The impact of laparoscopic versus open colorectal cancer surgery on subsequent laparoscopic resection of liver metastases: A multicenter study

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Background. *Laparoscopic liver surgery is expanding. Most laparoscopic liver resections for colorectal carcinoma metastases are performed subsequent to the resection of the colorectal primary, raising concerns about the feasibility and safety of advanced laparoscopic liver surgery in the context of an abdomen with possible postoperative adhesions. The aim was to compare the outcome of laparoscopic hepatectomy for colorectal metastases after open versus laparoscopic colorectal surgery.*

Methods. *This observational, multicenter study reviewed 394 patients undergoing laparoscopic minor and major liver resection for colorectal carcinoma metastases. Main outcome measures were intraoperative unfavorable incidents and short-term results in patients who had previous open versus laparoscopic colorectal cancer surgery.*

Results. *Three hundred six patients (78%) had prior open and 88 (22%) had prior laparoscopic colorectal resection. Laparoscopic major hepatectomies were undertaken in 63 (16%). Intraoperative unfavorable incidents during laparoscopic liver surgery were significantly higher among patients who had prior open colorectal surgery (26%) compared with the laparoscopic group (14%;* P = *.017). Positive resection margins and postoperative complications were not associated with the approach adopted for the resection of the primary cancer. On multivariate logistic regression analysis, intraoperative unfavorable incidents were associated significantly only with prior open colorectal surgery (odds ratio, 2.8;* P = *.006) and laparoscopic major hepatectomy (odds ratio, 2.4;* P = *.009).*

Conclusion. *Laparoscopic minor hepatectomy can be performed safely in patients who have undergone previous open colorectal surgery. Laparoscopic major hepatectomy after open colorectal surgery may be challenging. Careful risk assessment in the decision-making process is required not to compromise patient safety and to guarantee the expected benefits from the minimally invasive approach. (Surgery 2015;157:1046-54.)*

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LAPAROSCOPIC LIVER SURGERY is expanding and becoming a safe and oncologically efficient alternative to open surgery for the treatment of colorectal carcinoma liver metastasis (CRCLM).[1-4] Most hepatectomies for metastases are performed subsequent to the resection of the colorectal primary, raising concerns about the feasibility and safety of laparoscopic liver resection (LLR) in the context of an abdomen with possible postoperative adhesions.

A recent, large, population-based, national epidemiologic survey examining adhesions in laparoscopic and open colorectal resection

suggested that the minimally invasive approach results in fewer adhesion-related admissions and reoperations.[5] This study offered the first relevant evidence on the midterm benefit of laparoscopic colorectal surgery, supporting the idea that any subsequent abdominal operative procedure could be carried out in a safer environment.

Laparoscopic colorectal surgery is widely adopted in Europe, although the actual proportion of laparoscopic resections differs across centers. A recent UK study analyzing unselected consecutive data from 2 District General Hospitals with established laparoscopic colorectal practices found that more than one-half of major cases of colorectal surgery over the study period were performed by open surgery.[6] A previous 2009 survey demonstrated that although 50% of responding members of the Association of Coloproctology of Great Britain and Ireland performed laparoscopic resections, only 25% of the procedures are carried out laparoscopically.[7]

With the expansion of laparoscopic liver surgery, an increasing number of patients will potentially benefit from the minimally invasive approach for the surgical treatment of liver metastases, with advantages in terms of less pain and faster recovery compared with open opeartions.[8] To date, there are no studies analyzing whether previous open colorectal surgery may compromise feasibility and safety of LLR.

The aim of this multicenter study was to investigate the impact of open versus laparoscopic colorectal surgery on the subsequent minimally invasive surgery for CRCLM.

PATIENTS AND METHODS

This observational, multicenter study from 3 European University tertiary referral centers was conducted on prospectively collected databases of patients undergoing LLR of CRCLM through June 2013 at Oslo University Hospital-Rikshospitalet (1998–2013; Norway), the University Hospital Southampton NHS Foundation Trust (2004–2013; United Kingdom), and the Ghent University Hospital (2005–2013; Belgium).

Indications for liver resection and decisions regarding the laparoscopic approach were discussed by the hepatobiliary multidisciplinary teams, including surgeons, pathologists, oncologists, gastroenterologists, and radiologists. Patients meeting the following criteria were not considered suitable for the laparoscopic approach: patients with cirrhosis Child-Pugh categories B and C, very large fixed tumour, and tumour next to the hilum, the inferior vena cava, and the middle hepatic vein. More recently, with the improvement of laparoscopic expertise (after approximately 100 procedures), tumour next to the hilum and the inferior vena cava were deemed suitable for laparoscopy unless a vascular reconstruction was planned.

Routine blood tests, abdominal ultrasonography, abdominal CT with triphasic liver contrast enhancement, and liver-specific double contrast MRI scanning were performed and reviewed in all patients. At Oslo University Hospital-Rikshospitalet, MRI became a routine investigation from 2012. Before, MRI and/or ultrasonography with contrast were performed only in case of diagnostic uncertainty. This represents about 10% of all patients.

Four senior laparoscopic hepatobiliary-pancreatic consultants (MAH, NWP, RIT, and BE) were involved in this series and standard nomenclature was used to describe the resection performed.[9]

Exclusion criteria from final analysis were: liver resection simultaneous with colorectal cancer resection or before colorectal surgery, redo liver resection, LLR performed by "hand-assisted" or "hybrid" techniques,[10] and uncertainty regarding the approach adopted for the resection of the primary cancer. A pure laparoscopic approach[10] was pursued routinely in each center. The operative techniques for laparoscopic minor and major hepatectomy have been described in details by our groups elsewhere.[1,11-15]

The primary endpoint was the assessment of the impact of prior open versus laparoscopic colorectal surgery on intraoperative unfavorable incidents[16,17] and short-term outcomes after minor and major LLR for CRCLM. For this purpose, the group of patients undergoing LLR of CRCLM was divided in 2 subgroups according to the laparoscopic versus open approach adopted for the resection of the primary colorectal tumor. Intraoperative unfavorable incidents were classified according to the Oslo classification (Table I) on the basis of the Satava approach to surgical error evaluation.[16,17] Intraoperative unfavorable incidents were divided into 3 categories of severity: grade I, an error without consequence or near miss; grade II, an error with immediate identification and correction, also referred to as recovery; or grade III, an error that is unrecognized that leads to a significant consequence or complication.

The following data were also analyzed in the 2 groups: demographics, type of colorectal resection (right-sided colectomy and total colectomy versus left-sided colectomy, anterior resection, abdominoperineal resection, and Hartmann procedure), stage of the primary colorectal

Table I. The modified Satava approach[16] to grade unfavorable incidents *(n of patients)*

Intraoperative incidents	*Prior open colorectal surgery†*	*Prior laparoscopic colorectal surgery*
Grade I		
Incidents managed without change of operative approach and without further consequences for the patient. This includes minor injury of adherent or adjacent organs and minimal change of intraoperative tactics and cases with blood loss over normal range.*	Blood loss 1,000–1,999 mL (n = 37) Small bowel injury requiring laparoscopic direct suture (n = 7) Diaphragmatic injury requiring direct suture (n = 2) Minor pneumothorax (n = 3)	Blood loss 1,000–1,999 mL (n = 9) Small hemothorax (n = 1)
Grade II		
Incidents with further consequences for the patient, including cases requiring limited resection of intraoperatively injured organs or cases with blood loss, which is appreciably over normal range.* For laparoscopic/thoracoscopic/endoscopic surgery, it includes intraoperative incidents requiring conversion.	Blood loss ≥2,000 mL (n = 12) Conversion to open surgery (n = 23) Large bowel injury requiring conversion and direct suturing (n = 1) Gas embolism requiring conversion (n = 1)	Conversion to open surgery (n = 2)
Grade III		
Incident leading to significant consequences for patient.	Major bleeding (≥4,000 mL) requiring major transfusions/conversion/packing (n = 3)	—

*For liver resection the values of 1,000 and 2,000 mL are considered to be within normal range and to be appreciably over normal range, respectively, (corresponding with intraoperative incidents grades I and II).
†Ten patients in this group had multiple intraoperative unfavorable incidents.

carcinoma (UICC/AJCC stage I-II vs III-IV), colorectal anastomotic leak requiring surgery, prior upper abdominal surgery, early (1998–2009) versus late (2010–2013) laparoscopic liver experience established according to the median number of liver resections, American Society of Anesthesiologists (ASA) 1–2 versus 3–4 grade, synchronous (present at the time of colorectal surgery) versus metachronous (developed subsequently) liver metastasis, months between colorectal surgery and liver surgery, preoperative chemotherapy (before liver resection), minor hepatectomy versus major hepatectomy (including hemihepatectomy and extended hemihepatectomy), operation time, patients requiring intraoperative transfusion, conversion rate, microscopic positive resection margins (<1 mm tumour-free margin), duration of intensive care unit/high dependency unit stay, postoperative duration of stay, and postoperative complication rate (according to the Clavien-Dindo classification).[18] No enhanced recovery protocols after laparoscopic hepatectomy were implemented at the time of this study. In the absence of complications, discharge was determined after clinical judgment when the patient was able to tolerate solid food and had adequate pain control, and in the absence of relevant complications.

Statistical analysis. Analyses were performed using the statistical software Stata for Windows (Stata Corporation; College Station, TX). Median values and interquartile ranges were considered for continuous variables as their values' distribution was skewed. The nonparametric Mann–Whitney test was used to compare continuous variables. Chi-square or Fisher's exact tests were applied for analysis of categorical variables. Main outcome measures found to be significantly different between the open and laparoscopic colorectal groups in the general or subgroup analysis were analyzed

further for validation in multivariate models. Specifically, the association between "previous laparoscopic colorectal surgery" and "intraoperative unfavorable incidents" was analyzed using a multivariate logistic regression model (variables included in the model: gender, age, ASA, stage of colorectal carcinoma, previous open colorectal resection, right-sided colorectal resection, leak after colorectal surgery, previous upper abdominal surgery, synchronous liver metastasis, preoperative chemotherapy, laparoscopic major hepatectomy and late/early laparoscopic liver experience). The variable "postoperative duration of stay" was analyzed as a time-to-event data using the Cox proportional regression model (variables included in the model: gender, age, ASA, previous open colorectal resection, right-sided colorectal resection, leak after colorectal surgery, previous upper abdominal surgery, preoperative chemotherapy, laparoscopic major hepatectomy, intraoperative unfavorable incidents, postoperative complications, and late/early laparoscopic liver experience). The variables "intraoperative blood loss/transfusions" and "conversions" were not analyzed further as "conceptually included" in the variable "intraoperative unfavorable incident." In the multivariate models, the variable age was dichotomized according to the median value (67 years).

RESULTS

A total of 394 patients undergoing LLR of CRCLM were included in the study. The median age was 67 years (range, 32–84); 251 patients (64%) were male and 143 (36%) female.

Two hundred forty-one patients (61%) had nonanatomic and 153 (39%) had anatomic liver resections. The anatomic resections included 90 left lateral sectionectomies, 48 right hemihepatectomies, and 15 left hemihepatectomies. Laparoscopic major hepatectomies were in total 63 (16%).

One hundred sixty-four LLR (42%) were performed in Oslo, 129 (33%) in Southampton and 101 (26%) in Ghent. Laparoscopic major hepatectomies were mainly performed in Southampton (34%), compared with Ghent (11%), and Oslo (5%).

Overall, 306 patients (78%) had prior open and 88 (22%) had prior laparoscopic colorectal resection. The demographics and details of preoperative variables are summarized in Table II. Right-sided and total colectomies were significantly more common in the prior open colectomy group. Unsurprisingly, the proportion of patients who had prior laparoscopic colorectal resection was higher in the 2010–2013 time period (late experience), compared with the 1998–2009 time period (early experience).

Intraoperative and postoperative outcomes for LLR analyzed by the approach (laparoscopic vs open) adopted for the resection of the primary colorectal cancer are shown in Table II. A significantly greater proportion of intraoperative unfavorable incidents during laparoscopic liver surgery was found among patients who had prior open colorectal surgery (26%) compared with the laparoscopic group (14%). The details of intraoperative unfavorable incidents are summarized in Table I. These included significant intraoperative blood loss (>1,000 mL), conversions, small bowel injury, large bowel injury, diaphragmatic injury, pneumothorax, hemothorax, and gas embolism. Notably, no difference in intraoperative unfavorable incidents has been found among the 3 centers (22% for Southampton, 23% for Oslo, and 24% for Ghent; $P = .974$).

Mean postoperative duration of stay after LLR was 1 day shorter in patients who had prior laparoscopic colorectal surgery; however, median duration of stay was the same (4 days, Table II).

When analysis was performed by minor/major hepatectomy (Tables III and IV), intraoperative unfavorable incidents were significantly higher during laparoscopic major hepatectomy in patients who had previous open colorectal surgery (Table IV). Conversely, no difference in intraoperative unfavorable incidents was found during laparoscopic minor liver resection with respect to the previous approach for the resection of the primary cancer (Table III).

Postoperative duration of stay was shorter in patients who had previous laparoscopic compared with open colorectal resection in both in the minor (Table III) and major hepatectomy (Table IV) groups (a median of 3 vs 4 days for minor hepatectomy, and a median of 4 vs 6 days for major hepatectomy).

Overall, minor and major complication rates after LLR were 18% and 3%, respectively. Major complications included 2 postoperative deaths. Interestingly, the proportion of bile leaks was only 1% (4/394). Regarding major complications (Clavien-Dindo class IIIb, IV and V), 7 patients required intensive care unit admission for chest infection, acute respiratory distress syndrome, severe pulmonary edema, severe pulmonary embolism, sepsis caused by subphrenic collection (radiologically drained), and major intraoperative bleeding requiring packing. One patient required emergency laparotomy for washout of an infected collection. Finally, 1 patient underwent emergency laparoscopy on postoperative day 1 for persisting intraabdominal bleeding. Only 1 major

Table II. Demographic, intraoperative, and postoperative outcomes for laparoscopic liver surgery analyzed by the approach (laparoscopic vs open) adopted for the resection of the primary colorectal cancer

Variable	*Prior open colorectal resection: 306 (78%)*	*Prior laparoscopic colorectal resection: 88 (22%)*	P *value*
Age, median (IQR)	67 (59–73)	67.5 (58.5–75)	.512
Gender (M/F)	201/105	50/38	.127
Colorectal resection			.007
Right-sided colectomy	235 (77%)	55 (62.5%)	
Left-sided colectomy	71 (23%)	33 (38.5%)	
Colorectal anastomotic leak requiring surgery	16 (5%)	2 (2%)	.384
Prior upper abdominal surgery	16 (5%)	4 (5%)	1
Time			<.0001
Early experience (1998–2009)	177 (58%)	26 (30%)	
Late experience (2010–2013)	129 (42%)	62 (70%)	
ASA grade (1–2/3–4)	219 (72%)/87 (28%)	72 (82%)/16 (18%)	.054
Stage colorectal carcinoma† (I–II/III–IV)	63 (22%)/11 (13%)	223 (78%)/74 (87%)	.066
Liver metastasis (metachronous/synchronous)	177 (58%)/129 (42%)	34 (39%)/54 (61%)	.001
Months between colorectal and liver surgery	12 (6–23)	9.5 (5–17)	.017
Preoperative chemotherapy‡	174 (57%)	57 (65%)	.184
Major hepatectomy	43 (14%)	20 (23%)	.050
Operation time (min)	205 (137–290)	195 (108–300)	.227
Blood loss (mL)	250 (50–700)	235 (50–500)	.120
Patients requiring intraoperative transfusions	45 (15%)	5 (6%)	.025
Conversions	23 (8%)	2 (2%)	.085
Intraoperative unfavorable incidents	79 (26%)	12 (14%)	.017
Positive resection margins (R1)	46 (15%)	12 (14%)	.745
Complications*			.557
None	242 (79%)	73 (83%)	
Minor/moderate (grade I, II, IIIa)	55 (18%)	14 (16%)	
Major (grade IIIb, IV, V)	9 (3%)	1 (1%)	
Deaths	2 (0.07%)	0	1
ICU/HDU stay (d)	0 (0–1)	0 (0–1)	.888
Duration of stay (d)			.022
Median	4	4	
Range	3–6	2–5	
Mean	5	4	

*Clavien-Dindo classification of postoperative complications.[18]
†UICC/AJCC staging. Unknown stage in 23 patients.
‡Before laparoscopic liver resection.
1) Stage
2) Chemotherapy
3) Complications (Clavien-Dindo)
Continuous variables are expressed as median values (interquartile range [IQR]).
ASA, American Society of Anesthesiologists; *HDU*, high dependency unit; *ICU*, intensive care unit.

complication occurred in patients who had prior laparoscopic colorectal surgery (Table II). Overall, postoperative complications were not different in patients who had prior open versus laparoscopic colorectal surgery ($P = .557$).

Regarding the 2 fatalities, 1 patient died on postoperative day 1 after a laparoscopic right hepatectomy as a consequence of massive lactic acidosis. In absence of any clear cause at post mortem examination, long-term treatment with metformin has been addressed as the main precipitating factor. The second death occurred after a laparoscopic to open right hepatectomy. The patient developed a large right subphrenic collection, severe pneumonia, and respiratory arrest. Both patients had prior open colorectal surgery.

The association between prior open colorectal surgery and "intraoperative unfavorable incidents" was further analyzed in a multivariate logistic regression model. The model showed that only prior open colorectal surgery (odds ratio, 2.8; $P = .006$) and major laparoscopic hepatectomy (odds ratio, 2.4; $P = .009$) were associated independently with intraoperative unfavorable incidents (Table V).

Table III. Laparoscopic minor hepatectomies (n = 331) analyzed with respect to the previous approach adopted for the resection of the primary colorectal cancer (laparoscopic vs open)

Variable	*Prior open colorectal resection* (n = *263*)	*Prior laparoscopic colorectal resection* (n = *68*)	P *value*
Previous right-sided colectomy	61 (23%)	26 (38%)	.012
Stage colorectal carcinoma* (I–II/III–IV)	51 (21%)/196 (79%)	8 (12%)/58 (88%)	.116
Liver metastasis			<.0001
Metachronous	147 (56%)	21 (31%)	
Synchronous	116 (44%)	47 (69%)	
Operation time (min)	187 (130–263)	170 (95–235)	.064
Blood loss (mL)	220 (50–600)	200 (40–500)	.238
Patients requiring intraoperative transfusions	37 (14%)	5 (7%)	.157
Conversions	16 (6%)	2 (3%)	.580
Intraoperative unfavorable incidents	59 (22%)	12 (18%)	.391
Positive resection margins (R1)	40 (15%)	10 (15%)	.918
Complications†			.882
None	215 (82%)	57 (84%)	
Minor/moderate (grade I, II, IIIa)	42 (16%)	10 (15%)	
Major (grade IIIb, IV, V)	6 (2%)	1 (1%)	
Deaths	0	0	—
ICU/HDU stay (d)	0 (0–1)	0 (0–1)	.480
Duration of stay (d)	4 (3–6)	3 (2–5)	.025

*UICC/AJCC staging. Unknown stage in 23 patients.
†Clavien-Dindo classification of postoperative complications.[18]
Continuous variables are expressed as median values (interquartile range).
HDU, High dependency unit; *ICU*, intensive care unit.

Table IV. Laparoscopic major hepatectomies (n = 63) analyzed with respect to the previous approach adopted for the resection of the primary colorectal cancer (laparoscopic vs open)

Variable	*Prior open colorectal resection* (n = *43*)	*Prior laparoscopic colorectal resection* (n = *20*)	P *value*
Previous right-sided colectomy	10 (23%)	7 (35%)	.328
Stage colorectal carcinoma† (I-II/III-IV)	12 (31%)/27 (69%)	3 (16%)/16 (84%)	.340
Liver metastasis			.705
Metachronous	30 (70%)	13 (65%)	
Synchronous	13 (30%)	7 (35%)	
Operation time (min)	390 (290–420)	300 (225–400)	.140
Blood loss (mL)	675 (450–1,200)	375 (150–575)	.002
Patients requiring intraoperative transfusions	8 (19%)	0	.047
Conversions	7 (16%)	0	.087
Intraoperative unfavorable incidents	20 (47%)	0	<.0001
Positive resection margin (R1)	6 (14%)	2 (10%)	1
Complications*			.284
None	27 (63%)	16 (80%)	
Minor/moderate (grade I, II, IIIa)	13 (30%)	4 (20%)	
Major (grade IIIb, IV, V)	3 (7%)	0	
Deaths	2 (4.7%)	0	1
ICU/HDU stay (d)	1 (1–2)	1 (1–2)	.501
Duration of stay (d)	6 (4–9)	4 (3.5–6)	.053

*Clavien-Dindo classification of postoperative complications.[18]
†UICC/AJCC staging. Unknown stage in 23 patients.
1) Stage
2) Clavien-Dindo complications
Continuous variables are expressed as median values (interquartile range [IQR]).
HDU, High dependency unit; *ICU*, intensive care unit.

Table V. Multivariate logistic regression analysis of variables associated with intraoperative unfavorable events

Variable	*Odds ratio*	*Standard error*	P *value*	*95% CI*
Gender	1.525	0.420	.125	0.889–2.618
Age	0.642	0.168	.090	0.385–1.071
ASA	1.463	0.426	.191	0.827–2.589
Stage colorectal carcinoma* (I-II/III-IV)	1.461	0.541	.305	0.708–3.017
Previous open colorectal resection	2.831	1.068	.006	1.351–5.930
Right-sided colorectal resection	1.105	0.322	.731	0.625–1.956
Leak after colorectal surgery	2.020	1.050	.176	0.729–5.595
Previous upper abdominal surgery	1.200	0.689	.750	0.390–3.696
Synchronous liver metastasis	0.846	0.247	.568	0.477–1.501
Preoperative chemotherapy†	1.064	0.283	.814	0.632–1.793
Laparoscopic major hepatectomy	2.384	0.788	.009	1.248–4.557
Late (2010–2013) vs early (1998–2009) laparoscopic liver experience.	1.235	0.330	.814	0.632–1.793

*UICC/AJCC staging. Unknown stage in 23 patients.
†Before laparoscopic liver resection.
Gender (male vs female); age ≥ 67 vs < 67 years; ASA class 3–4 vs 1–2.
ASA, American Society of Anesthesiologists.

Prior open colorectal surgery was not associated with postoperative duration of stay on Cox multivariate regression analysis (hazard ratio, 0.81; $P = .111$). Instead, preoperative chemotherapy (hazard ratio, 0.59; $P < .0001$), laparoscopic major hepatectomy (hazard ratio, 0.58; $P < .0001$), intraoperative unfavorable incidents (hazard ratio, 0.62; $P < .0001$), postoperative complications (hazard ratio, 0.38; $P < .0001$), and late laparoscopic liver experience (hazard ratio, 0.76; $P = .014$) were associated inversely with late discharge.

DISCUSSION

An increasing number of liver centers are expected to implement LLR of CRCLM in the future with the view to optimizing postoperative recovery.[8] Most hepatectomies for CRCLM are still performed subsequent to the resection of the colorectal primary where postoperative scarring and adhesions may jeopardize the feasibility and safety of laparoscopic liver surgery and compromise the benefits of minimally invasive surgery. The question of whether the approach (open vs laparoscopic) adopted for the resection of the primary cancer may influence intraoperative results and postoperative outcomes of subsequent LLR of CRCLM has not been answered before. Our data showed that prior open colorectal surgery is associated with significantly higher intraoperative unfavorable incidents during laparoscopic major liver surgery but not increased postoperative complications.

Evidence in support of the midterm benefits of minimally invasive abdominal surgery has been published recently in a large, population-based study suggesting that laparoscopic colorectal surgery results in fewer adhesion-related admissions and reoperations compared with open surgery.[5] However, the proportion of laparoscopic colorectal cases differs significantly among centers depending on the availability of laparoscopic expertise and training opportunities. Surprisingly, recent studies have shown that open surgery is still commonly performed for colorectal cancer resections.[6,7] We reported a 22% proportion of patients with CRCLM who had prior colorectal resection laparoscopically. This proportion represents the average of several different centers referring patients with CRCLM to 3 tertiary referral centers throughout a 13-year period. Our observation is consistent with a 2009 UK survey showing that 25% of colorectal procedures are carried out laparoscopically.[7] A significant shift in practice toward laparoscopy is taking place, with authors supporting laparoscopic surgery for >80% of elective colorectal cancer cases.[19]

The Oslo classification of intraoperative unfavorable incidents based on the Satava approach of surgical error evaluation has been considered the optimal method to assess the impact of previous open colorectal surgery on LLR. Satava[16,17] proposed a simple approach to grade incidents occurring during simulation of a laparoscopic operation to evaluate the development of surgical skills of trainees. This approach is suited very well to grade any intraoperative unfavorable incidents or errors. In absence of any other "objective" way of measuring adhesions and scar formation after previous surgery, the assessment of "intraoperative unfavorable incidents" represents a reliable

indirect measure of intraabdominal hostile environment. We specifically observed the following intraoperative unfavorable incidents: significant intraoperative blood loss, conversions, small bowel injury, large bowel injury, diaphragmatic injury, pneumothorax, hemothorax, and gas embolism. The occurrence of intraoperative unfavorable incidents was associated significantly with prior open colorectal surgery and laparoscopic major hepatectomy at multivariate analysis, identifying 2 high-risk categories of patients for LLR.

Our postoperative and oncologic results compare favorably with the largest open liver surgery series reporting bile leak in 4%, perihepatic abscess in 3%, and postoperative hemorrhage in 2.7% of patients, with a postoperative mortality rate ranging from 0 to 6.6%.[20] The oncologic controversies in LLR relate to the risk of port site metastasis and the risk of surgical resection margin compromise. In this series, we did not observe port sites malignant seeding. Recent large series analyzing surgical margin status after open liver resections for CRCLMs reported positive margins between 5 and 46%.[21-27]

The uptake of laparoscopy for major hepatectomy remains slow owing to concerns over technical difficulties and safety for potential uncontrolled major vascular injuries. However, excellent results without increasing complications, readmission rate, and costs compared with open surgery have been achieved in high-volume hepatobiliary centers with expertise in advanced laparoscopic surgery.[2,28-32] Accurate patient selection for LLR remains the key to optimized outcome, and our results suggest that prior open colorectal surgery may add an element of difficulty to be considered in the selection process for laparoscopic major hepatectomy.

Several confounding factors have been analyzed to establish their potential influence on operative and postoperative variables. These factors included previous upper abdominal surgery, clinically relevant anastomotic leak after colorectal surgery, and right-sided colectomy. These factors are expected to induce scarring and adhesions in the right upper quadrant territory where liver surgery take place. Right-sided colectomy and total colectomy were significantly more common among LLR patients who had undergone previous laparoscopic surgery. However, none of these variables showed a significant association with intraoperative unfavorable events at multivariate analysis.

Patients with synchronous metastases were more common in the prior laparoscopic colorectal surgery group and unsurprisingly the interval between colorectal and liver surgery was a median of 2.5 months shorter in this group. No relevant clinical differences were expected after such a short time, and in fact multivariate analysis failed to show any association of synchronous/metachronous metastases with intraoperative unfavorable events or postoperative durations of stay.

Postoperative duration of stay after LLR was significantly longer in the open colorectal group. Although trend was confirmed both after laparoscopic minor and major hepatectomy, multivariate analysis failed to confirm the association between prior open colorectal surgery and duration of stay. Therefore, prior open colorectal surgery acted as a confounding factor in this case.

The main limitation of this study is the observational retrospective design and the relatively small number of patients undergoing laparoscopic major hepatectomy. However, this is the first large sample study providing relevant evidence on the potential impact of open colorectal surgery on subsequent LLR of CRCLM.

In conclusion, laparoscopic minor hepatectomy can be performed safely in patients who have undergone previous open colorectal surgery. Laparoscopic major hepatectomy after open colorectal surgery may be challenging. Careful risk assessment in the decision-making process is required not to compromise patient safety and to guarantee the expected benefits from the minimally invasive approach.

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