Scatton O, Abu Hilal M, Belli G, Kwon CH, Edwin B, Choi GH, Aldrighetti LA, Cai X, Cleary S, Chen KH, Schön MR, Sugioka A, Tang CN, Herman P, Pekolj J, Chen XP, Dagher I, Jarnagin W, Yamamoto M, Strong R, Jagannath P, Lo CM, Clavien PA, Kokudo N, Barkun J, Strasberg SM (2015) Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. *Ann Surg* 261:19–29
24. Pawlik TM, Scoggins CS, Zorzi D et al (2005) Effect of surgical margin status on survival and site of recurrence after hepatic resection for colorectal metastases. *Ann Surg* 241(5):715–724
25. Muratore A, Ribero D, Zimmiti G et al (2010) Resection margin and recurrence-free survival after liver resection of colorectal metastases. *Ann Surg Oncol* 17(5):1324–1329
26. Torzilli G, Montorsi M, Del Fabbro D et al (2006) Ultrasonographically guided surgical approach to liver tumours involving the hepatic veins close to the caval confluence. *Br J Surg* 93:1238–1246
27. Torzilli G, Botea F, Donadon M et al (2010) Minimesohepatectomy for colorectal liver metastasis invading the middle hepatic vein at the hepatocaval confluence. *Ann Surg Oncol* 17:483
28. Dahiya D, Wu TJ, Lee CF et al (2010) Minor versus major hepatic resection for small hepatocellular carcinoma (HCC) in cirrhotic patients: a 20-year experience. *Surgery* 147:676–685
29. Matsui Y, Terakawa N, Satoi S et al (2007) Postoperative outcomes in patients with hepatocellular carcinomas resected with exposure of the tumor surface: clinical role of the no-margin resection. *Arch Surg* 142:596–602
30. Torzilli G, Donadon M, Cimino M et al (2009) Systematic subsegmentectomy by ultrasound-guided finger compression for hepatocellular carcinoma in cirrhosis. *Ann Surg Oncol* 16(7):1843
31. Hirokawa F, Kubo S, Nagano H, Nakai T, Kaibori M, Hayashi M, Takemura S, Wada H, Nakata Y, Matsui K, Ishizaki M, Uchiyama K (2015) Do patients with small solitary hepatocellular carcinomas without macroscopically vascular invasion require anatomic resection? Propensity score analysis. *Surgery* 157:27–36
32. Rao A, Rao G, Ahmed I (2012) Laparoscopic vs. open liver resection for malignant liver disease. A systematic review. *Surgeon* 10:194–201
33. Kaneko H, Otsuka Y, Takagi S et al (2004) Hepatic resection using stapling devices. *Am J Surg* 187:280–284
34. Gumbs AA, Gayet B, Gagner M (2008) Laparoscopic liver resection: when to use the laparoscopic stapler device. *HPB (Oxford)* 10(4):296–303
35. Abu Hilal MA, McPhail MJW, Zeidan B et al (2008) Laparoscopic vs. open left lateral sectionectomy: a comparative study. *Eur J Surg Oncol* 34:1285–1288
36. Aldrighetti L, Pulitano C, Catena M et al (2008) A prospective evaluation of laparoscopic vs. open left lateral sectionectomy. *J Gastrointest Surg* 12:457–462
37. McPhail MJ, Scibelli T, Abdelaziz M et al (2009) Laparoscopic vs. open left lateral hepatectomy. *Expert Rev Gastroenterol Hepatol* 3:345–351
38. Kazaryan AM, Rosok BI, Marangos IP et al (2011) Comparative evaluation of laparoscopic liver resection for posterosuperior and anterolateral segments. *Surg Endosc* 25(12):3881–3889
39. Calise F (2012) Segmentectomies (Chapters 26–34): A Foreword. In: Calise F, Casciola L (eds) *Minimally, surgery of the liver*. Springer, Milan, pp 187–190