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ORIGINAL ARTICLE

Comparison of minimally invasive and open colorectal resections for patients undergoing simultaneous R0 resection for liver metastases: a propensity score analysis

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Abstract
Purpose The role of minimally invasive colorectal resection for patients undergoing a simultaneous resection for synchronous liver metastases had not been established. This study compared the short- and long-term outcomes between minimally invasive and open colorectal resection for patients undergoing simultaneous resection for liver metastases.
Methods This study reviewed 101 consecutive patients undergoing simultaneous colorectal resection and R0 resection of synchronous liver metastases between January 2008 and December 2012. In the study, 36 consecutive patients who underwent minimally invasive colorectal resection were matched with 36 patients who had an open approach by propensity scoring. The analyzed variables included patient and tumor characteristics and short-term and long-term outcomes.
Results After propensity score matching, the two groups had similar clinicopathologic variables. No patient undergoing the minimally invasive procedure experienced conversion to the open technique. No postoperative mortality occurred in either group. In the minimally invasive group, the estimated blood loss ($P<0.007$), bowel function return time ($P<0.016$), and postoperative hospital stay ($P<0.011$) were significantly lower than those in the open group, although the operating time was significantly longer ($P<0.001$). No significant differences in postoperative complications were observed between the groups. The two groups did not differ significantly in terms of the 5-year overall survival rate (51 vs. 55 %; $P=0.794$) and disease-free survival rate (38 vs. 27 %; $P=0.860$).
Conclusion Minimally invasive colorectal resection with simultaneous resection of liver metastases has an outcome similar to open approach but some short-term advantages.

Keywords Minimally invasive surgery · Synchronous colorectal liver metastases · Survival

Introduction

Colorectal cancer (CRC) is the third most commonly diagnosed cancer in males and the second in females, with over 1.2 million new cancer cases and 608,700 deaths estimated to have occurred worldwide in 2008 [1]. Approximately 25 % of CRC patients present with synchronous colorectal liver metastases (SCRLMs) at the time of initial diagnosis [2]. Complete surgical resection of SCRLMs is now the standard of care, with recent studies reporting that approximately 25~50 % of these patients after simultaneous radical resection will survive five or more years [3–6].

Traditionally, patients undergo a two-stage procedure, with resection of the primary colorectal tumor followed by chemotherapy and subsequent liver resection. Accumulating evidence has demonstrated that, in SCRLM patients, simultaneous resection is an acceptable and safe option due to advances in the surgical technique of liver resection and enhancements in anesthesia and critical care [7, 3, 8, 9]. This strategy has potential benefits in terms of quality of life and

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cost, particularly because using contemporary chemotherapy regimens may damage the liver parenchyma and leave patients ineligible for surgical resection [7].

More recently, with advances in modern minimally invasive technology, minimally invasive colorectal resection for SCRLM patients or total one-step minimally invasive procedure has been reported [10–16]. However, most of the studies have been preliminary experiences without long-term outcomes. Most importantly, the feasibility of minimally invasive resection for SCRLMs should be guaranteed oncologically. Another important point is the selection bias that may skew the research results, whereby younger and healthier patients who are anticipated to have superior outcomes may be preferentially offered minimally invasive surgery [17].

To our knowledge, this is the first study comparing the short- and long-term outcomes of minimally invasive colorectal resection and those of open technique for patients who underwent simultaneous hepatic resection with propensity score matching (PSM).

Materials and methods

Study population and patient selection

We reviewed our prospectively constructed SCRLM database between January 2008 and December 2012 and identified 101 consecutive patients who underwent simultaneous colorectal resection and R0 resection of synchronous liver metastases. The study flow diagram is shown in Fig. 1. In the study, 36 consecutive patients who underwent minimally invasive colorectal resection were matched with 36 patients who had an open approach by PSM. Perioperative clinicopathologic data, morbidity, mortality, and oncologic outcome were compared between the minimally invasive and open groups. The study was approved by the institutional review board of Zhongshan Hospital, which is affiliated with Fudan University. All patients provided written informed consent.

All patients were assessed preoperatively with hepatic B-ultrasound; contrast-enhanced chest, abdominal, and pelvic computed tomography; and liver magnetic resonance imaging. Positron emission tomography was carried out in selected cases. Decisions regarding selection for surgery and the provision of selection for surgery were made by a multidisciplinary team that included surgeons, oncologists, radiologists, and other related professions. The criteria for selection for simultaneous surgery have been documented previously [18], including fitness for anesthesia, expected margin-negative resection of the primary disease, no unresectable extrahepatic disease, and adequate predicted volume of hepatic remnant post resection. The criteria for selection for simultaneously minimal invasive operation include the following: patients who meet all the standards of open surgery and patients medically fit to undergo pneumoperitoneum. With respect to colorectal surgery, colorectal cancer can be resected radically. Patients with obstructive colorectal cancer, with cancer perforation, or with T4 colorectal cancer were excluded. With regard to liver metastasis resection, adequate volume and functional reserve of the remnant liver are crucial; 5 cm or less in diameter located in the peripheral segments (Couinaud segments II to VI) are ideal candidates for segmental or nonanatomic resections, larger lesions are acceptable if located in the left lateral section, and the minimally invasive approach to left lateral sectionectomy should be considered standard

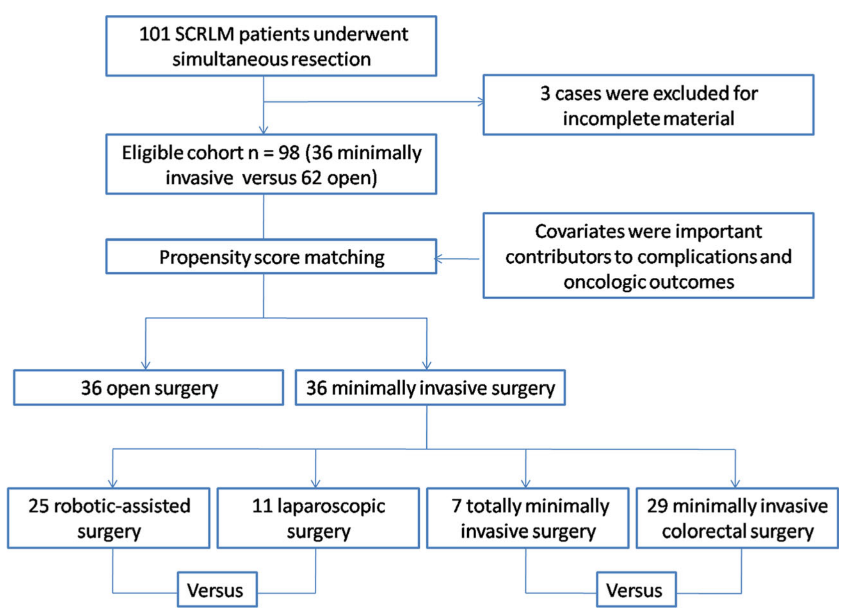


Fig. 1 Study flow diagram

practice. A minimally invasive approach may be suitable for patients with multiple lesions when the lesions can be resected with a single anatomic hepatectomy with a clear margin, but not when multiple, complicated, or bilobar procedures are required. Patients with metastatic tumors adjacent to major vessels, requiring vascular reconstruction, or located in the caudate lobe were excluded. And the final decisions regarding selections were made by the MDT, patients, and the patients' relatives.

Those who had liver cirrhosis or who underwent previous hepatic resections or ablations of the SCRLMs were all excluded from the present study. R0 resection was defined as gross complete removal of the tumor with a clear microscopic margin and without residual tumors.

Surgical technique

The technique of simultaneous, minimally invasive colorectal and hepatic resection was performed as described elsewhere [10–16]. Colorectal resection was followed by liver resection with complete abdominal exploration in all cases. An intraoperative ultrasound (IOUS) is routinely performed to assess the extent of liver disease and exclude further metastatic lesions. For all liver resections, a sling is secured around the hepatoduodenal ligament in preparation for the Pringle maneuver, although the latter procedure is not employed routinely. The parenchymal transection is performed with a combination of devices, including Tissue link, Cavitron Ultrasonic Surgical Aspirator (CUSA), and ACE ultrasonic dissector. Colorectal resection is performed adhering to the accepted principles of minimally invasive colorectal surgery—namely, medial to lateral dissection, high ligation of feeding vessels, no-touch technique, and total mesorectal excision (TME) for left-sided resections.

Data collection

Standard demographic and clinicopathologic data for each patient and data on tumor characteristics of the primary CRC and liver metastasis was collected. Postoperative mortality was defined as death within 30 days after surgery. Postoperative complications were defined as adverse events that occurred within 30 days after surgery. Complications were diagnosed according to patients' symptoms, with the aid of laboratory and radiological evaluation to confirm clinical suspicions. Diagnosis of anastomotic or bile leakage was based on clinical suspicion, resulting in contrast radiography (radiograph or computed tomographic scan). Signs of clinical leakage included abdominal pain or fever and discharge of pus or bowel contents through the indwelling drain. The follow-up regimen included routine computed tomography of the chest, abdomen, and pelvis; liver magnetic resonance imaging; and regular colonoscopic surveillance. Disease recurrence was recorded based on clinical, radiological, or endoscopic findings at the time of diagnosis. Dates of last follow-up and vital statuses were collected for all patients. Overall survival (OS) was calculated from the day of treatment to the date of death by CRC or the last follow-up. Disease-free survival (DFS) was measured from the date of surgery until the date of documented disease recurrence. Prospective data collection and data quality management were performed by an independent full-time research assistant.

Propensity score matching

The PSM approach for the present study proceeded in two steps. First, the propensity score of each patient who underwent minimally invasive surgery was calculated based on a logistic regression model, including age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) score, primary tumor location, largest size of primary tumor, histological type, differentiation, depth of primary tumor invasion, primary node status, vascular invasion, largest size of liver metastasis, no. of liver metastases, tumor distribution, preoperative median CEA, primary tumor operation, liver operation, and chemotherapy regimen. These variables were chosen empirically based on factors we believed to be important contributors to the operative difficulty risk of complications/mortalities and differences in oncologic outcomes. In the second step, the minimally invasive surgery patients were matched 1:1 based on the closest propensity score to open surgery patients. The process of matching based on the propensity score yields a matched sample (1:1) that is better balanced in the covariates included in the selection model [19–21].

Statistical analysis

PSM was performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC, USA). The other statistical analyses after PSM were performed using SPSS version 16.0 (SPSS, Chicago, IL, USA). Summary statistics were obtained using established methods and were represented as percentages or mean values with standard deviation. After PSM, the baseline characteristics and perioperative and long-term oncologic outcomes of the matched data were compared using t test for continuous variables and chi-square analysis or Fisher's exact test for categorical variables. Survival rates were estimated using the Kaplan-Meier method, and differences in survival curves were compared using the log-rank test. All P values were two-sided, and a P value less than 0.05 was deemed to indicate statistical significance.

Results

Patients, tumor, and operative details

During the study period, a total of 101 patients underwent simultaneous R0 resection of SCRLMs, no extrahepatic metastases occurred in any case, and three patients were excluded for incomplete material. Among the remaining 98 SCRLM patients, 36 minimally invasive colorectal resections were propensity score-matched 1:1 to the 62 open resections. The demographic and pathologic data for 72 matched patients are summarized in Table 1. The patients who underwent minimally invasive and open resection were well matched in terms of age, gender, BMI, ASA score, primary tumor location, primary tumor size, tumor histological type, tumor differentiation, depth of primary tumor invasion, primary nodal status,

Table 1 Comparative analysis of clinicopathological characteristics between the minimally invasive and open surgery groups

Variable		Minimally invasive (n=36)	Open (n=36)	P value
Age (years)		57.5±7.3	57.4±10.4	0.979
Gender, n (%)	Male	19 (52.8)	21 (58.3)	0.635
	Female	17 (47.2)	15 (41.7)	
BMI (kg/m^2)		21.1±1.8	21.2±1.6	0.868
ASA score, n (%)	1	32 (88.9)	31 (86.1)	1.000
	2	4 (11.1)	5 (13.9)	
Primary tumor location, n (%)	Colon	18 (50.0)	19 (52.8)	0.814
	Rectum	18 (50.0)	17 (47.2)	
Largest size of primary tumor (cm)		5.6±1.6	5.7±1.9	0.816
Histological type, n (%)	Adenocarcinoma	33 (91.7)	32 (88.9)	1.000
	Mucinous adenocarcinoma	3 (8.3)	4 (11.1)	
Differentiation, n (%)	Well, moderate	19 (52.8)	19 (52.8)	1.000
	Poor and other	17 (47.2)	17 (47.2)	
Depth of primary tumor invasion, n (%)	T1/T2	1 (2.8)	2 (5.6)	1.000
	T3/T4	35 (97.2)	34 (94.4)	
Primary node status, n (%)	Negative	17 (47.2)	14 (38.9)	0.475
	Positive	19 (52.8)	22 (61.1)	
Vascular invasion, n (%)	Negative	26 (72.2)	26 (72.2)	1.000
	Positive	10 (27.8)	10 (27.8)	
Largest size of LM (cm)		3.7±2.0	4.2±2.2	0.308
No. of LMs		1.9±1.2	2.1±1.0	0.449
Tumor distribution, n (%)	Unilobar	29 (80.6)	26 (72.2)	0.405
	Bilobar	7 (19.4)	10 (27.8)	
Preoperative median CEA (ng/ml), n (%)	≤5	11 (30.6)	9 (25.0)	0.599
	>5	25 (69.4)	27 (75.0)	
Primary tumor operation, n (%)	Left hemicolectomy	2 (5.6)	3 (8.3)	0.807
	Sigmoid colectomy	16 (44.4)	16 (44.4)	
	Anterior resection	15 (41.7)	12 (33.3)	
	Abdominoperineal resection	3 (8.3)	5 (14.0)	
Liver operation, n (%)	Wedge resections	17 (47.2)	14 (38.9)	0.819
	Segmentectomy	14 (38.9)	16 (44.4)	
	Hemihepatectomy	5 (13.9)	6 (16.7)	
Preoperative chemotherapy, n (%)	FOLFOX	6 (16.7)	11 (30.6)	0.618
	FOLFIRI	2 (5.6)	2 (5.6)	
Postoperative chemotherapy, n (%)	FOLFOX	18 (50.0)	20 (55.6)	0.866
	FOLFIRI	11 (30.6)	11 (30.6)	
	Xelox	4 (11.1)	4 (11.1)	
	Other	3 (8.3)	1 (2.7)	

ASA American Society of Anesthesiologists, *BMI* body mass index, *LMs* liver metastases

Table 2 Comparative short-term outcomes between the minimally invasive and open surgery groups

Variable	Minimally invasive (n=36)	Open (n=36)	P value
Operating time (min)	317.5±47.4	251.7±49.6	<0.001
Estimated blood loss (ml)	278.1±173.3	382.5±145.6	0.007
Bowel movement (days)	3.3±1.4	4.0±1.1	0.016
Hospital stay (days)	7.4±1.6	9.0±3.5	0.011
Mortality	0	0	–
Morbidity	9	11	0.599
Small bowel obstruction	1	2	
Anastomotic leakage	0	1	
Intraabdominal abscess	2	2	
Intrahepatic abscess	1	1	
Bile leakage	1	0	
Wound infection	1	2	
Pneumonia	2	2	
Pleural effusion	1	1	

presence of vascular invasion, largest hepatic lesion, no. of liver metastases, bilobar metastatic distribution, preoperative serum CEA level, and perioperative chemotherapy regimen.

Details of the operative data are also shown in Table 1. No in-hospital or 30-day mortality occurred in the two groups, and no patient who underwent a minimally invasive procedure experienced conversion to the open technique. In the two groups, the primary tumor resection techniques mostly used were sigmoid colectomy and anterior resection, the liver surgery techniques mostly used were wedge resection and segmentectomy, the perioperative chemotherapy regimens mostly used were FOLFOX and FOLFIRI, and all these variables were not significantly different between the two groups.

Short-term outcomes

Between the minimally invasive and open resection groups, the estimated blood loss (P=0.007), bowel function return time (P=0.016), and postoperative hospital stays (P=0.011) were significantly lower in the open group, although the operating time was significantly longer (P<0.001). No postoperative mortality occurred in either group. The postoperative complications were similar in the minimally invasive and open groups (22 vs. 33 %; P=0.293), and all were successfully treated medically or by percutaneous drainage. Details of the short-term outcomes are given in Table 2.

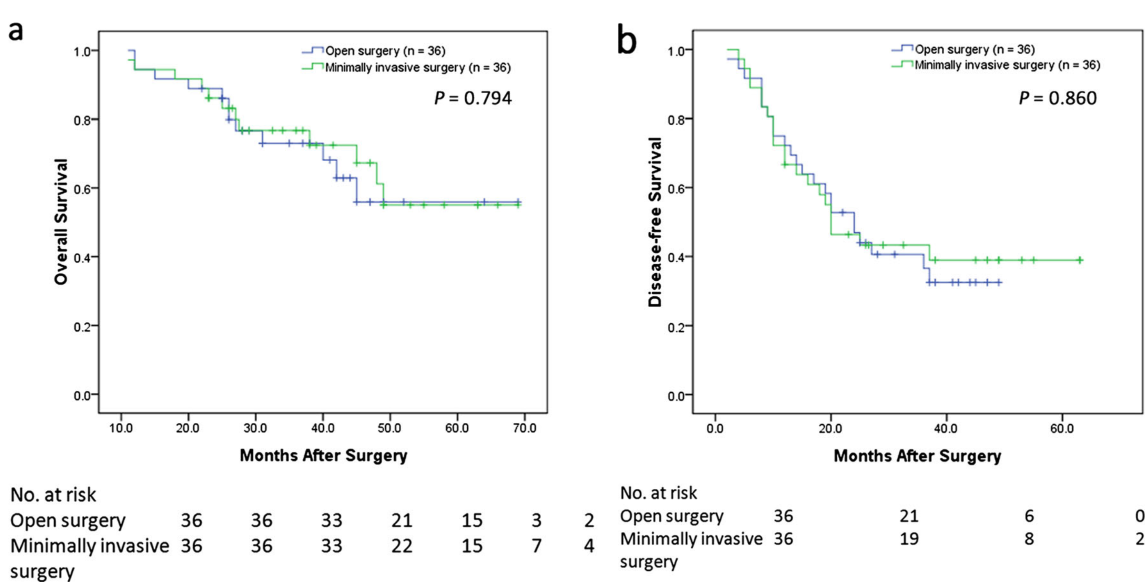


Fig. 2 Kaplan-Meier estimates of survival between the minimally invasive colorectal resection and open surgery groups. Kaplan-Meier analysis of OS (P=0.794) (**a**) and DFS (P=0.860) (**b**) between the minimally invasive and open surgery groups

Long-term outcomes

Follow-up information until October 2013 was obtained in these 72 patients, and the median follow-up period was 43.4 months (range, 11–69 months). The 5-year OS is 51 %, and the 5-year DFS is 33 %. At the last follow-up, 24 (33.3 %) patients had died; 44 (61.1 %) patients had tumor recurrence, 28 (38.9 %) had recurrence in the liver only, 6 (8.3 %) in the lung only, and 10 (13.9 %) in other sites. Using the Kaplan-Meier method, the two groups did not differ significantly in terms of the 5-year OS rate (P=0.794) and DFS rate (P=0.860) (Fig. 2).

Table 3 Comparative analysis of clinicopathological characteristics between the robotic-assisted and laparoscopic surgery groups

Variable		Robotic assisted (*n*=25)	Laparoscopic (*n*=11)	*P* value
Age (years)		58.5±7.6	55.3±6.3	0.230
Gender, *n* (%)	Male	13 (52.0)	6 (54.5)	0.888
	Female	12 (48.0)	5 (45.5)	
BMI (kg/m^2)		21.1±1.8	21.1±1.9	0.988
ASA score, *n* (%)	1	24 (96.0)	8 (72.7)	0.076
	2	1 (4.0)	3 (27.3)	
Primary tumor location, *n* (%)	Colon	13 (52.0)	5 (45.5)	0.717
	Rectum	12 (48.0)	6 (54.5)	
Largest size of primary tumor (cm)		5.5±1.7	5.8±1.5	0.619
Histological type, *n* (%)	Adenocarcinoma	24 (96.0)	9 (81.8)	0.216
	Mucinous adenocarcinoma	1 (4.0)	2 (18.2)	
Differentiation, *n* (%)	Well, moderate	14 (56.0)	5 (45.5)	0.559
	Poor and other	11 (44.0)	6 (55.5)	
Depth of primary tumor invasion, *n* (%)	T1/T2	0 (0.0)	1 (9.1)	0.306
	T3/T4	25 (100.0)	10 (90.9)	
Primary node status, *n* (%)	Negative	10 (40.0)	7 (63.6)	0.191
	Positive	15 (60.0)	4 (36.4)	
Vascular invasion, *n* (%)	Negative	19 (76.0)	7 (63.6)	0.454
	Positive	6 (24.0)	4 (36.4)	
Largest size of LM (cm)		4.1±2.1	3.0±1.5	0.142
No. of LMs		1.9±1.2	2.0±1.2	0.779
Tumor distribution, *n* (%)	Unilobar	18 (72.0)	11 (100.0)	0.076
	Bilobar	7 (28.0)	0 (0.0)	
Median CEA (ng/ml), *n* (%)	≤5	6 (24.0)	5 (45.5)	0.252
	>5	19 (76.0)	6 (55.5)	
Primary tumor operation, *n* (%)	Left hemicolectomy	0 (0)	2 (18.2)	0.071
	Sigmoid colectomy	12 (48.0)	4 (36.4)	
	Anterior resection	12 (48.0)	3 (27.2)	
	Abdominoperineal resection	1 (4.0)	2 (18.2)	
Liver operation, *n* (%)	Wedge resections	11 (44.0)	6 (54.5)	0.606
	Segmentectomy	11 (44.0)	3 (27.3)	
	Hemihepatectomy	3 (12.0)	2 (18.2)	
Preoperative chemotherapy, *n* (%)	FOLFOX	3 (8.3)	3 (8.3)	0.464
	FOLFIRI	2 (5.6)	0 (0)	
Postoperative chemotherapy, *n* (%)	FOLFOX	12 (48.0)	6 (54.5)	0.079
	FOLFIRI	10 (40.0)	1 (9.1)	
	Xelox	1 (4.0)	3 (27.3)	
	Other	2 (8.0)	1 (9.1)	

ASA American Society of Anesthesiologists, *BMI* body mass index, *LMs* liver metastases

Table 4 Comparative short-term outcomes between the robotic-assisted and laparoscopic surgery groups

Variable	Robotic assisted (*n*=25)	Laparoscopic (*n*=11)	*P* value
Operating time (min)	318.8±44.1	314.6±56.3	0.808
Estimated blood loss (ml)	270.8±161.6	294.6±205.1	0.711
Bowel movement (days)	3.4±1.2	3.0±1.8	0.396
Hospital stay (days)	7.5±1.7	7.0±1.3	0.368
Mortality	0	0	–
Morbidity	6	3	1.000
Small bowel obstruction	1	0	
Anastomotic leakage	0	0	
Intraabdominal abscess	1	1	
Intrahepatic abscess	1	0	
Bile leakage	1	0	
Wound infection	0	1	
Pneumonia	1	1	
Pleural effusion	1	0	

Comparison of different minimally invasive surgery techniques

Of the 36 patients who underwent minimally invasive colorectal resection, 25 underwent robotic-assisted resection and 11 underwent laparoscopic resection. The demographic and pathologic variables (Table 3), short-term outcomes (Table 4), and OS and DFS outcomes were not significantly different between the two groups (*P*=0.871; *P*=0.834, respectively) (Fig. 3).

Seven of 36 patients who underwent minimally invasive colorectal resection had a total one-step minimally invasive procedure: 5 underwent robotic-assisted hepatic resection and 2 underwent laparoscopic hepatic resection; 29 had an open liver resection. Except the operating time being approximately 1 h longer of the total one-step minimally invasive procedure, the demographic and pathologic variables (Table 5), short-term outcomes (Table 6), and long-term outcomes were not significantly different between the two groups (*P*=0.794; *P*=0.860, respectively) (Fig. 4).

Discussion

In past decades, the strategy of delayed hepatectomy gained popularity and has been established as the standard surgical practice. Some authors hold the view that simultaneous

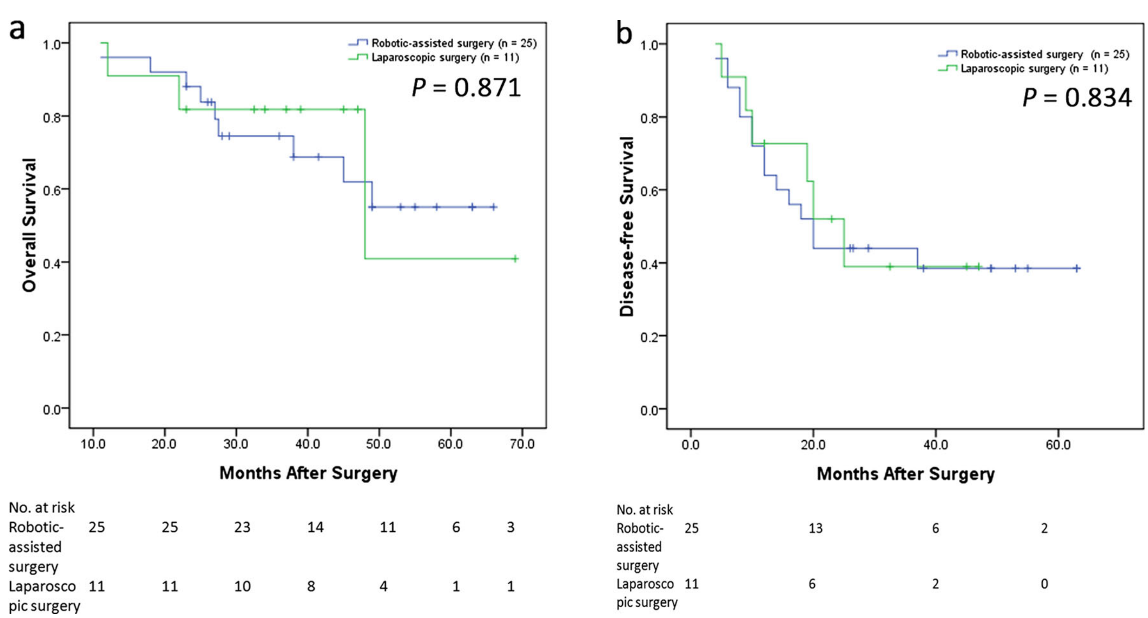


Fig. 3 Kaplan-Meier estimates of survival between the robotic-assisted and laparoscopic resection groups. Kaplan-Meier analysis of OS (*P*=0.871) (**a**) and DFS (*P*=0.834) (**b**) between the robotic-assisted and laparoscopic resection groups

Table 5 Comparative analysis of clinicopathological characteristics between the minimally invasive CRC resection and total one-step minimally invasive resection groups

Variable		Minimally invasive CRC (*n*=29)	Total one-step minimally invasive (*n*=7)	*P* value
Age (years)		57.0±7.9	59.6±3.4	0.411
Gender, *n* (%)	Male	14 (48.3)	5 (71.4)	0.408
	Female	15 (51.7)	2 (28.6)	
BMI (kg/m^2)		20.9±1.7	21.9±2.2	0.206
ASA score, *n* (%)	1	26 (89.7)	6 (85.7)	1.000
	2	3 (10.3)	1 (14.3)	
Primary tumor location, *n* (%)	Colon	15 (51.7)	3 (42.9)	1.000
	Rectum	14 (48.3)	4 (57.1)	
Largest size of primary tumor (cm)		5.7±1.7	5.3±1.1	0.563
Histological type, *n* (%)	Adenocarcinoma	27 (93.1)	6 (85.7)	0.488
	Mucinous adenocarcinoma	2 (6.9)	1 (14.3)	
Differentiation, *n* (%)	Well, moderate	15 (51.7)	4 (57.1)	1.000
	Poor and other	14 (48.3)	3 (42.9)	
Depth of primary tumor invasion, *n* (%)	T1/T2	1 (3.4)	0 (0.0)	1.000
	T3/T4	28 (96.6)	7 (100.0)	
Primary node status, *n* (%)	Negative	14 (48.3)	3 (42.9)	1.000
	Positive	15 (51.7)	4 (57.1)	
Vascular invasion, *n* (%)	Negative	20 (69.0)	6 (85.7)	0.645
	Positive	9 (31.0)	1 (14.3)	
Largest size of LM (cm)		3.8±2.0	3.3±1.8	0.511
No. of LMs		1.9±1.2	1.9±0.9	0.882
Tumor distribution, *n* (%)	Unilobar	22 (75.9)	7 (100.0)	0.303
	Bilobar	7 (24.1)	0 (0.0)	
Median CEA (ng/ml), *n* (%)	≤5	9 (31.0)	2 (28.6)	1.000
	>5	20 (69.0)	5 (71.4)	
Primary tumor operation, *n* (%)	Left hemicolectomy	1 (3.4)	1 (14.3)	0.384
	Sigmoid colectomy	13 (44.8)	3 (42.8)	
	Anterior resection	13 (44.8)	2 (28.6)	
	Abdominoperineal resection	2 (7.0)	1 (14.3)	
Liver operation, *n* (%)	Wedge resections	13 (44.8)	4 (57.1)	0.719
	Segmentectomy	11 (37.9)	3 (42.9)	
	Hemihepatectomy	5 (17.3)	0 (0.0)	
Preoperative chemotherapy, *n* (%)	FOLFOX	5 (13.9)	1 (2.8)	1.000
	FOLFIRI	2 (5.6)	0 (0)	
Chemotherapy regimen	FOLFOX	14 (48.4)	4 (57.2)	1.000
	FOLFIRI	9 (31.0)	2 (28.6)	
	Xelox	3 (10.3)	1 (14.2)	
	Other	3 (10.3)	0 (0.0)	

ASA American Society of Anesthesiologists, *BMI* body mass index, *LMs* liver metastases

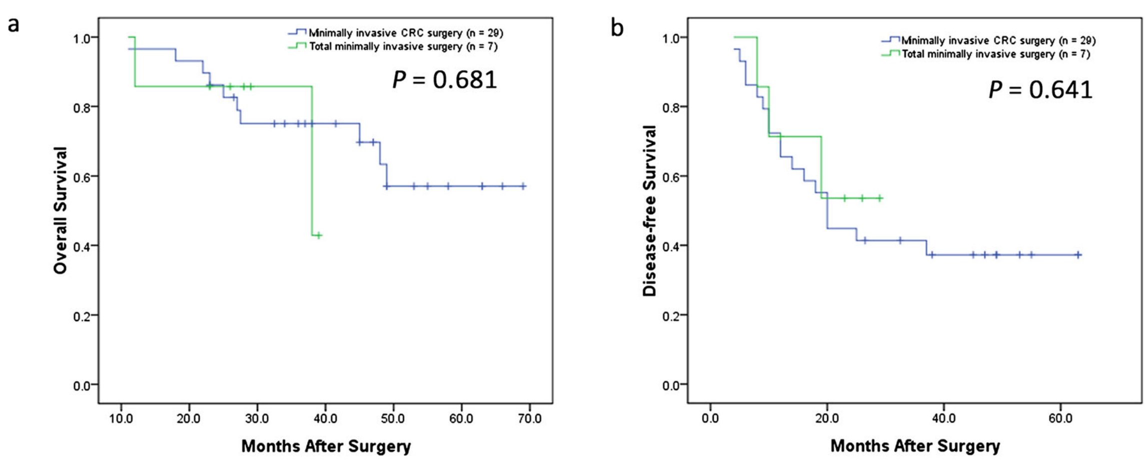
resections may increase the rate of postoperative complications [22]. Given that the morbidity and mortality associated with hepatectomy have decreased substantially over the past 20 years, the classic paradigm of a staged operation for SCRLMs has been questioned. Specifically, given the improved feasibility and safety of performing major hepatic resections, some investigators have suggested that the simultaneous approach to SCRLMs may be preferable. Other large studies, including meta-analyses, have also shown that simultaneous resections are not associated with increased rates of hepatic or colon complications compared with delayed resection [3, 7–9, 23]. Furthermore, as demonstrated by some large studies and a meta-analysis of the timing of hepatectomy for patients with SCRLMs, the long-term outcomes of OS and

Table 6 Comparative short-term outcomes between the minimally invasive CRC resection and total one-step minimally invasive resection groups

Variable	Minimally invasive CRC (n=29)	Total one-step minimally invasive (n=7)	P value
Operating time (min)	306.9±38.6	361.4±57.6	0.005
Estimated blood loss (ml)	279.3±184.6	272.8±127.2	0.931
Bowel movement (days)	3.2±1.4	3.6±1.5	0.586
Hospital stay (days)	7.2±0.8	7.9±3.3	0.359
Mortality	0	0	–
Morbidity	7	2	1.000
Small bowel obstruction	1	0	
Anastomotic leakage	0	0	
Intraabdominal abscess	2	0	
Intrahepatic abscess	1	0	
Bile leakage	1	0	
Wound infection	1	0	
Pneumonia	1	1	
Pleural effusion	0	1	

DFS are similar between the simultaneous and delayed resection groups [7, 3, 8, 9]. In our study, the 5-year OS is 51 %, agreeing with recent studies reporting that approximately 25~50 % of these patients after simultaneous radical resection will survive five or more years [3–6].

Minimally invasive colorectomy and hepatectomy are realizable options for patients with colorectal and liver cancer, respectively. The minimally invasive approach has several well-known advantages over conventional laparotomy, including less pain, an earlier recovery, and a shorter hospital stay. The results of large randomized studies about colorectal cancer have shown that the long-term outcome after minimally invasive surgery is equivalent to that after open surgery [24–26]. With respect to hepatic cancer, the data show that minimally invasive hepatic resection is as effective as the open counterpart to obtain tumor-free resection margins [27–29]. But for the SCRLMs, very few studies have focused on it. In our study, the estimated blood loss, bowel function return time, and postoperative hospital stay of SCRLM patients with the minimally invasive surgery were significantly lower than those with open resection. All these factors may positively influence the outcome in cancer patients, allowing early access to adjuvant chemotherapy, better acceptance of repeated operations, and preservation of immune function [28, 29]. We also found that the two groups did not differ significantly in terms of the 5-year overall survival rate and disease-free



(a) No. at risk

Robotic-assisted surgery	29	29	27	20	15	7	4
Laparoscopic surgery	7	7	6	2	0	0	0

(b) No. at risk

Robotic-assisted surgery	29	16	8	2
Laparoscopic surgery	7	3	0	0

Fig. 4 Kaplan-Meier estimates of survival between the minimally invasive CRC resection and total one-step minimally invasive resection groups. Kaplan-Meier analysis of OS (P=0.681) (**a**) and DFS (P=0.641) (**b**) between the minimally invasive CRC resection and total minimally invasive resection groups

survival rate. The data may lead to the reasonable conclusion that minimally invasive simultaneous colorectal and/or hepatic resection could be a valid therapeutic option for SCRLM patients, but this is a retrospective study with small sample, it should be validated in randomized controlled trials with large sample.

Minimally invasive resection of primary colorectal cancer or total one-step minimally invasive procedure for SCRLM patients has been reported for initial experiences with no long-term outcomes [10–14]. Our study bridged this gap by showing no differences in terms of postoperative complications. However, the advantages observed are noteworthy: the estimated blood loss after minimally invasive surgery was significantly lower than that using the open approach. Furthermore, the bowel function return and hospital stay were significantly shorter than those with the open surgery. All these short-term outcomes are comparable with the time reported by others [11, 12, 14, 15]. Particularly important, the 5-year OS was 51 % and the 5-year DFS was 33 % in our study, values that were not significantly different from the open surgery and that complied with recent studies for SCRLMs [3–6]. All the results demonstrate that the technique of minimally invasive colorectal resection or total one-step minimally invasive procedure is both feasible and safe. However, it needs further and more research to validate.

In our hospital, robotic-assisted colorectal and liver resections with the da Vinci Si Surgical System or laparoscopic resection were extensively used. Of the 36 patients who underwent minimally invasive resection, all of the variables, including OS and DFS, were not significantly different between the 25 robotic-assisted resections and 11 laparoscopic resections. However, a major drawback to robotic-assisted surgery is the high cost involved, but robotic total mesorectal excision may allow for better preservation of urinary and sexual functions [30] and has low conversion rates and favorable morbidity [31]. Of the seven patients who had a total one-step minimally invasive procedure, excluding the operating time being approximately 1 h longer than minimally invasive colorectal resection, other short-term outcomes were not significantly different. However, the obvious benefit is that the procedure avoids the long incision for open hepatic resection and early recovery, allowing early access to adjuvant chemotherapy, as the longer operating time in the minimally invasive resection could be shortened by the progress of surgical skills.

Planning and carrying out a minimally invasive approach in these CRLM patients are determined by the severity of the disease, economic burden, and consent of the patients. Patients may be unwilling to be randomized to an open operation when the existing data suggest overwhelmingly that minimally invasive resection is a choice. So, it is difficult to perform a randomized controlled trial of minimally invasive versus open resection. Thus, comparisons will be limited to observational studies that are potentially confounded by selection bias that may skew the research results, whereby younger and healthier patients who are anticipated to have superior outcomes may be preferentially offered minimally invasive surgery [17]. So, we applied PSM in our study. PSM has become increasingly used in observational studies in medical research to reduce the impact of treatment-selection bias in the comparison of treatment to a nonrandomized control using observational data [19–21] since it was first introduced by Rosenbaum and Rubin in 1983 [32].

In conclusion, despite the limitations of our study resulting from its small sample size, based on our preliminary data, we conclude that minimally invasive colorectal resection with simultaneous resection of liver metastases has outcomes similar to those for the open approach but with some short-term advantages. It may be an alternative to open surgery for surgeons experienced with the minimally invasive approach in both colorectal and liver surgery.

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

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