Scandinavian Journal of Surgery 100: 54–65, 2011

LAPAROSCOPIC LIVER SURGERY: NEW FRONTIERS

B. Edwin[1, 2], A. Nordin[3], A. M. Kazaryan[1, 4]

[1] Intervention Centre, Oslo University Hospital, Rikshospitalet, Oslo, Norway
[2] Department of Hepatic, Gastrointestinal and Paediatric Surgery, Oslo University Hospital, Rikshospitalet, Oslo, Norway
[3] Transplantation and Liver Surgery Unit, Helsinki University Hospital, Helsinki, Finland
[4] Institute of Clinical Medicine, Faculty of Medicine, University of Oslo, Oslo, Norway

ABSTRACT

Laparoscopic liver resection (LHR) has shown classical advantages of minimally invasive surgery over open counterpart. In spite of introduction in early 1990´s only few centres worldwide adapted LHR to routine practice. It was due to considerable technical challenges and uncertainty about oncologic outcomes.

Surgical instrumentation and accumulation of surgical experience has largely enabled to solve many technical considerations. Intraoperative navigation options have also been improved. Consequently indications have been drastically expanded nearly reaching criteria equal to open liver resection in expert centres.

Recent studies have verified oncologic integrity of LHR. However, mastering of LHR is still a quite demanding task limiting expansion of this patient friendly technique. This emphasizes the necessity of systematic training for laparoscopic liver surgery.
This article reviews the state of the art of laparoscopic liver surgery lightening burning issues of research and clinical practice.

Key words: Laparoscopic surgery; liver resection; surgical outcomes; morbidity; mortality; survival

INTRODUCTION

Liver resection represents one of the last areas of resistance to the assault of laparoscopic surgery. Laparoscopic liver resection (LHR) was firstly reported by Reich and co-authors and Gagner et al. in the early 1990-s (1, 2). Since that time improvements in laparoscopic techniques and technological advances in instrumentation have significantly extended the surgeon's ability to perform the procedure safely. This together with accumulated propitious experiences and encouraging literature reports has conformably expanded indications to laparoscopic techniques. However, LHR is still fully presented only in few expert centres worldwide.

The aim of this review is to present the state of the art of laparoscopic liver surgery.

LITERATURE

Current literature was reviewed by searching PubMed/Medline database (from January 1991 to September 2010). Out of 425 publications were identified by the defined search algorithm, 390 were found to be relevant to LHR (Fig. 1). A total of 328 (84%) publications were in English, and 355 (91%) represented original papers. A reference was made to the most relevant studies. Pronounced rise in a number of papers dedicated to LHR is observed throughout

Correspondence:
Bjørn Edwin, M.D.
Intervention Centre
Oslo University Hospital – Rikshospitalet
N - 0027, Oslo, Norway
Email: bjorn.edwin@ous-hf.no

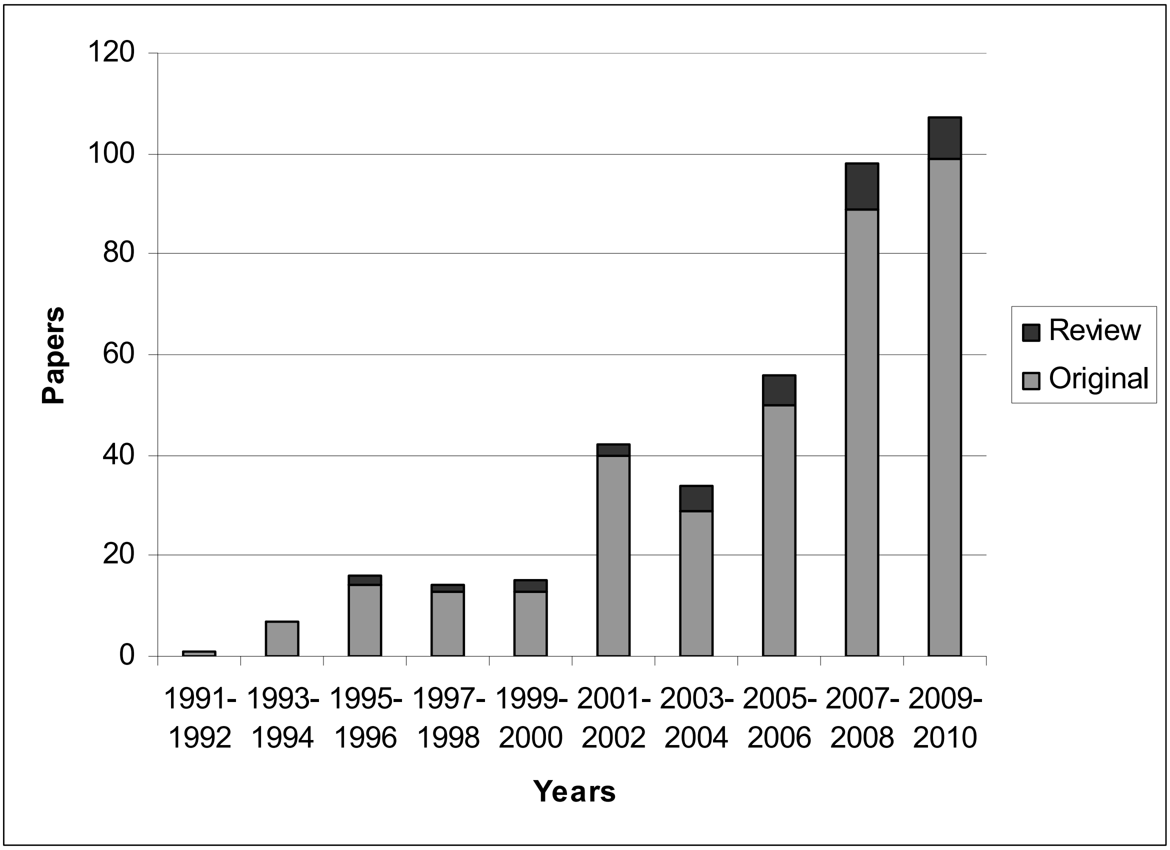

Fig. 1. Number of full papers related to laparoscopic liver resection (PubMed/Medline database).

the 2000-s, this probably corresponds both to an increased research interest of surgical community and to a wider clinical application of this patient-friendly approach.

Key outcomes of major studies are summarized in the Table 1 and 2.

INDICATION ISSUES, LIMITATIONS

Nowadays indications to LHR have nearly attained to classic indications to open liver resection (3, 4). They include benign (adenoma and symptomatic focal nodular hyperplasia, haemangioma or giant liver cysts) and malignant (both primary and metastatic) lesions in the liver, and living donor liver harvesting. A high percentage of benign tumours was presented in early series of LHR, whereas the proportion of malignant tumours has significantly increased in recent years (5–7). This is in agreement with the current practice not to increase the proportion of operations of benign liver tumours over standard levels seen in open procedures (8).

Very large tumours or necessity of biliary or vascular reconstruction have been considered as the only ultimate contraindications to LHR. However, biliary and to certain extent vascular reconstructions are in principle feasible.

Scanty availability of expert surgeons in field of laparoscopic liver surgery and insufficient hospital capacities significantly influence on the width of actual use of laparoscopic approach. Whereas expert centres offer laparoscopic approach to about half of their patients, only a minor part of hepatobiliary centres worldwide apply routinely laparoscopic techniques to remove liver lesions (9, 10).

Maturation of master surgeons is much more challenging and time-consuming in laparoscopic liver surgery than in other surgical subspecialities (11). Approximately 60 operations have to be performed in order to overcome the learning curve effect. Not only the number of operations but the regular practice and standardization of the laparoscopic procedures are key factors in proper development of laparoscopic liver surgery program (11). LHR require expertise in two areas: advanced laparoscopic technical skills and meticulous knowledge of liver anatomy and liver surgery. The world surgical practice during the last two decades and our experience have shown that it is possible to gain adequate knowledge of surgical anatomy and master a number of advanced laparoscopic operations without a large experience in a counterpart open procedure. Although, it has to be emphasized that the decision making and liver surgery is a multidisciplinary team work and laparoscopic liver surgery should be initiated in centres with expertise in both liver and laparoscopic surgery

TABLE 1

Survey over major reports of laparoscopic liver resection (studies with over 70 cases).

First author, year	Country	Journal	Number of cases	Malignant lesions; Major hepatectomies	Operative time; Vascular occlusion	Blood loss; Blood transfusions	Morbidity; Mortality	Involved margin; Margin magnitude	Conversion; Hospital stay
Koffron, 2007	USA	Ann Surg	273 [a]	37%; 35%	93min; 32% [b]	98 ml; –	9%; –	–; –	8% [c]; 2 days
Buell, 2008	Two centre study: USA	Ann Surg	253	42%; 25%	162min; 0%	222ml; 2.8%	16%; 1.6%	3%; 8.5 mm	2.4%; 2 days
Dagher, 2009	Multi–centre study: France, Australia, USA	Ann Surg	210	54%; 100%	250min; 11%	300ml; 14%	22%; 1%	2.7%; 10.5 mm	12%; 6 days
Bryant, 2009	France	Ann Surg	166	60%; 19%	180min ; 53%	200ml; 5%	15%; 0%	–; 11.5 mm	10%; 6 days
Dagher, 2010	Tri-centre study: France, Italy	J Am Coll Surg	163	100%; 10%	250min; "on demand"	180ml; 10%	22%; 1.2%	–; 12 mm	9%; 7days
Kazaryan, 2010	Norway	Arch Surg	147	81%; 5%	164min; 0%	350ml; 18%	13%; 0.7%	6%; 6 mm	3%; 3 days
Cho, 2008	South Korea	Surg Endosc	128	91%; 28%	279min; 0%	557ml; 31%	17%; 0%	–; 16 mm	3%; 11 days
Chen, 2008	Two centre study: Taiwan	Ann Surg Oncol	116	100%; 2.4%	156min; 0%	139ml; 7%	6%; 0%	–; –	5%; 6 days
Topal, 2008	Belgium	Surg Endosc	109	71%; 19%	95min; 9%	100ml; –	5.5%; 0.9%	1.3%; 10 mm	6%; 6 days
Vibert, 2006	France	Br J Surg	89	73%; 43%	180/360min [d]; 11%	– ; 6%	35%; 1.1%	–; 5 and 10mm [e]	13%; 11 days
Descottes, 2003	Multi-centre study: France, Belgium, Italy, Luxembourg	Surg Endosc	87	0%; 3.4%	– ; 16%	–; 6%	5%; 0% ;	–; –	10%; 5 days
O'Rourke, 2004	Australia	HPB	84	39%; 15 %	149min; –	396ml; –	5%; 0%	4%; 11mm	9%; –
Sasaki, 2009	Japan	Br J Surg	82	93%; 0%	177min; 0%	64ml; 5%	0%; 3.7%	–; 5 and 7 mm [e]	1.2%; 9 days
Kaneko, 2005, 2008 [f]	Japan	HPB, J Hepato-biliary Pancreat Surg	81	77%; 0%	~180min; –	~300ml; –	11%; 0%	–; –	1.2%; –
Shafaee, 2011	Tri-centre study: France, Norway, USA	J Am Coll Surg	76[e]	84%; 25%	180min; –	300ml; 9%	26%; 0%	9%;	11%; 6 days
Dagher, 2007	France	Surg Endosc	70	54%; 27%	227min; 0%	397ml; 13%	16%; 1.4%	–; 11 mm	10%; 6 days

[a] Laparoscopically assisted open resections are not included.
[b] Applied in case of hemihepatectomies only.
[c] Conversions from purely laparoscopic to hand-assisted laparoscopic approach.
[d] Operative time for minor and major resections respectively.
[e] For colorectal metastases and hepatocellular carcinoma respectively.
[f] Due to missing information in the publication from 2008, some data are withdrawn from the publication from 2005.
[e] Repeat liver resections
Parameters are presented as median (or mean if median value is not available).
In studies where parameter was not directly presented, the parameter was deduced from available data if possible.

TABLE 2

Survey over case-control and case-matched studies comparing laparoscopic and open liver resection (studies with over 15 cases in each group)

First author, year	Country	Journal	Number of cases: Laparoscopic/ open	Malignant lesions; Major hepatecto-mies	Operative time; Vascular occlusion	Blood loss; Blood transfusions	Morbidity; Mortality	Involved margin; Margin magni-tude	Conversion; Hospital stay
Rau, 1998	Germany	Hepatogastro-enterology	17 / 17	0%; 0%	184 / 128 min*; –	458 / 556 ml; –	6 / 6 %; 0 / 0 %	–; –	6 %; 8 / 12 days*
Farges, 2002	France	J Hepatobiliary Pancreat Surg	21 / 21	0%; 0%	177 / 156 min; –	218 / 285 ml; 5 / 0 %	10 / 10 %; 0 / 0 %	–; –	0%; 5 / 6.5 days*
Morino, 2003	Italy	Surg Endosc	30 / 30	47 / 83%; 0%	148 / 142 min; 13 / 53 %*	320 / 479 ml*; 15 / 7 %	7 / 7 %; 0 / 0 %	0 / 4 %; –	0%; 6 / 9 days*
Belli, 2007	Italy	Surg Endosc	23 / 23	100% (HCC only); 0%	148 / 125 min*; 0 / 22 %	260 / 377 m*l; 0 / 17 %*	13 / 48 %*; 4 / 0 %	0 / 0%; –	4.3%; 8 / 12 days*
Lee, 2007	China (Hong Kong)	Hong Kong Med J	25 / 25	76 / 84%; 0%	220 / 195 min; 0 / 4 %	100 / 250 ml*; 4 / 0 %	4 / 4 %; 0 / 0 %	– 14 / 14 mm	8%; 4 / 7 days*
Aldrighetti, 2008	Italy	J Gastrointest Surg	25 / 25	76 / 84%; 0% (LLS only)	260 / 220 min; 0 / 40%	165 / 214 ml*; 0 / 0 %	10 / 25 %; 0 / 0 %	0 / 0 %; 11 / 13 mm	0%; 4.5 / 6 days*
Troisi, 2008	Belgium	Surg Endosc	20 / 20	0%; 5 / 10%	220 / 240 min; used / used	–; 30 / 20 %	20 / 45 %; 0 / 0 %	0 / 0 %; –	10%; 7 / 10 days*
Polignano, 2008	Great Britain	Surg Endosc	25 / 25	84 / 92%; 0 / 0%	362 / 366 min; 12 / 32%*	135 / 420 ml*; 0 / 0 %	22 / 40 %*; 0 / 0 %	8 / 4 %; –	8%; 7 / 13 days
Cai, 2008	China (Hong Kong)	Surg Endosc	31 / 31	100 %; 10 / 10%	140 / 503 min; 12 / 32%	135 / 588 ml; – / –	0 / 16 %*; 0 / 0 %	– –	8%; 7.5 / 12 days*
Abu Hilal, 2008	Great Britain	Eur J Surg Oncol	24 / 20	71 / 75 %; 0% (LLS only)	180 / 155 min; 35 % / –	80 / 470 ml*; – / –	13 / 25 %; 0 / 0 %	–; 11 / 12mm	0%; 3.5 / 7 days*
Topal, 2008	Belgium	Surg Endosc	109 / 250 76 / 76 (matched)	71 / 95 %; 16 / 44%	95 / 179 min*; 9 % / 31	150 / 300 ml*; – / –	6 / 27 %*; 0 / 0 %	1.3 / 2 %; 10 / 7.5 mm	6%; 6 / 8 days*
Tsinberg, 2009	USA	Surg Endosc	31 / 43	45 / 72 %; 0%	201 / 172 min; 3 / 37%*	123 / 300 ml*; – / –	13 / 16 %; 0 / 0 %	18 / 3 %; 8 / 8.5 mm	0%; 3 / 7 days*
Ito, 2009	USA	J Gastrointest Surg	65 / 65	57% / –; 0%	170 / 140 min*; 40 / 89%*	100 / 200 ml*; 2 / 25%*	12 / 44 %*; 0 / 0 %	0 / 0 –	20%; 4 / 6 days*
Dagher, 2009	France	Am J Surg	22 / 50	57% / –; 100% (RH only)	360 / 328 min; 0 / 70%*	520 / 735 ml; 14 / 18%	14 / 46 %*; 0 / 2 %	– 20 / 17 mm	9%; 8 / 13 days*
Tranchart, 2010	France	Surg Endosc	42 / 42	100% (HCC only); 12 / 12%	233 / 222 min; 0 / 43%*	364 / 724 ml*; 10 / 17%	21 / 41 %*; 2 / 2 %	0 / 0 10.5 / 10.5 mm	5%; 7 / 10 days*

HCC – hepatocellular carcinoma; LLS – left lateral sectionectomy; RH – right hemihepatectomy;
* Statistically significant difference
Parameters are presented as median (or mean if median value is not available).

(9). On the other hand, many expert hepatobiliary surgeons find extremely challenging to learn technically advanced laparoscopic procedures, such as HR. This emphasizes the necessity of systematic training for laparoscopic liver surgery.

TECHNICAL CONSIDERATIONS

TOTAL LAPAROSCOPIC RESECTION, HAND-ASSISTED RESECTION, LAPAROSCOPIC-ASSISTED OPEN LIVER RESECTION

The majority of centres apply mainly totally LHR, whereas hand-assisted resections and laparoscopic-assisted open liver resection (hybrid resection) are used in routine practice in other centres. Hand-assisted LHR implies the placement of a gas-tight hand port through a 6–10 cm incision. Hybrid liver resection consists of laparoscopic mobilization of the liver followed by hilar dissection and parenchymal transection through open incision. There is no agreement about indications to hand-assisted or hybrid liver resection. Hand assistance has been systematically adopted by some centres, while it has been considered as having a limited role by others (12–18).

Hand-assisted technique is indicated mainly in hepatectomies or resections of posterosuperior segments (13, 17, 19). Hybrid resection has been adopted especially for living donor right hepatectomies enabling to keep conventional surgical technique of liver handling together with provision of less invasive procedure (20). Hybrid techniques are also employed as an alternative to laparoscopic surgery for relatively challenging resections when performance of laparoscopic resections is not considered safe due to moderate experience (21, 22). Both techniques could present a bridge from open to fully LHR. These approaches supply the tactile sensation lacking during laparoscopy, however these approaches require a larger incision which reduces the benefits of minimally invasive surgery. Fatigue in the inserted hand and air leakage represent drawbacks of the hand-assisted method (23). Hand-port could be useful in expert centres as very challenging situations and tumour localizations, when surgeon does not reach significant progress in the procedure or wishes to have tactile control of resection, could be safely managed by hand-assisted techniques. Conversion to hand-assisted method instead of laparotomy can be considered as a better alternative (14). Otherwise these compromising minimally invasive resections are associated with higher blood loss and larger incision, therefore they result in less cosmetics and longer patient convalescence (13–15, 24).

In our experience we nearly always initiate totally laparoscopic approach. Apropos the hand assistance was applied to avoid conversion in very few technically challenging cases. Intraoperative ultrasonography could partly substitute the lacking tactile sensation during totally laparoscopic resection, therefore its application during LHR is mandatory to insure adequate tumour identification and margin control (25, 26).

ANATOMIC, NON-ANATOMIC RESECTIONS, LIVER RESECTION EXTENT, PARENCHYMA SPARING CONCEPT

Recent studies have shown similar perioperative and long-term outcomes of anatomic and non-anatomic liver resection concerning both colorectal liver metastases and hepatocellular carcinoma although the margin width is important for the latter (9, 27–32). The resection with clear surgical margin (R0) is adequate for the treatment of colorectal liver metastases (33). Extensive liver resection involves a considerable reduction of hepatic parenchyma that can lead to clinical manifestation of decompensation, including hepatic insufficiency (34, 35). The extent of HR correlates with the rate of postoperative complications (36) and it is associated with higher tumour recurrence rate due to heightened activation of regenerative growth factors (37–40).

Major HR is still widely used in patients with multiple tumours within the same lobe, large central tumours, or for tumours in close proximity to major vascular structures within the liver. The remarkable advancement in surgical instrumentation for parenchyma dissection and ablative modalities has given an alternative approach implying multiple concomitant liver resections or concomitant thermal ablations (41, 42). These techniques have received a new incitement with introduction of laparoscopic techniques. Multiple simultaneous parenchyma-sparing resections should be preferred over single major resection in case of multiple lesions (37, 41, 43). Laparoscopic techniques facilitate both concomitant multiple resections as well as repeated resections due to minimal adhesion formation and the minimally invasive procedure is better tolerated by patients. The parenchyma-sparing concept increases the possibilities for repeated resections and the probability to maintain sufficient liver functional reserve (44, 45). In this setting it could prolong patient life.

CHALLENGING RESECTIONS: HEMIHEPATECTOMIES, POSTEROSUPERIOR SEGMENTS

Hemihepatectomy is associated with substantially increased technical demands. Consequently it results in a more time-consuming procedure. In spite of the intraoperative technical challenges of major resections, the laparoscopic approach provides improved postoperative course to the patients (19, 46). A recent multicentre study including 210 patients has reported good clinical outcomes of laparoscopic hemihepatectomies with mortality below 1% which corresponds to the best outcomes reported in open surgery (19).

The resections of segments I, VII, VIII, IVa (so called posterosuperior segments) are considered to be technically difficult because of poor exposure (47–49). Many centres still do not consider these lesions for laparoscopic approach, others are inclined to resort the hand-assistance in such cases. However, it has been shown that by application of appropriate adjustment of surgical techniques, patient positioning and special equipment (flexible laparoscope, curved instruments) it is possible to reach outcomes similar to procedures in easy accessible segments (II, III, IVb, V, VI) (50).

TRANSECTION EQUIPMENT

A wide range of advanced laparoscopic equipment applied during LHR has been reported. Choice of devices depends largely on the personal experience and preferences of the surgical team, though certain devices have received general acknowledgement. An ultrasound surgical aspirator (widespread trade marks – CUSA, Selector, Integra, USA and Aspirator, Olympus, Japan) and a bipolar coagulator Ligasure (Covidien, USA) represent instruments which are widely used worldwide (51). Endovascular stapling devices are used in various degrees in different centres. These devices are very useful in transection of the main portal branches and hepatic veins, while their wide application significantly increases costs (52). The remaining staples have disadvantages of hindering and even preventing additional haemostasis of the liver parenchyma with mono- and bipolar electrocautery, thus it is advised to apply clips for transection of segmental vessels and bile ducts (53). Other transection devices have been extensively used by certain surgeons while being disregarded by others (Water jet, ERBE, Netherlands; TissueLink, Salient Surgical Technologies, USA; Habib, Rita Medical, New York, USA) (51, 54).

INTRAOPERATIVE ISSUES

OPERATIVE TIME

Operative time varies significantly between the studies reflecting to both types of performed resections and accumulated experience / technical skills. Operative time is usually within 100–250 minutes in general and it corresponds to time reported for open counterpart liver resection (4–6, 14–15, 47, 49, 54–74).

BLOOD LOSS

Difficulties in achieving haemostasis during liver parenchymal transection have been a major challenge for surgeons. The blood loss varies moderately from centre to centre and comprises around 200–400 ml. It trends to be lower at laparoscopic approach than at open resection resulting in decreased requirements for blood transfusion(6, 24, 59–62, 66, 68–69, 71, 73, 75–78). Even though intraoperative bleedings occur rarely, they could be more difficult to manage due to the lack of manual compression, occasionally necessitating conversion to open procedure. Major blood loss and need to blood transfusion in particular increase a risk of postoperative morbidity and mortality (79–80). Control of resection by laparoscopic ultrasonography plays a crucial role to avoid accidental vascular and biliary injuries and to secure resection margins (81, 82).

GAS EMBOLISM

Theoretical premises and experimental studies have led to anxiety among clinicians concerning a potential risk of gas embolism during LHR which was especially highlighted in regard to posterosuperior segments (13, 83–84). This risk has been greatly overestimated (3, 85). However, there is still lack of sufficient knowledge in this area – therefore majority of surgeons argues a necessity of strict maintenance of low intra-abdominal pressure during the procedure, at least below 12 mm Hg, though some researches cite even 8 mm Hg as an upper threshold (67, 86). An appropriate central vein pressure was considered to be below 5 cm H_2O in order to reduce blood loss in open liver surgery. Concerning laparoscopic approach, due to the risk of gas embolism at presence of pneumoperitoneum, a central vein pressure at a range of 3–6 cm H_2O is considered optimal (87–90). It decreases bleeding during the tissue transection and at the same time minimizes the risk of gas embolism. These two parameters should be well balanced emphasizing the importance of the anaesthesiologic team in LHR (91).

OTHER INTRAOPERATIVE INCIDENTS, CONVERSION TO LAPAROTOMY

The conversion rate reported in the literature is in a range of 2–15% (5, 14–15, 47, 50, 54, 56–58, 60–61, 73, 92–94). However, with surgical experience the conversion rate reduces and currently does not exceed 5% in expert centres (5, 15, 50, 54, 58, 60–61, 73, 94). The main reason to conversion was bleeding and fatal haemorrhage has been reported to be the most serious intraoperative incident (47, 50, 56, 89–90, 94–95). Other less crucial reported causes of conversion represent technical intricacies due to poor exposure, severe adhesions, anatomic limitations, close proximity to major vascular structures, doubts in regard to tumour extent or resection margin status, and lack of operative progress (3, 10). Conversion from laparoscopic to open liver resection should not be considered a failure. Patient's safety and oncologic integrity of the procedure should be of supreme importance (10, 63).

Whereas postoperative complications are well reported in the literature, small emphasis has been made to registration and reporting intraoperative incidents/complications which do not require conversion. Bowel perforation is an intraoperative incident which can be managed without conversion in majority of cases (89, 94, 96).

VASCULAR OCCLUSION

The Pringle manoeuvre and other methods of intraprocedural vascular occlusion are also widely used for LHR with intent to decrease blood loss (24, 70, 97). However, the contemporary transection equipment and advanced operative techniques have made routine use of vascular occlusion unnecessary together with decreased blood loss (63–66, 68–69, 71, 98–99). This could both shorten operative time and prevent liver dysfunction (100–101).

POSTOPERATIVE COURSE, LENGTH OF STAY

LHR is associated with significant reduction in hospital stay, less opioid administration, faster diet resumption, and reduction in time to ambulation after surgery (5, 7, 24, 59–65, 67–69, 71–75, 77–78). Cosmetic outcomes are beneficial and postoperative hospital stay comprises 5–8 days in average, however this parameter depends largely on non-medical issues (health system, institutional routines) and it has been shown that median postoperative hospital stay could be only 3 days (73, 94). Laparoscopic techniques combined with the fast track surgery could further shorten hospital stay down to 1–2 days (14–15, 94, 102).

MORTALITY, POSTOPERATIVE MORBIDITY

Perioperative mortality of LHR is below 1% which corresponds to the best outcomes reported for open surgery (10). Postoperative complication rate comprises around 10–15% and is reported to be similar or less frequent than observed in open liver resection (24, 59, 63–64, 71, 77). Postoperative bile leakage develops in about 1.5% and represents typical crucial complication for LHR as well as it does for open surgery (14, 49, 55, 58, 94). Bile leakage is usually managed by percutaneous drainage and bile duct stenting (49, 55, 94, 103). Postoperative intra-abdominal bleeding is very rare but threatening complication, it could be managed via relaparoscopy (47, 49). Although liver resection specific complications were reported in similar rate with open surgery, rate of liver decompensation among cirrhotic patients has a trend to decrease at application of laparoscopic approach (63, 71, 76). General morbidity – cardiopulmonary complications, abscesses and wound complications have a tendency to reduce in application of laparoscopic approach (59, 63, 64, 68, 71, 77). Rate of incisional hernias after LHR is appreciably lower then after the open counterpart (24, 72).

ONCOLOGIC OUTCOMES

While there is no doubt about common sense to prefer laparoscopic approach over open counterpart for benign liver lesion, some hesitations arise in regard to malignant liver lesions (104–105). One can expect improved oncologic outcomes after application of laparoscopic techniques due to less invasive intervention and therefore less stress response, less immunologic alterations and minor activation of regenerative growth which promotes tumour recurrence (106–107). However these theoretical and experimental premises have to be confirmed in clinical settings. One disadvantage of laparoscopic resection is the possibility to miss additional liver lesions but using modern dynamic CT and MRI scans as well as proper intraoperative ultrasonography the risk should be minimal (10).

SURGICAL MARGINS

Concerns about the adequacy of surgical margins and possible tumour seeding prevented the widespread adoption of laparoscopic techniques for liver malignancies in earlier years. Comparative studies concluded that there was no difference in resection margin magnitude and rate of margin-free resections between laparoscopic and open liver resection (6, 24, 59–60, 67, 71, 76). Besides, the extent of surgical margin has been questioned and at present the tumour free margin or R0 resection should be adequate for colorectal metastases (33). In hepatocellular cancer the development of micrometastases depend on tumour size and histological grade necessitating a margin width of at least 1 cm and above (108–113). Apropos, no incidence of port-site recurrence or tumour seeding has been reported. Intraoperative laparoscopic ultrasound control of tumour location and resection line are considered crucial in this context (81,82).

COLORECTAL LIVER METASTASES, HEPATOCELLULAR CARCINOMA

Liver resection is generally accepted as the standard of care and may cure patients with colorectal metastases (114–115). For patients with hepatocellular carcinoma, who do not meet transplantation criteria, liver resection offers the next best survival rate (116–117). Many centres have reported surgical and middle-term oncologic outcome of laparoscopic resection of colorectal liver metastases and hepatocellular carcinoma. Only few centres have reported long-term outcomes including 5 year overall, recurrence-free and disease-free survivals along with recurrence pattern. 3 year and 5 year overall survival for both pathologies are reported around 70–80% and 50–60% respectively (49, 58, 62, 118–122).

Recurrence pattern has shown to be similar to the pattern described for open resection of colorectal liver metastases and hepatocellular carcinoma, whereas long-term outcomes are at least as good as reported for open liver resection (58, 93, 118–120). As mentioned earlier, laparoscopy has contributed in higher rate of repeat liver resections after recurrences, in addition treatment of both recurrences of the primary tumour and recurrences in other organs has become more aggressive (114, 119, 123–126). Thus many recurrences are treated now, this necessitates to follow a distinguished definition of disease-free and recurrence-free survival (119, 127).

A recent tri-institutional study showed similar surgical outcomes after repeat LHR compared with outcomes reported for primary resections (124). This study verified that the sub-group of patients having laparoscopic primary liver resection was associated with decreased median blood loss (290 versus 400 ml) and lower rate of blood transfusions. Tumour involved resection margins were reported in 9% and 5 year survival in sub-group of patients with colorectal metastases was 55%.

There seems not to be any prospective randomized controlled trials comparing the oncologic outcome of

TABLE 3

Middle- and long-term survival after laparoscopic liver resection for malignant lesions (studies with over 24 cases)

First authors, year	Country	Journal	Number of patients	3-year overall survival, %	5-year overall survival, %
Colorectal metastases					
Nguyen, 2009	Multi-centre study: USA, France	Ann Surg	109	69	50
Kazaryan, 2010	Norway	Ann Surg	107	68	51
Casting, 2009	Two-centre study: France	Ann Surg	60	82	64
Shafaee, 2011	Tri-centre study: France, Norway, USA	J Am Coll Surg	55[a]	83	55
Vibert, 2006	France	Br J Surg	41	87	–
Sasaki, 2009	Japan	Br J Surg	39	64	64
Hepatocellular carcinoma					
Dagher, 2010	Tri-centre study: France, Italy	J Am Coll Surg	163	93	65
Chen, 2008	Two-centre study: Taiwan	Ann Surg Oncol	116	74	62
Bryant, 2009	France	Ann Surg	63	70	60
Belli, 2009	Italy	Br J Surg	54	67	–
Sasaki, 2009	Japan	Br J Surg	37	73	53
Dagher, 2008	France	Surg Endosc	32	72	–
Kaneko, 2005	Japan	Am J Surg	30	–	61
Lai, 2009	China (Hong Kong)	World J Surg	30	–	50
Cherqui, 2006	France	Ann Surg	27	93	–
Cai, 2008	China (Hong Kong)	Surg Endosc	24	68	56

[a] Repeat liver resections.

LHR to open resection. The present knowledge is mainly based on short-term, non-randomised comparative studies or historical comparison with outcomes of open surgery. An alternative way is to score patients by the currently most reliable systems of survival prognosis (for example by the Fong's score or the Basingstoke Predictive Index in case of colorectal liver metastases) and use a calculated survival as a reference to compare with achieved survival after LHR. Implementation of such approach showed favourite oncologic outcomes after LHR for colorectal liver metastases (119).

OTHER MALIGNANCIES

Patients with other liver malignancies would benefit from application of laparoscopic approach, and one could probably transfer oncologic integrity of LHR, revealed for colorectal liver metastases and hepatocellular carcinoma, to other malignancies (cholangiocarcinoma, metastatic tumours in the liver). Such cases were reported in small series (47, 49, 63, 94, 128), though 3-year survival was reported to comprise 50% after laparoscopic resection of liver metastases from neuroendocrine gastrointestinal tumours (128). This corresponds to survival reports reported for open liver resection in patients with neuroendocrine liver metastases (129–130).

Survival data from the major studies are summarized in Table 3.

LAPAROSCOPIC LIVER RESECTION IN TRANSPLANTATION SURGERY

In patients with hepatocellular carcinoma, previous liver resection may compromise subsequent liver transplantation by creating adhesions and increasing surgical difficulty. Initial laparoscopic resection may reduce such technical consequences. It was shown that application of laparoscopic techniques facilitates subsequent liver transplantation and was associated with reduced operative time, blood loss and transfusion requirements compared with transplantation subsequent to open initial resection (131).

Laparoscopic techniques showed its role in harvesting of living donor liver for transplantation (20, 132–133). Left lateral section procurement looks to be most appropriate, whereas right liver procurement by laparoscopic-assisted techniques was also reported (20, 133). Early comparative study has verified similar safety of such approach compared with conventional open harvesting (133). The laparoscopic procedure was associated with significantly decreased blood loss but increased operative time. However with surgical experience the operative time is likely to considerably reduce. However, laparoscopic live-donor liver resection should only be performed in registered centres and under worldwide surveillance (9).

COST ANALYSIS

Total hospital cost for treatment of patients undergoing LHR is lower than cost for open counterparts in western countries (73–74, 77). It is explained mainly by decreased postoperative hospital stay. However the cost of operative intervention itself tends to be higher for laparoscopic techniques due to usually more frequent use of disposable instruments (14, 77). However this parameter depends on applied surgical techniques and thus procedural costs could be similar for laparoscopic and open liver resections (68). In developing countries the cost of hospital stay is relatively low compared with equipment costs. Thus laparoscopic treatment could be overall more expensive in the third world (134–135). The faster return of patients to their work would contribute additional values to the society (136).

NEW TECHNOLOGIES

These technologies have not yet received an appreciable application in laparoscopic liver surgery but they have high potentials for certain clinical cases for future in accordance with opinion of experts.

ROBOTICS

Robotic LHR with application da Vinci Surgical System has been reported in several centers (137–138). Its application could be especially beneficial for procedures requiring biliary or vascular reconstruction.

INTRAOPERATIVE THREE-DIMENSIONAL NAVIGATION

Three dimensional reconstruction of crucial anatomic structures (vessels and bile ducts) based on analysis of preoperative imaging could play an important role especially for hemihepatectomies (139–140). This technique enables safe manipulation in close proximity to major vessels by means of improved intraoperative navigation. On-line guidance of LHR by open MRI reported in a porcine model presents another alternative approach (141). However in a reported form this navigation is unlikely to get spread due to essential reduction of the surgeon's working space with currently available open MRI systems.

SINGLE PORT, NOTES

With aim to further minimize surgical approach single-port LHR has been recently introduced and has currently been receiving fast spread (98). Its cosmetic benefits are evident but other expected benefits of less invasive approach have to be confirmed. Transluminal (transgastric) endoscopic liver resection was reported in experiment on porcine model however its benefits are controversial and clinical potentials are uncertain (142).

CONCLUSIONS

Tremendous advances have taken place in the field of laparoscopic liver surgery. It is now apparent that in experienced hands laparoscopic techniques in liver resection are as safe as open techniques.

The benefits of the laparoscopic approach include less analgesic requirements, shorter hospital stay, decreased transfusion requirements, faster recovery, better cosmetic outcome and less adhesions which subsequently facilitates repeat resections. The oncological results of laparoscopic surgery seem to be similar or possibly better to those of the open approach, both for hepatocellular carcinoma, colorectal and neuroendocrine liver metastases. Further analysis is still necessary to clarify these presumptions. A randomised clinical trial directly comparing the laparoscopic and open approaches would be preferable.

Indications for LHR are nearly the same as for open surgery, and technical feasibility has been reported as the most important limiting factor. At present only very large tumours, cases requiring vascular reconstruction and less absolutely biliary reconstruction are ultimately indicated for open resection. Nevertheless prerequisite "in experienced hands" must be regarded seriously, this factor plays a crucial role in slow spread of laparoscopic techniques in liver surgery. There are few expert centres worldwide, but the techniques spread are growing, as confirmed by the elevating number of recently published papers on this subject.

REFERENCES

1. Reich H, McGlynn F, DeCaprio J et al: Laparoscopic excision of benign liver lesions. Obstet Gynecol 1991;78:956–958
2. Gagner M, Rheault M, Dubuc J: Laparoscopic partial hepatectomy for liver tumor. Surg Endosc 1992;6:99
3. Vigano L, Tayar C, Laurent A et al: Laparoscopic liver resection: a systematic review. J Hepatobiliary Pancreat Surg 2009; 16:410–421
4. Kazaryan AM, Rosok BI, Edwin B: Laparoscopic and open liver resection for colorectal metastases: different indications? HPB (Oxford) 2010;12:434
5. Farges O, Jagot P, Kirstetter P et al: Prospective assessment of the safety and benefit of laparoscopic liver resections. J Hepatobiliary Pancreat Surg 2002;9:242–248
6. Morino M, Morra I, Rosso E et al: Laparoscopic vs open hepatic resection: a comparative study. Surg Endosc 2003; 17:1914–1918
7. Rau HG, Buttler E, Meyer G et al: Laparoscopic liver resection compared with conventional partial hepatectomy – a prospective analysis. Hepatogastroenterology 1998;45:2333–2338
8. Buell JF, Tranchart H, Cannon R et al: Management of benign hepatic tumors. Surg Clin North Am 2010;90:719–735
9. Buell JF, Cherqui D, Geller DA et al: The international position on laparoscopic liver surgery: The Louisville Statement, 2008. Ann Surg 2009;250:825–830
10. Nguyen KT, Gamblin TC, Geller DA: World review of laparoscopic liver resection-2,804 patients. Ann Surg 2009;250:831–841
11. Vigano L, Laurent A, Tayar C et al: The learning curve in laparoscopic liver resection: improved feasibility and reproducibility. Ann Surg 2009;250:772–782
12. Fong Y, Jarnagin W, Conlon KC et al: Hand-assisted laparoscopic liver resection: lessons from an initial experience. Arch Surg 2000;135:854–859

13. Huang MT, Wei PL, Wang W et al: A series of laparoscopic liver resections with or without HALS in patients with hepatic tumors. J Gastrointest Surg 2009;13:896–906
14. Koffron AJ, Auffenberg G, Kung R et al: Evaluation of 300 minimally invasive liver resections at a single institution: less is more. Ann Surg 2007;246:385–392
15. Buell JF, Thomas MT, Rudich S et al: Experience with more than 500 minimally invasive hepatic procedures. Ann Surg 2008;248:475–486
16. Poultsides G, Brown M, Orlando R, III: Hand-assisted laparoscopic management of liver tumors. Surg Endosc 2007;21: 1275–1279
17. Robles R, Marin C, Abellan B et al: A new approach to hand-assisted laparoscopic liver surgery. Surg Endosc 2008;22:2357–2364
18. Salit Y, Bitterman A, Lefel O et al: Hand-assisted laparoscopic surgery for liver tumors. Isr Med Assoc J 2010;12:424–427
19. Dagher I, O'Rourke N, Geller DA et al: Laparoscopic major hepatectomy: an evolution in standard of care. Ann Surg 2009;250:856–860
20. Koffron AJ, Kung R, Baker T et al: Laparoscopic-assisted right lobe donor hepatectomy. Am J Transplant 2006;6:2522–2525
21. Nitta H, Sasaki A, Fujita T et al: Laparoscopy-assisted major liver resections employing a hanging technique: the original procedure. Ann Surg 2010;251:450–453
22. Baker TB, Jay CL, Ladner DP et al: Laparoscopy-assisted and open living donor right hepatectomy: a comparative study of outcomes. Surgery 2009;146:817–823
23. Dulucq JL, Wintringer P, Stabilini C et al: Laparoscopic liver resections: a single center experience. Surg Endosc 2005; 19:886–891
24. Ito K, Ito H, Are C et al: Laparoscopic versus open liver resection: a matched-pair case control study. J Gastrointest Surg 2009;13:2276–2283
25. Mala T, Edwin B, Gladhaug I et al: A comparative study of the short-term outcome following open and laparoscopic liver resection of colorectal metastases. Surg Endosc 2002; 16:1059–1063
26. Santambrogio R, Opocher E, Ceretti AP et al: Impact of intraoperative ultrasonography in laparoscopic liver surgery. Surg Endosc 2007;21:181–188
27. Lee KF, Wong J, Cheung YS et al: Resection margin in laparoscopic hepatectomy: a comparative study between wedge resection and anatomic left lateral sectionectomy. HPB (Oxford) 2010;12:649–653
28. Zorzi D, Mullen JT, Abdalla EK et al: Comparison between hepatic wedge resection and anatomic resection for colorectal liver metastases. J Gastrointest Surg 2006;10:86–94
29. Finch RJ, Malik HZ, Hamady ZZ et al: Effect of type of resection on outcome of hepatic resection for colorectal metastases. Br J Surg 2007;94:1242–1248
30. Eltawil KM, Kidd M, Giovinazzo F et al: Differentiating the impact of anatomic and non-anatomic liver resection on early recurrence in patients with hepatocellular carcinoma. World J Surg Oncol 2010;8:43
31. Huang ZY, Chen G, Hao XY et al: Outcomes of non-anatomic liver resection for hepatocellular carcinoma in the patients with liver cirrhosis and analysis of prognostic factors. Langenbecks Arch Surg 2011;396:193–199
32. Ueno S, Kubo F, Sakoda M et al: Efficacy of anatomic resection vs nonanatomic resection for small nodular hepatocellular carcinoma based on gross classification. J Hepatobiliary Pancreat Surg 2008;15:493–500
33. Pawlik TM, Vauthey JN: Surgical margins during hepatic surgery for colorectal liver metastases: complete resection not millimeters defines outcome. Ann Surg Oncol 2008;15:677–679
34. Yamanaka N, Okamoto E, Oriyama T et al: A prediction scoring system to select the surgical treatment of liver cancer. Further refinement based on 10 years of use. Ann Surg 1994; 219:342–346
35. Chen XP, Lau WY, Huang ZY et al: Extent of liver resection for hilar cholangiocarcinoma. Br J Surg 2009;96:1167–1175
36. Konopke R, Kersting S, Bunk A et al: Colorectal liver metastasis surgery: analysis of risk factors predicting postoperative complications in relation to the extent of resection. Int J Colorectal Dis 2009;24:687–697
37. Tanaka K, Shimada H, Matsumoto C et al: Impact of the degree of liver resection on survival for patients with multiple liver metastases from colorectal cancer. World J Surg 2008; 32:2057–2069
38. Paschos KA, Bird NC: Liver regeneration and its impact on post-hepatectomy metastatic tumour recurrence. Anticancer Res 2010;30:2161–2170
39. Koh SL, Ager EI, Christophi C: Liver regeneration and tumour stimulation: implications of the renin-angiotensin system. Liver Int 2010 Nov;30(10):1414–1426
40. Harun N, Nikfarjam M, Muralidharan V et al: Liver regeneration stimulates tumor metastases. J Surg Res 2007;138:284–290
41. Gold JS, Are C, Kornprat P et al: Increased use of parenchymal-sparing surgery for bilateral liver metastases from colorectal cancer is associated with improved mortality without change in oncologic outcome: trends in treatment over time in 440 patients. Ann Surg 2008;247:109–117
42. Imamura H, Seyama Y, Kokudo N et al: Single and multiple resections of multiple hepatic metastases of colorectal origin. Surgery 2004;135:508–517
43. Torzilli G, Montorsi M, Donadon M et al: "Radical but conservative" is the main goal for ultrasonography-guided liver resection: prospective validation of this approach. J Am Coll Surg 2005;201:517–528
44. Nishio H, Hamady ZZ, Malik HZ et al: Outcome following repeat liver resection for colorectal liver metastases. Eur J Surg Oncol 2007;33:729–734
45. Antoniou A, Lovegrove RE, Tilney HS et al: Meta-analysis of clinical outcome after first and second liver resection for colorectal metastases. Surgery 2007;141:9–18
46. Gayet B, Cavaliere D, Vibert E et al: Totally laparoscopic right hepatectomy. Am J Surg 2007;194:685–689
47. Dagher I, Proske JM, Carloni A et al: Laparoscopic liver resection: results for 70 patients. Surg Endosc 2007;21:619–624
48. Sandler A, Kimura K, Soper R: Nonanatomic hepatic resection with a pledgetted suturing technique. J Pediatr Surg 2001; 36:209–212
49. Vibert E, Perniceni T, Levard H et al: Laparoscopic liver resection. Br J Surg 2006;93:67–72
50. Cho JY, Han HS, Yoon YS et al: Feasibility of laparoscopic liver resection for tumors located in the posterosuperior segments of the liver, with a special reference to overcoming current limitations on tumor location. Surgery 2008;144:32–38
51. Marvin MR, Buell JF: Laparoscopic liver surgery. Adv Surg 2009;43:159–173
52. Saidi RF, Ahad A, Escobar R et al: Comparison between staple and vessel sealing device for parynchemal transection in laparoscopic liver surgery in a swine model. HPB (Oxford) 2007;9:440–443
53. Gumbs AA, Gayet B, Gagner M: Laparoscopic liver resection: when to use the laparoscopic stapler device. HPB (Oxford) 2008;10:296–303
54. Kaneko H, Otsuka Y, Tsuchiya M et al: Application of devices for safe laparoscopic hepatectomy. HPB (Oxford) 2008; 10:219–224
55. Cho JY, Han HS, Yoon YS et al: Experiences of laparoscopic liver resection including lesions in the posterosuperior segments of the liver. Surg Endosc 2008;22:2344–2349
56. Descottes B, Lachachi F, Sodji M et al: Early experience with laparoscopic approach for solid liver tumors: initial 16 cases. Ann Surg 2000;232:641–645
57. O'Rourke N, Shaw I, Nathanson L et al: Laparoscopic resection of hepatic colorectal metastases. HPB (Oxford) 2004; 6:230–235
58. Sasaki A, Nitta H, Otsuka K et al: Ten-year experience of totally laparoscopic liver resection in a single institution. Br J Surg 2009;96:274–279
59. Topal B, Fieuws S, Aerts R et al: Laparoscopic versus open liver resection of hepatic neoplasms: comparative analysis of short-term results. Surg Endosc 2008;22:2208–2213
60. Abu HM, McPhail MJ, Zeidan B et al: Laparoscopic versus open left lateral hepatic sectionectomy: A comparative study. Eur J Surg Oncol 2008;34:1285–1288
61. Aldrighetti L, Pulitano C, Catena M et al: A prospective evaluation of laparoscopic versus open left lateral hepatic sectionectomy. J Gastrointest Surg 2008;12:457–462
62. Belli G, Limongelli P, Fantini C et al: Laparoscopic and open treatment of hepatocellular carcinoma in patients with cirrhosis. Br J Surg 2009;96:1041–1048

63. Cai XJ, Yang J, Yu H et al: Clinical study of laparoscopic versus open hepatectomy for malignant liver tumors. Surg Endosc 2008;Nov 22(11):2350–2356
64. Dagher I, Di GG, Dubrez J et al: Laparoscopic versus open right hepatectomy: a comparative study. Am J Surg 2009; 198:173–177
65. Endo Y, Ohta M, Sasaki A et al: A comparative study of the long-term outcomes after laparoscopy-assisted and open left lateral hepatectomy for hepatocellular carcinoma. Surg Laparosc Endosc Percutan Tech 2009;19:e171–e174
66. Lee KF, Cheung YS, Chong CN et al: Laparoscopic versus open hepatectomy for liver tumours: a case control study. Hong Kong Med J 2007;13:442–448
67. Mala T, Edwin B, Gladhaug I et al: A comparative study of the short-term outcome following open and laparoscopic liver resection of colorectal metastases. Surg Endosc 2002; 16:1059–1063
68. Rowe AJ, Meneghetti AT, Schumacher PA et al: Perioperative analysis of laparoscopic versus open liver resection. Surg Endosc 2009;23:1198–1203
69. Sarpel U, Hefti MM, Wisnievsky JP et al: Outcome for patients treated with laparoscopic versus open resection of hepatocellular carcinoma: case-matched analysis. Ann Surg Oncol 2009;16:1572–1577
70. Tang CN, Tai CK, Ha JP et al: Laparoscopy versus open left lateral segmentectomy for recurrent pyogenic cholangitis. Surg Endosc 2005;19:1232–1236
71. Tranchart H, Di GG, Lainas P et al: Laparoscopic resection for hepatocellular carcinoma: a matched-pair comparative study. Surg Endosc 2010;24:1170–1176
72. Troisi R, Montalti R, Smeets P et al: The value of laparoscopic liver surgery for solid benign hepatic tumors. Surg Endosc 2008;22:38–44
73. Tsinberg M, Tellioglu G, Simpfendorfer CH et al: Comparison of laparoscopic versus open liver tumor resection: a case-controlled study. Surg Endosc 2009;23:847–853
74. Vanounou T, Steel JL, Nguyen KT et al: Comparing the clinical and economic impact of laparoscopic versus open liver resection. Ann Surg Oncol 2010;17:998–1009
75. Abu HM, Underwood T, Zuccaro M et al: Short- and medium-term results of totally laparoscopic resection for colorectal liver metastases. Br J Surg 2010;97:927–933
76. Belli G, Fantini C, D'Agostino A et al: Laparoscopic versus open liver resection for hepatocellular carcinoma in patients with histologically proven cirrhosis: short- and middle-term results. Surg Endosc 2007;21:2004–2011
77. Polignano FM, Quyn AJ, de Figueiredo RS et al: Laparoscopic versus open liver segmentectomy: prospective, case-matched, intention-to-treat analysis of clinical outcomes and cost effectiveness. Surg Endosc 2008;22:2564–2570
78. Shimada M, Hashizume M, Maehara S et al: Laparoscopic hepatectomy for hepatocellular carcinoma. Surg Endosc 2001; 15:541–544
79. de Boer MT, Molenaar IQ, Porte RJ: Impact of blood loss on outcome after liver resection. Dig Surg 2007;24:259–264
80. Shiba H, Ishida Y, Wakiyama S et al: Negative impact of blood transfusion on recurrence and prognosis of hepatocellular carcinoma after hepatic resection. J Gastrointest Surg 2009; 13:1636–1642
81. Kleemann M, Hildebrand P, Birth M et al: Laparoscopic ultrasound navigation in liver surgery: technical aspects and accuracy. Surg Endosc 2006;20:726–729
82. Santambrogio R, Opocher E, Ceretti AP et al: Impact of intraoperative ultrasonography in laparoscopic liver surgery. Surg Endosc 2007;21:181–188
83. Fors D, Eiriksson K, Arvidsson D et al: Gas embolism during laparoscopic liver resection in a pig model: frequency and severity. Br J Anaesth 2010;105:282–288
84. Schmandra TC, Mierdl S, Hollander D et al: Risk of gas embolism in hand-assisted versus total laparoscopic hepatic resection. Surg Technol Int 2004;12:137–143
85. Gagner M: Small incision, big surgeon: Laparoscopic liver resection for tumors without a doubt: Comment on "Laparoscopic Liver Resection for Malignant and Benign Lesions: Ten-Year Norwegian Single-Center Experience". Arch Surg 2010;145:40–41
86. Tevar AD, Thomas MJ, Buell JF: Laparoscopic liver resection. In: Evans SRT Ed. Surgical Pitfalls: Prevention and Management. Saunders, W. B.; 2008:359–366
87. Walia A: Anesthetic management for liver resection. J Gastrointest Surg 2006;10:168–169
88. Jones RM, Moulton CE, Hardy KJ: Central venous pressure and its effect on blood loss during liver resection. Br J Surg 1998;85:1058–1060
89. Gagner M, Rogula T, Selzer D: Laparoscopic liver resection: benefits and controversies. Surg Clin North Am 2004;84:451–462
90. Abu HM, Underwood T, Taylor MG et al: Bleeding and hemostasis in laparoscopic liver surgery. Surg Endosc 2010; 24:572–577
91. Jayaraman S, Khakhar A, Yang H et al: The association between central venous pressure, pneumoperitoneum, and venous carbon dioxide embolism in laparoscopic hepatectomy. Surg Endosc 2009;23:2369–2373
92. Bryant R, Laurent A, Tayar C et al: Laparoscopic liver resection-understanding its role in current practice: the Henri Mondor Hospital experience. Ann Surg 2009;250:103–111
93. Chen HY, Juan CC, Ker CG: Laparoscopic liver surgery for patients with hepatocellular carcinoma. Ann Surg Oncol 2008; 15:800–806
94. Kazaryan AM, Pavlik M, I, Rosseland AR et al: Laparoscopic liver resection for malignant and benign lesions: ten-year Norwegian single-center experience. Arch Surg 2010;145:34–40
95. Gigot JF, Glineur D, Santiago Azagra J et al: Laparoscopic liver resection for malignant liver tumors: preliminary results of a multicenter European study. Ann Surg 2002;236:90–97
96. van der Voorf M, Heijnsdijk EA, Gouma DJ: Bowel injury as a complication of laparoscopy. Br J Surg 2004;91:1253–1258
97. Lesurtel M, Cherqui D, Laurent A et al: Laparoscopic versus open left lateral hepatic lobectomy: a case-control study. J Am Coll Surg 2003;196:236–242
98. Aldrighetti L, Guzzetti E, Ferla G: Laparoscopic hepatic left lateral sectionectomy using the LaparoEndoscopic Single Site approach: evolution of minimally invasive liver surgery. J Hepatobiliary Pancreat Sci 2011;18:103–105
99. Edwin B, Mala T, Gladhaug I et al: Liver tumors and minimally invasive surgery: a feasibility study. J Laparoendosc Adv Surg Tech A 2001;11:133–139
100. Pulitano C, Catena M, Arru M et al: Laparoscopic liver resection without portal clamping: a prospective evaluation. Surg Endosc 2008;22:2196–2200
101. Lee KF, Wong J, Ng W et al: Feasibility of liver resection without the use of the routine Pringle manoeuver: an analysis of 248 consecutive cases. HPB (Oxford) 2009;11:332–338
102. Kehlet H, Wilmore DW: Evidence-based surgical care and the evolution of fast-track surgery. Ann Surg 2008;248:189–198
103. Buell JF, Thomas MJ, Doty TC et al: An initial experience and evolution of laparoscopic hepatic resectional surgery. Surgery 2004;136:804–811
104. Shukla PJ, Barreto SG: Surgery for malignant liver tumors. J Cancer Res Ther 2009;5:154–160
105. Nguyen KT, Gamblin TC, Geller DA: Laparoscopic liver resection for cancer. Future Oncol 2008;4:661–670
106. Perry KA, Enestvedt CK, Hosack LW et al: Increased vascular endothelial growth factor transcription in residual hepatocellular carcinoma after open versus laparoscopic hepatectomy in a small animal model. Surg Endosc 2010;24:1151–1157
107. Ueda K, Turner P, Gagner M: Stress response to laparoscopic liver resection. HPB (Oxford) 2004;6:247–252
108. Vandeweyer D, Neo EL, Chen JW et al: Influence of resection margin on survival in hepatic resections for colorectal liver metastases. HPB (Oxford) 2009;11:499–504
109. Tamandl D, Herberger B, Gruenberger B et al: Influence of hepatic resection margin on recurrence and survival in intrahepatic cholangiocarcinoma. Ann Surg Oncol 2008;15:2787–2794
110. Poon RT, Fan ST, Ng IO et al: Significance of resection margin in hepatectomy for hepatocellular carcinoma: A critical reappraisal. Ann Surg 2000;231:544–551
111. Capussotti L, Muratore A, Amisano M et al: Liver resection for large-size hepatocellular carcinomas in 47 non-cirrhotic patients – no mortality and long-term survival. Hepatogastroenterology 2006;53:768–772
112. Bruix J, Sherman M: Management of hepatocellular carcinoma. Hepatology 2005;42:1208–1236
113. Bruix J, Sherman M: Management of hepatocellular carcinoma: an update. Hepatology 2010; (in Press)

114. Primrose JN: Surgery for colorectal liver metastases. Br J Cancer 2010;102:1313–1318
115. Brown RE, Bower MR, Martin RC: Hepatic resection for colorectal liver metastases. Surg Clin North Am 2010;90:839–852
116. Hasegawa K, Kokudo N: Surgical treatment of hepatocellular carcinoma. Surg Today 2009;39:833–843
117. Abrams P, Marsh JW: Current approach to hepatocellular carcinoma. Surg Clin North Am 2010;90:803–816
118. Castaing D, Vibert E, Ricca L et al: Oncologic results of laparoscopic versus open hepatectomy for colorectal liver metastases in two specialized centers. Ann Surg 2009;250:849–855
119. Kazaryan AM, Marangos IP, Røsok BI et al: Laparoscopic resection of colorectal liver metastases: surgical and long term oncologic outcome. Ann Surg 2010;252(6):1005–1012
120. Nguyen KT, Laurent A, Dagher I et al: Minimally invasive liver resection for metastatic colorectal cancer: a multi-institutional, international report of safety, feasibility, and early outcomes. Ann Surg 2009;250:842–848
121. Lai EC, Tang CN, Yang GP et al: Minimally invasive surgical treatment of hepatocellular carcinoma: long-term outcome. World J Surg 2009;33:2150–2154
122. Dagher I, Belli G, Fantini C et al: Laparoscopic hepatectomy for hepatocellular carcinoma: a European experience. J Am Coll Surg 2010;211:16–23
123. Belli G, Cioffi L, Fantini C et al: Laparoscopic redo surgery for recurrent hepatocellular carcinoma in cirrhotic patients: feasibility, safety, and results. Surg Endosc 2009;23:1807–1811
124. Shafaee Z, Kazaryan AM, Marvin MR et al: Is laparoscopic repeat hepatectomy feasible? A tri-institutional analysis. J Am Coll Surg 2011;212 (2):171–179
125. Chong PS, Finlay IG: Surgical options in the management of advanced and recurrent colorectal cancer. Surg Oncol 2007;16:25–31
126. Gallagher DJ, Kemeny N: Metastatic colorectal cancer: from improved survival to potential cure. Oncology 2010;78:237–248
127. Vigano L, Ferrero A, Lo TR et al: Liver surgery for colorectal metastases: results after 10 years of follow-up. Long-term survivors, late recurrences, and prognostic role of morbidity. Ann Surg Oncol 2008;15:2458–2464
128. Kazarian AM, Marangos IP, Rosok BI et al: [Laparoscopic resection of malignant liver tumors: immediate and long-term results]. Vopr Onkol 2010;56:172–181
129. Musunuru S, Chen H, Rajpal S et al: Metastatic neuroendocrine hepatic tumors: resection improves survival. Arch Surg 2006;141:1000–1004
130. Saxena A, Chua TC, Sarkar A et al: Progression and survival results after radical hepatic metastasectomy of indolent advanced neuroendocrine neoplasms (NENs) supports an aggressive surgical approach. Surgery 2011;149:209–220
131. Laurent A, Tayar C, Andreoletti M et al: Laparoscopic liver resection facilitates salvage liver transplantation for hepatocellular carcinoma. J Hepatobiliary Pancreat Surg 2009;16:310–314
132. Cherqui D, Soubrane O, Husson E et al: Laparoscopic living donor hepatectomy for liver transplantation in children. Lancet 2002;359:392–396
133. Soubrane O, Cherqui D, Scatton O et al: Laparoscopic left lateral sectionectomy in living donors: safety and reproducibility of the technique in a single center. Ann Surg 2006;244:815–820
134. Udwadia TE, Udwadia RT, Menon K et al: Laparoscopic surgery in the developing world. An overview of the Indian scene. Int Surg 1995;80:371–375
135. Kazaryan AM, Kuznetsov NS, Shulutko AM et al: Evaluation of endoscopic and traditional open approaches to pheochromocytoma. Surg Endosc 2004;18:937–941
136. Ellison EC, Carey LC: Lessons learned from the evolution of the laparoscopic revolution. Surg Clin North Am 2008;88:927–941, v. Review
137. Idrees K, Bartlett DL: Robotic liver surgery. Surg Clin North Am 2010;90:761–774
138. Berber E, Akyildiz HY, Aucejo F et al: Robotic versus laparoscopic resection of liver tumours. HPB (Oxford) 2010;12:583–586
139. Lamata P, Lamata F, Sojar V et al: Use of the Resection Map system as guidance during hepatectomy. Surg Endosc 2010;24(9):2327–2337
140. Yamanaka J, Okada T, Saito S et al: Minimally invasive laparoscopic liver resection: 3D MDCT simulation for preoperative planning. J Hepatobiliary Pancreat Surg 2009;16:808–815
141. Chopra SS, Schmidt SC, Eisele R et al: Initial results of MR-guided liver resection in a high-field open MRI. Surg Endosc 2010;24:2506–2512
142. Phee SJ, Ho KY, Lomanto D et al: Natural orifice transgastric endoscopic wedge hepatic resection in an experimental model using an intuitively controlled master and slave transluminal endoscopic robot (MASTER). Surg Endosc 2010;24:2293–2298

Received: November 15, 2010