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ORIGINAL SCIENTIFIC REPORT (INCLUDING PAPERS PRESENTED AT SURGICAL CONFERENCES)

Laparoscopic Hepatectomy Versus Open Hepatectomy for the Management of Hepatocellular Carcinoma: A Comparative Study Using a Propensity Score Matching

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Abstract

Objectives The aim of this study was to compare the results between laparoscopic hepatectomy and open hepatectomy in two French university hospitals, for the management of hepatocellular carcinoma (HCC) using a propensity score matching.

Materials and methods A patient in the laparoscopic surgery group (LA) was randomly matched with another patient in the open approach group (OA) using a 1:1 allocated ratio with the nearest estimated propensity score. Matching criteria included age, presence of comorbidities, American Society of Anesthesiologists score, and resection type (major or minor). Patients of the LA group without matches were excluded. Intraoperative and postoperative data were compared in both groups. Survival was compared in both groups using the following matching criteria: number and size of lesions, alpha-fetoprotein rate, and cell differentiation.

Results From January 2012 to January 2017, a total of 447 hepatectomies were consecutively performed, 99 hepatectomies of which were performed for the management of hepatocellular carcinomas. Forty-nine resections were performed among the open approach (OA) group (49%), and 50 resections were performed among the laparoscopic surgery (LA) group (51%). Mortality rate was 2% in the LA group and 4.1% in the OA group. After propensity score matching, there was a statistical difference favorable to the LA group regarding medical complications (54.55% versus 27.27%, $p = 0.04$), and operating times were shorter ($p = 0.03$). Resection rate R0 was similar between both groups: 90.91% ($n = 30$) in the LA group and 84.85% ($n =$) in the OA group. There was no difference regarding overall survival ($p = 0.98$) and recurrence-free survival ($p = 0.42$).

Conclusions Laparoscopic liver resection for the management of HCC seems to provide the same short-term and long-term results as compared to the open approach. Laparoscopic liver resections could be considered as an alternative and become the gold standard in well-selected patients.

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Introduction

Hepatocellular carcinoma (HCC) usually develops on a cirrhotic liver (75–80% of cases), occasionally on a non-cirrhotic chronic hepatopathy and exceptionally on a healthy liver. HCC accounts for one of the most common malignant tumors in Western countries with an increased incidence in patients with chronic liver disease, especially those with HCV- and HBV-related cirrhosis [1, 2]. The global prevalence of HCC reaches 16.0/100,000 people according to age, making HCC the seventh most common cancer in 2008, ranking third in annual mortality (14.6/100,000) [3]. Yet, in spite of the success of liver transplantation (LT), surgical liver resection is still the treatment of choice for HCC because of the shortage of available organs. Liver resection can be performed in only 25–30% of patients, and the 5-year survival of untreated patients is 5% [4]. Laparoscopic liver resection is now considered as an alternative to the open approach for the management of malignant liver lesions [5, 6]. However, laparoscopic hepatectomy in cirrhotic patients remains a topic of debate because it is considered to be at risk due to disease-specific complications (portal hypertension, coagulopathy, renal failure, edematous ascitic decompensation). Indications for laparoscopic hepatectomies were defined during the first international consensus conference held in Louisville, USA [7], in 2008 and revised in Morioka [8] in 2014. The short-term and medium-term benefits of the laparoscopic approach have already been demonstrated [9, 10]; laparoscopic liver surgery remains limited to simple and peripheral resections. The aim of this study was to compare the results between laparoscopic hepatectomy and open hepatectomy in two French university hospitals, for the management of HCC using a propensity score matching (PSM).

Materials and methods

Study population

From January 2012 to January 2017, data of all patients who underwent hepatectomy for HCC in two university hospitals were prospectively collected. Indications for resection were discussed in multidisciplinary meeting without taking into consideration the laparoscopic or open approaches. Indications for laparoscopic hepatectomies were determined according to the latest recommendations [7, 8]:

- For HCC on non-cirrhotic liver (in the absence of significant fibrosis);
- For HCC on *Child A* cirrhosis with no sign of portal hypertension in anterior liver segments [11, 12].

Expert surgeons performed both laparoscopic and open surgeries. Laparoscopic resections were performed in each team by two expert surgeons with more than 5 years of expertise in hepatic laparoscopic approach at the beginning of the study (RM, PP, TP, RK). In all cases, the objective of surgical treatment was to perform a HCC macroscopic complete resection with a remaining liver volume $> 50\%$ to the total liver volume [13]. In all cases, esogastroscopy was performed, and if necessary preoperative esophageal varicose was controlled. The laparoscopic and laparotomy surgical techniques used have already been described [14–16]. An intraoperative Doppler ultrasound was systematically performed to confirm the number and size of lesions, to look for non-visible lesions, and to define the resection type: a major or a minor one.

Intraoperative and postoperative parameters

The following variables were analyzed: type of hepatic resection, use of radiofrequency, number of resected segments, operating time, pedicle clamping (number, duration, and type), conversion rate, blood loss, number of transfusions, length of hospital stay, and R0 margin rate. All postoperative complications were recorded. During the first postoperative year, patients were controlled every three months and then every six months, and they underwent a blood testing including an alpha-fetoprotein (AFP) assay, as well as an abdominal pelvic CT scan.

Definitions

Couinaud classification [17] was used for the definition of liver segmentation, and Brisbane classification in 2000 [18] was used for definition of liver resections. Comorbidity was defined as the presence of at least one of the following disorder: dyslipidemia, diabetes, arterial hypertension, history of thromboembolism disease, arteriopathy, chronic renal failure, cardiopathy, arrhythmia, and chronic bronchopneumopathy. Postoperative mortality and morbidity were assessed at 90 days following surgery according to the Clavien-Dindo classification [19]. Complications were subdivided into medical complications (including respiratory complications (atelectasis, pneumopathy), cardiovascular complications (arrhythmia, myocardial ischemia, cardiac decompression, hypertension), renal complications (acute renal failure, pyelonephritis, cystitis), liver failure, ascites occurrence), and surgical complications (including parietal infections, deep collections, biliary fistulas, bleeding, evisceration, and acute digestive ischemia). The AST to platelet ratio index (APRI) is a noninvasive score based on serum markers allowing to evaluate liver steatosis and fibrosis [20–23] and is also a useful biomarker to predict postoperative complications [24, 25].

Intraoperative care and postoperative follow-up

All patients received prophylactic antibiotic therapy as well as anticoagulation with low molecular weight heparin to prevent deep vein thrombosis. No gastrointestinal motility-stimulating drugs were used. The nasogastric catheter was removed, and food intake was resumed on postoperative day 1.

A physician saw patients daily until hospital discharge. Demographic data, preoperative risk factors, and operative variables were reported. Liver failure parameters (total and conjugated bilirubin, transaminase, alkaline phosphatase and gamma glutamyl transpeptidase, and levels of prothrombin) were measured at days 1, 3, 5, 7, and 10. A chest radiograph was performed at day 1 and day 3, and a thoracic abdominal pelvic CT scan with injection was performed only when clinical signs were observed. Abdominal drainage was not used systematically and was removed on postoperative day 3 if the fluid was serous and did not contain any bile. Patients were controlled between 4 and 6 weeks postoperatively and then at 3 months after surgery in order to complete the follow-up. In case of a malignant pathology, patients were controlled every 3 months in the first postoperative year and then every 6 months with blood tests including tumor markers and abdominal pelvic CT scan.

Propensity score matching (PSM)

All demographic and preoperative data of patients operated on using laparoscopy (LA) or the open approach (OA) were compared by means of a univariate analysis allowing to assess the comparability of both groups. Propensity score matching was used to account for clinical different between groups. The propensity score was computed using a logistic regression including the following variables: age, body mass index (BMI), presence of comorbidities, American Society of Anesthesiologists (ASA) score, and resection type. Variables included were chosen based on the results of the univariate analysis and/or the known influence of specific factors on the decision of the surgery type. The score was then used to match LA to OA (1:1) using a "nearest-neighbor matching" method [26–28]. After matching, both groups were compared according to their initial data to re-evaluate the comparability of both groups. Finally, matched groups could be compared using the different variables of interest of this study.

Recurrence and survival

The starting point was the day of the initial liver resection. Causes of death were reported. All HCC-related deaths and recurrences were estimated and used for calculating the overall recurrence-free survival. Survival analyses were estimated after matching by considering the number and size of nodules [29, 30], alpha-fetoprotein, and cell differentiation type. The analysis was performed after at least 1-year follow-up for each patient.

Statistical analysis

Categorical data were reported as absolute numbers (n) with proportion (%), and continuous variables as median with 1st and 3rd quartiles range. Groups were compared using Mann–Whitney test, Chi-square test, or Fisher's exact test as appropriate. Overall and recurrence-free survival rates were analyzed using the Kaplan–Meier method. Survival curves were compared using the log-rank test. A p value < 0.05 was considered significant. Analyses were performed by means of the 3.2.0 version R software (R Core Team, R Foundation for Statistical Computing, Vienna, Austria).

Results

Population and short-term results before matching

From January 2012 to January 2017, a total of 447 hepatectomies were consecutively performed, 99 hepatectomies of which were performed for the management of hepatocellular carcinomas. Forty-nine resections were performed using the open approach (OA) (49%) and 50 resections were performed using laparoscopy (LA) (51%). Regarding patient characteristics, both groups were comparable before matching, with the exception of the number of resected segments: fewer in the LA group as compared to the OA group [2 (2–4) vs. 1 (1–2); $p < 0.001$]; the number of nodules: fewer in the LA group as compared to the OA group [1 (1 (1–3) vs. 1; $p < 0.01$]; and the type of resection performed: more major resections were performed in the OA group (34.69%) as compared to the LA group (10.0%) ($p = 0.003$) (Table 1). Liver resection was performed in 73.7% in cirrhotic *Child A* patient ($n = 73$). Major hepatectomy was performed in 63.6% in cirrhotic patient ($n = 14$; 11 in OA group and 3 in LA group), and minor hepatectomy was performed in 76.6% in cirrhotic patient ($n = 59$; 23 in OA group and 36 in LA group). Details of resections performed are shown in Table 2. There was a significant difference before matching; there were fewer resected segments in the LA group as compared to the OA group (2(1–4) vs. 1(1–2); $p = 0.02$). Additionally, there was a statistical difference in terms of operating time (185 min (162.5–240) in the LA group versus 260 min (220–340) in the OA group; $p < 0.01$), in terms of length of hospital stay (7 days (6–10) in the LA group versus

Table 1 Demographic data and preoperative variables before and after propensity score matching for HCC

	Open liver resection ($N = 49$)	Laparoscopic liver resection ($N = 50$)	p	Open liver resection ($N = 33$)	Laparoscopic liver resection ($N = 33$)	p
Sex (M:F)	39:11	41:8	0.47	27:6	26:7	0.78
Age (yr) [median, (IQR)]	65.6 (62.7–71.5)	65.2 (58.0–72.6)	0.76	65.3 (64.3–71.5)	68.3 (61.0–73.2)	0.59
BMI (kg/m^2) [median, (IQR)]	26.4 (24.4–29.8)	26.5 (23.8–29.3)	0.29	27.0 (25.2–29.8)	27.0 (24.5–29.8)	0.38
> 30 (kg/m^2) [*n* (%)]	33 (84.0)	31 (75.0)	0.50	25 (75.6)	22 (66.7)	0.603
< 30 (kg/m^2) [*n* (%)]	16 (16,0)	19 (25.0)		8 (23.4)	11 (32.3)	
ASA I/II [*n* (%)]	25 (51.0)	26 (52.0)	0.92	15 (45.5)	15 (45.5)	1
ASA III/IV [*n* (%)]	24 (49,0)	24 (48.0)		18 (54.5)	18 (54.5)	
Comorbidity [*n* (%)]	43 (87.8)	40 (81.6)	0.29	28 (84.8)	26 (78.8)	0.15
Dyslipidemia [*n* (%)]	16 (32.6)	15 (28.0)	0.61	9 (27.3)	11 (33.3)	0.59
Diabetes [*n* (%)]	15 (30.6)	16 (32.0)	0.88	10 (30.3)	11 (33.3)	0.78
Arterial hypertension [*n* (%)]	28 (57.1)	29 (58.0)	0.93	18 (54.6)	19 (57.6)	0.80
History of thromboembolism disease [*n* (%)]	3 (6.1)	4 (8.0)	1	3 (9.1)	3 (9.1)	1
Arteriopathy [*n* (%)]	3 (6.1)	6 (12.0)	0.48	2 (6.1)	4 (12.1)	0,41
Renal failure [*n* (%)]	4 (8.2)	2 (4.0)	0.43	3 (9.1)	2 (6.1)	0.66
Cardiopathy [*n* (%)]	3 (6.1)	5 (10.0)	0.71	1 (3.0)	5 (15.2)	0.10
Arrhythmia [*n* (%)]	1 (2.0)	4 (8.0)	0.36	0 (0.0)	4 (12.1)	0.13
Chronic bronchopneumopathy [*n* (%)]	7 (14.3)	8 (16.0)	0.81	5 (15.2)	5 (15.2)	1
Liver disease [*n* (%)]						
Cirrhosis [*n* (%)]	34 (69.4)	39 (78.0)	0.33	21 (63.6)	24 (72.7)	0.44
Child A	34 (100%)	39 (100%)		21 (100%)	24 (100%)	
Steatosis [*n* (%)]	5 (10.2)	3 (6.0)		3 (9.1)	1 (3.1)	
Healthy [*n* (%)]	10 (20.4)	8 (16.0)		9 (27.3)	8 (24.2)	
Bilirubin (μmol/L)	9.0 (6.8–10.6)	7.0 (6.0–10.0)	0.50	8.0 (6.0–9.8)	7.9 (6.0–10.0)	0.89
AST (IU/L)	35.0 (24.0–57.0)	32.0 (25.5–71.0)	0.69	34.0 (23.0–61.0)	32.0 (27.0–72.0)	0.92
ALT (IU/L)	33.0 (22.0–59.0)	37.5 (25.3–61.3)	0.49	33.0 (22.0–59.0)	40.0 (25.0–62.0)	0.87
GGT (IU/L)	88.0 (41.0–272.0)	73.0 (36–169.0)	0.43	72.0 (35.0–167.0)	54.0 (30.0–169.0)	0.84
APL (IU/L)	91.0 (68.0–120.0)	83.0 (64.25–115.75)	0.49	90.0 (68.0–112.0)	72.0 (57.0–115.0)	0.88
Prothrombin ratio (% of normal)	96.0 (83.0–100.0)	92.0 (81.3–100.0)	0.24	98.0 (86.0–100.0)	92.0 (79.0–100.0)	0.26
Creatinine (μmol/L)	75.0 (63.0–82.0)	70.0 (60.2–81.0)	0.60	77.0 (61.0–83.0)	70.0 (59.0–80.0)	0.42
Albumin (g/dL)	41.0 (38.0–45.0)	41.0 (36.0–44.0)	0.33	41.0 (38.0–45.0)	41.0 (36.0–44.0)	0.30
Platelet count × 10^9/L	235.0 (168.0–291.0)	203.0 (152.0–250.0)	0.10	241.0 (180.0–305.0)	213 (159.0–250.0)	0.14
MELD score (mean, range)	8 (2–11)	7 (2–10)	0.87	7 (2–11)	7 (2–10)	0.92
Spleen size (cm) in cirrhotic patient (mean, range)	11.6 (9.3–15.2)	12.1 (9.2–14.9)	0.64	12.8 (9.3–15.2)	12.3 (9.4–14.9)	0.72
Alpha-fetoprotein (mg/mL)	4.0 (0.0–6.5)	3.5 (2.18–6.40)	0.69	4.0 (1.5–6.5)	3.5 (1.5–6.7)	0.75
Score APRI [median(range)]	0.5 (0.3–0.8)	0.3 (0.3–0.9)	0.98	0.4 (0.2–0.8)	0.4 (0.3–1.1)	0.44
Number of nodules [median(IQR)]	1.0 (1.0–3.0)	1.0 (1.0–1.0)	< 0.01	1.0 (1.0–3.0)	1.0 (1.0–1.0)	0.01
Size max. of nodule [median, (IQR)]	30.0 (20.0–52.0)	30.0 (21.0–48.7)	0.88	30.0 (20.0–48.0)	30.0 (23.0–50.0)	0.89
Type of resection [*n* (%)]						
Major [*n* (%)]	17(34.7)	5(10.00)	0.003	4 (12.1)	4 (12.1)	1
Minor [*n* (%)]	32 (65.3)	45 (90.00)		29 (87.9)	29 (87.9)	

Table 2 Operation details and outcome before and after propensity score matching for HCC

	Open liver resection [49]	Laparoscopic liver resection [50]	*p*	Open liver resection [33]	Laparoscopic liver resection [33]	*p*
Type of resection [*n* (%)]						
Bisegmentectomy [*n* (%)]	15 (30.6)	15 (30.0)	0.95	14 (42.4)	9 (27.3)	0.36
Segmentectomy [*n* (%)]	10 (20.4)	17 (34.0)	0.12	9 (27.3)	13 (39.4)	0.35
Right hepatectomy [*n* (%)]	7 (14.3)	3 (6.0)	0.20	1 (3.0)	3 (9.1)	0.48
Left hepatectomy [*n* (%)]	5 (10.20)	2 (4.0)	0.26	3 (9.1)	1 (3.0)	0.48
Extended right hepatectomy [*n* (%)]	3 (6.12)	0 (0.0)	0.11	0 (0.0)	0 (0.0)	–
Wedge resection [*n* (%)]	13 (26.5)	14 (28.0)	0.87	11 (33.3)	8 (24.2)	0.63
Mixed (resection with RF) [*n* (%)]	14 (28.6)	7 (14.0)	0.08	9 (27.3)	5 (15.2)	0.16
Nb of resected segments. median (IQR)	2.0 [1.0–4.0]	1.0 [1.0–2.0]	0.02	2.0 [0.0–2.0]	1.0 [1.0–2.0]	0.62
Operation duration (min). median (IQR)	260.0 [220.0–340.0]	185.0 [162.5–240.0]	< 0.01	250.0 [210.0–305.0]	185.0 [170.0–240.0]	0.03
Pedicle clamping. Cont/Int/No. clamp (*n*)	5/28/16	3/22/25	0.20	0/20/13	3/14/16	0.26
Duration of pedicle clamping (min). median (IQR)	28.0 [20.0–49.3]	17.0 [10.0–45.0]	0.04	40.0 [27.0–49.3]	30.0 [17.0–45.0]	0.30
Blood loss (L). median (IQR)	300.0 [30.0–500.0]	125.0 [30.0–356.0]	0.029	250.0 [30.0–450.0]	150.0 [30.0–400.0]	0.19
Blood transfusion [*n* (%)]	12 (24.49)	3 (6.0)	0.42	6 (18.18)	3 (9.09)	0.37
Hospital stay (days). median (IQR)	9.0 [7.0–13.0]	7.0 [6.0–10.0]	0.04	9.0 [7.0–12.0]	7.0 [6.0–10.0]	0.20
Surgical margins R0/R1/R2 (*n*)	42 (85.7)	47 (94.0)	0.20	28 (84.8)	30 (90.9)	0.72
Conversion rate [*n* (%)]	0 (0.0)	4 (8.0)	0.18	0 (0.0)	2 (6.1)	0.48
Complications [*n* (%)]						
Respiratory [*n* (%)]	9 (18.4)	6 (12.0)	0.38	8 (24.2)	5 (15.1)	0.50
Atelectasis [*n* (%)]	4 (8.2)	2 (4.0)	0.44	4 (12.1)	2 (6.1)	0.61
Pneumopathy [*n* (%)]	1 (2.0)	2 (4.0)	1	1 (3.03)	1 (3.03)	1
Cardiovascular [*n* (%)]	3 (6.12)	2 (4.0)	0.68	3 (9.09)	1 (3.03)	0.62
Acute renal failure [*n* (%)]	0 (0.0)	1 (2.0)	1	0 (0.0)	0 (0.0)	NA
Wound infection [*n* (%)]	1 (2.04)	2 (4.0)	1	1 (3.03)	1 (3.03)	1
Deep collection [*n* (%)]	7 (14.3)	7 (14.0)	0.97	5 (15.2)	4 (12.1)	1
Bleeding [*n* (%)]	1 (2.0)	0 (0.0)	0.49	0 (0.0)	0 (0.0)	NA
Liver failure [*n* (%)]	0 (0.0)	3 (6.0)	0.24	0 (0.0)	0 (0.0)	NA
Ascites [*n* (%)]	4 (8.16)	4 (8.0)	1	3 (9.09)	1 (3.03)	0.62
Biliary fistula [*n* (%)]	4 (8.16)	1 (2.0)	0.20	3 (9.09)	1 (3.03)	0.62
Medical complications [*n* (%)]	17 (34.7)	18 (36.7)	0.62	18 (54.6)	9 (27.3)	0.04
Surgical complications [*n* (%)]	5 (10.2)	4 (8.0)	0.74	4 (12.1)	2 (6.1)	0.68
Clavien-Dindo						
Classification 1–2	11	10	0.76	8	6	0.54
Classification 3–4	20	12	0.07	14	7	0.06
Postoperative mortality—30 [*n* (%)]	0 (0.0)	1 (2.0)	0.54	0 (0.0)	0 (0.0)	1
Postoperative mortality—60 [*n* (%)]	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Postoperative mortality—90 [*n* (%)]	2 (4.1)	0 (0.0)		1 (3.0)	0 (0.0)	

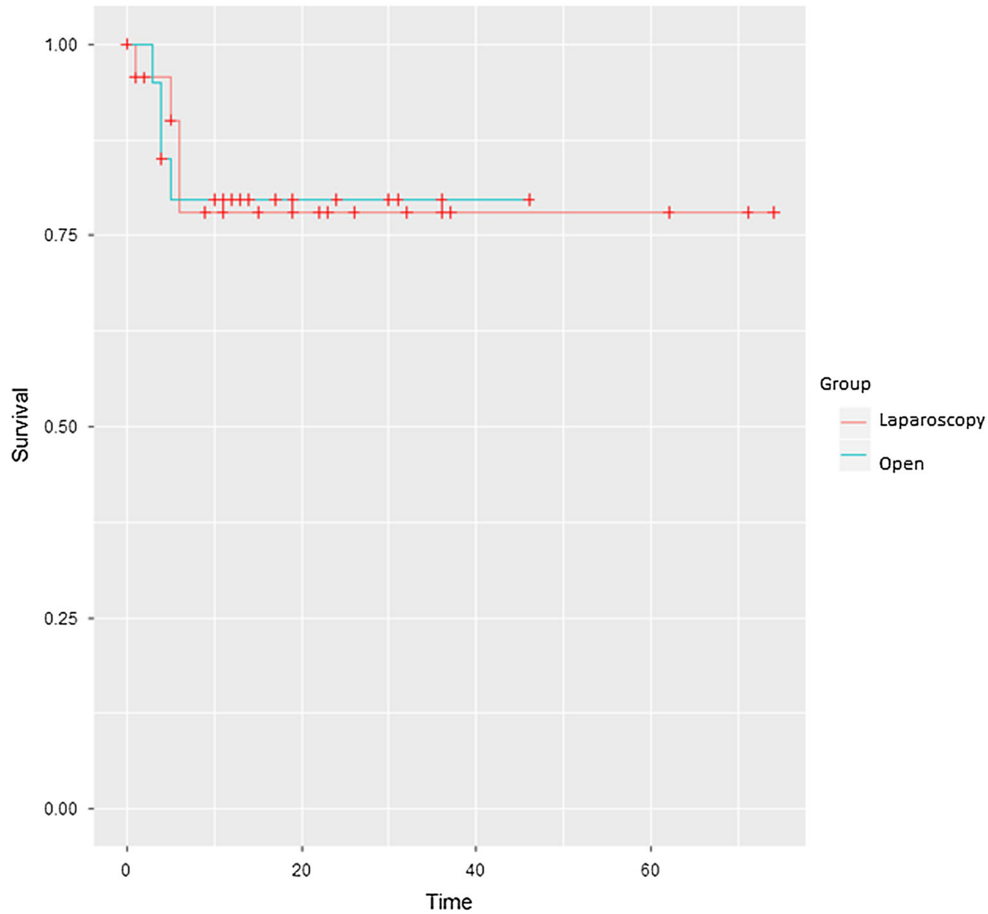

Fig. 1 Overall survival using Kaplan–Meier estimator

9 days (7–13) in the OA group; $p = 0.04$), in terms of blood loss (125 mL (30–356) in the LA group versus 300 mL (30–500); $p = 0.03$), and in terms of clamping time (17 min in the LA group (17.0–45.0)) versus 28 min in the OA group (20.0–49.3; $p < 0.04$). Resection rate R0 was 94% ($n = 47$) in the LA group versus 85.7% ($n = 42$) in the OA group, and there was no significant difference ($p = 0.20$).

The conversion rate was 12% ($n = 4$), the reason being a difficult resection in three cases and a biliary wound in one case.

The mortality rate was 0% in the OA group and 2.0% in the LA group. The reason for death was the onset of a hepatocellular failure after left lobectomy in an ASA III patient.

There was no significant difference in terms of medical complication (17% vs. 18%, $p = 0.62$).

Population and short-term results after matching

Both groups were comparable after matching, except for fewer nodules observed in the LA group as compared to the OA group (1(1–3) vs. 1(1–1); $p = 0.01$) (Table 1).

Details of resections performed are shown in Table 2. There was a statistical difference in favor of the LA group with regard to medical complications (54.55% vs. 27.27%, $p = 0.04$), and operating time was shorter ($p = 0.03$).

The conversion rate after matching was 6.6% ($n = 2$). The reasons for conversion were a difficult resection (1 case) and a biliary wound (1 case).

In addition, resection rate R0 was 90.91% ($n = 30$) in the LA group and 84.85% ($n = 28$) in the OA group ($p = 0.72$).

Overall and recurrence-free survival

Mean follow-up was 15 months in the study population before and after matching. Overall and recurrence-free survivals were calculated after re-matching using prognostic criteria. Each group comprised 24 patients, comparable concerning the number and size of nodules, alpha-fetoprotein, and cell differentiation type. At three years, overall survival rates were similar between the two groups, namely 78% in the LA group and 79% in the OA group ($p = 0.98$) (Fig. 1). There was no significant difference between 1-year recurrence-free survival and 3-year

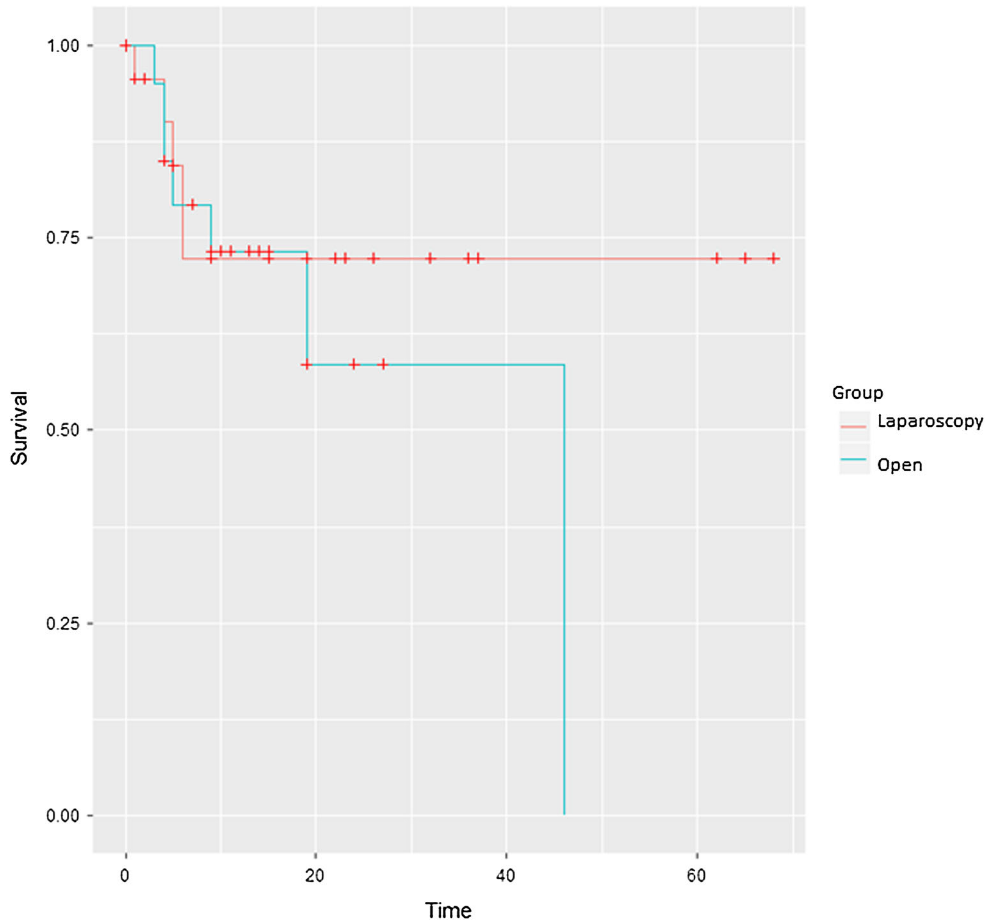

Fig. 2 Recurrence-free survival using Kaplan–Meier estimator

recurrence-free survival: 72% in LA group and 58.6% in OA group at 3 years ($p = 0.42$) (Fig. 2).

Discussion

The aim of this study was to compare short-term and survival results between laparoscopic hepatectomies and open hepatectomies performed for the management of hepatocellular carcinoma (HCC) using a propensity score matching (PSM).

There was a selection of indications for the laparoscopy group characterized by a higher number of limited and minor resections with fewer resected lesions. There was a significant difference between the two groups with a decrease in medical complications and in operating times in the LA group, after a matching and a propensity score were applied on essentials factors that influence morbidity and mortality. There was no difference in terms of overall survival and recurrence-free survival between the two groups after matching using prognostic factors and propensity score.

Although recent studies suggested the feasibility of laparoscopic hepatectomy [31–33], it remains a complex procedure, especially in cirrhotic patients [34]. Memeo et al. [16] have demonstrated the possibility of performing a laparoscopic hepatectomy in cirrhotic patients providing similar and acceptable clinical outcomes in terms of mortality and long-term survival. Today, laparoscopic hepatectomy in cirrhotic patients is increasingly considered as an acceptable approach and is frequently suggested as a first-line treatment for hepatocellular carcinoma [35] or as a bridge therapy before hepatic transplantation.

We preferably performed a resection using the open approach for lesions located in the central liver, or next to hepatic veins, and for hardly accessible lesions using laparoscopy (superior and posterior parts). Laparoscopic liver resection feasibility criteria, which are described in the literature [7, 8], were respected as follows: a lesion located in the anterior part (segments II–VI), the absence of contact with vessels, and size lower than 5 cm. This explains why more limited resections were performed using laparoscopy in this series. In order to eliminate this selection bias, this finding required a propensity score

Table 3 Review of the literature regarding laparoscopic versus open approach with propensity score for hepatocellular carcinoma

Years	Author	Group before matching OLR/LLR	Group after matching OLR/LLR	Duration of operation OLR/LLR (min). median	Blood loss OLR/LLR (mL). median	Hospital stay OLR/LLR (days)	Complications rate OLR/LLR (%)	Overall survival OLR/LLR (%)	Disease-free survival OLR/LLR (%)
2017	Xu HW et al. [52]	67/36	32/32	200 versus 255; $p < 0.001$	300 versus 325; $p = 0.186$).	9 versus 7.5; $p = 0.060$	31.3 versus 9.4; $p = 0.030$	85.7 versus 86.7; $p = 0.694$	72.9 versus 81.5; $p = 0.990$
2016	Cheung TT et al. [53]	/	110/330	255 versus 185 ; $p < 0.001$	400 versus 150; $p < 0.001$	7 versus 4; $p < 0.001$	16.4 versus 6.4; $p = 0.011$	67.4 versus 83.7; $p = 0.03$	47.9 versus 52.2; $p = 0.141$
2016	Takahara T et al. [54]	14262/929	929/929	356 versus 441; $p < 0.001$	1053 versus 865; $p < 0.001$	26.25 versus 21.37; $p < 0.001$	23.5 versus 16.4; $p < 0.001$	/	/
2016	*Sposito C* et al. [55]	226/43	43/43	/	173 versus 29; $p = 0.091$	8 versus 5; $p < 0{\cdot}001$	49 versus 19; $p = 0.004$	57.8 versus 48.8; $p = 0.802$	31.7 versus 25.5; $p = 0.990$
2016	Han DH et al. [57]	928/198	198/99	252.93 versus 285.11; $p = 0.085$	580.66 versus 389.55; $p = 0.008$	13.39 versus 8.40; $p < 0.001$	24.7 versus 13.1; $p = 0.020$	81.8 versus 89.6; $p = 0.086$	50.5 versus 40.2; $p = 0.701$
2015	Meguro M et al. [58]	200/60	35/35	312 versus 277; $p < 0.05$	420 mL versus 110 mL; $p < 0.05$	/	11 versus 8; $p > 0.05$	37.2 versus 43.8; $p = 0.954$	61.8 versus 82.1; $p = 0.672$
2015	Takahara T et al. [55]	2969/436	387/387	271 versus 294.4; $p = 0.025$	400 versus 158; $p < 0.001$	16 versus 13; $p < 0.001$	13.0 versus 6.7; $p = 0.003$	70.9 versus 76.8; $p = 0.358$	39.3 versus 40.7; $p = 0.422$
2014	Ahn KS et al. [59]	150/52	51/51	210.7 versus 202.0; $p = 0.667$	355.2 versus 350.0; $p = 0.241$	12.3 versus 8.2; $p = .004$	/	85.7 versus 80.1; $p = 0.173$	54.8 versus 67.8; $p = 0.519$
2014	Kim H et al. [60]	162/43	29/29	203.48 versus 210.48; $p = 0.681$	261.15 versus 483.85; $p = 0.065$	13.38 versus 7.69; $p < 0.001$	37.9 versus 13.8; $p = 0.118$	87.7 versus 92.2; $p = 0.267$	40.1 versus 54.0; $p = 0.929$

matching according to the main factors, which influence morbidity and mortality.

In our practice, the hepatic pedicle has been systematically controlled at the beginning of each procedure to be able to quickly perform a Pringle maneuver if necessary (56% in our series). Due to better hepatic tolerance, especially in cirrhotic patients [36–39], intermittent clamping is our standard technique (for 20 min with reperfusion periods of 10 min, except in cirrhotic patients whose clamping exceeded 15 min). We reported 3 permanent clamps, but this corresponds to very superficial resections. The combination of pedicle clamping and pneumoperitoneum pressure in laparoscopy can significantly reduce bleeding and virtually eliminate the use of continuous suction. Although all our cirrhotic patients were *Child A*, the laparoscopic approach seems to extend indications of resections, which are limited to Child–Pugh B patients with small and superficial tumors [40]. Studies demonstrated that the laparoscopic approach is associated with less blood loss and consequently requires less blood transfusion [41, 42]. This advantage can be explained by the development of laparoscopic equipment [43, 44] and by the pneumoperitoneum hemostatic effect. Most surgical teams use a 10- to 14-mmHg pneumoperitoneum pressure [45–47], providing adequate bleeding control (grade C). Tranchart et al. [48] suggested that a positive pneumoperitoneum pressure was probably the main factor that explains a decreased blood loss during a laparoscopic procedure as compared to an open liver surgery (grade C).

Additionally, the negative resection margin rate (R0) in this series is similar between the two groups (84.85% vs. 90.91%), which shows that the anatomical dissection of the intrahepatic tumor can be performed during laparoscopic resection. Laparoscopic ultrasound is a key to obtain these results. The possibility to perform an intraoperative ultrasound has been mentioned by liver surgery experts in international consensus conferences as an essential preliminary examination prior to any liver resection, regardless of the technique used [7, 8].

We report a 6.06% conversion rate, which is similar to the 5–15% range described in the literature [49–51]. The main reason for conversion was a difficult dissection and a biliary wound.

In our study, we demonstrated a significantly reduced operating time (185 min vs. 250 min, $p = 0.03$), as well as an overall decrease in medical complications (27.27% vs. 54.55%, $p = 0.04$). We did not demonstrate a significantly decreased postoperative hepatic failure as reported in the literature [52–60]. There was a reduction in the occurrence of postoperative ascites ($n = 3$ (9.09%) vs. $n = 1$ (3.03%); $p = 0.62$); this statistically insignificant result is probably due to the small number and subsequently to the lack of statistical power. As compared to the literature, we reported the APRI score since it is not only a biochemical marker of fibrosis [20–23] or a prognostic factor of HCC [25], but it is also a predictive factor of postoperative morbidity. As a matter of fact, Cheng et al. [24] demonstrated the correlation between a high APRI score and a significantly higher postoperative complication rate. The APRI score, the Child–Pugh and Meld score were similar in the both groups in our study. There are 9 studies in the literature [52–60] related to this issue, in which a propensity score is used, including 29–929 patients after matching; the results are reported in Table 3. It is worth highlighting reductions in operating time blood loss, in length of hospital stay, and in complications, which mainly account for postoperative hepatic failure in the laparoscopic hepatectomy group. Although overall survival and recurrence-free survival are similar between these studies, no specific matching was made based on prognostic criteria but was estimated on the population morbidity criteria. A second matching was made in our study using prognostic criteria (size and number of lesions, AFP rate, and cell differentiation).

In conclusion, laparoscopic liver resections for HCC seem to bring the same short-term and mid-term results as compared to the open approach and could be considered as an alternative to open surgery and become the gold standard for well-selected patients.

Compliance with ethical standards

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

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