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Laparoscopic liver resection for malignancy: A review of the literature

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Core tip: This paper is a review article of laparoscopic liver resection for malignancy. We review all large studies that investigated the techniques and outcomes of laparoscopic liver resection as well as those comparing laparoscopic to open resections.

Abstract

AIM: To review the published literature about laparoscopic liver resection for malignancy.

METHODS: A PubMed search was performed for original published studies until June 2013 and original series containing at least 30 patients were reviewed.

RESULTS: All forms of hepatic resections have been described ranging from simple wedge resections to extended right or left hepatectomies. The usual approach is pure laparoscopic, but hand-assisted, as well as robotic approaches have been described. Most studies showed comparable results to open resection in terms of operative blood loss, postoperative morbidity and mortality. Many of them showed decreased postoperative pain, shorter hospital stays, and even lower costs. Oncological results including resection margin status and long-term survival were not inferior to open resection.

CONCLUSION: In the hands of experienced surgeons, laparoscopic liver resection for malignant lesions is safe and offers some short-term advantages over open resection. Oncologically, similar survival rates have been observed in patients treated with the laparoscopic approach when compared to their open resection counterparts.

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INTRODUCTION

Twenty-years after the first reported laparoscopic liver resection by Gagner *et al*[1], there has been an exponential growth of reports of laparoscopic liver resections but the results are yet to be fully elucidated.

Although initially described for benign and peripheral lesions, 50% of overall laparoscopic liver resections are now performed for malignant lesions[2] and a growing number of centers are now performing major resections, including right and left hepatectomies, in North America, Europe, and Asia[3-8].

The purpose of this study is to review the published literature on laparoscopic liver resection for malignant lesions. We will discuss the different types of resection, the most common as well as the innovative techniques, the surgical outcomes, postoperative complications, and oncologic results.

MATERIALS AND METHODS

A PubMed search was performed for original published studies until June 2013. Articles were selected using the indexing terms "hepatectomy", "laparoscopy", and "liver neoplasm/surgery". Keyword search for "laparoscopy", "laparoscopic", "hepatectomy", "resection", "liver cancer", "liver neoplasm", "liver tumor", "hepatic cancer", and "hepatic neoplasm". Large series with more than 30 patients with malignant lesions were included. Reported procedure other than resection, such as radiofrequency ablation and cyst fenestration were excluded.

RESULTS

About 43 studies with more than 30 patients who underwent laparoscopic resection for liver malignancy were identified. No randomized clinical trials were available. Most data were reported as case series or case-control studies. Although the first large series was in 2002, the vast majority of reports were published in and after 2009. In this review, we analyzed preoperative findings such as indications and tumor size, intraoperative findings like blood loss and operative time, short-term outcomes, as well as oncologic outcomes (Table 1).

DISCUSSION

Indications and contraindications of laparoscopic liver resection

As with open surgery, hepatocellular carcinoma (HCC) and colorectal metastasis (CRM) are the main indications of malignant tumor resection[2,3,6,9-15]. Much less commonly, resections of cholangiocarcinoma, lymphoma, and non-colorectal liver metastasis (*e.g.*, neuroendocrine tumors, breast cancer, and renal cell carcinoma) have been performed[9,13,15-18].

In patients who cannot tolerate pneumoperitonium due to their cardiopulmonary status and those with adhesions that cannot be lysed laparoscopically, laparoscopic liver resection is contraindicated. Relative contraindications are in patients with lesions adjacent to the inferior vena cava or major vessels, in whom there is a need for biliary and/or vascular reconstruction, those with hilar lesions or in those with resections that require an extensive portal lymphadenectomy[2,19,20]. Although considered a contraindication for laparoscopic resection by a large number of surgeons, successful minimally invasive approach to gallbladder cancer has been performed in 7 patients published in two papers with no reports of port site metastasis[21,22].

Minor resection

Minor resections including segmentectomy, subsegmentectomy, and wedge resections are the most common type of laparoscopic liver resection performed. Left lateral sectionectomy (LLS) which was first reported by Azagra *et al*[44], is by far the most frequently reported anatomic resection given easy visualization of the lesions with laparoscopy, peripheral location of the intended resection area, and the ease of controlling the left hepatic vein. Inagaki *et al*[45] reported 30 LLS for hepatocellular carcinoma using Hand-assisted technique. They postulated 2 advantages to the Hand-assisted technique; First, better visualization of the surgical field and the transected margin with direct manipulation by the surgeon's hand, and second, immediate hemostasis by depressing the bleeding point and proper application of hemostatic instruments.

Major resection

After the first reported cases of laparoscopic major hepatectomy by Hüscher *et al*[46] in 1998, an increasing number of series describing major resections have been reported[6,13,14,17,23,25-27,47,48].

In the largest series of major hepatectomies of 210 patients, 136 with right hepatectomoies and 74 with left hepatectomies, Dagher *et al*[3] showed a mean operative time of 250 min, with mean EBL of 300 mL. The mortality in that series was 1%.

Gumbs *et al*[49,50] reported the first laparoscopic extended left hepatectomy as well as the first laparoscopic extended right hepatectomy in 2008. The patient who underwent laparoscopic extended right hepatectomy had gallbladder adenocarcinoma and underwent preoperative portal vein embolization followed by totally laparoscopic extended right hepatic resection with preservation of segment IVa and the left half of IVb due to concerns of postoperative hepatic reserve. A total of 3 patients underwent laparoscopic extended left hepatectomy. One patient suffered a bile leak that was treated with endoscopic biliary stents.

Three large series have also included patients who underwent extended hepatectomy[14,26,29]. The papers showed that extended hepatectomy can be safely performed when undertaken by experienced surgeons and with careful patient selection.

Uncommon resections and novel approaches

While laparoscopic resection of lesions in segments 2-6, the so called "laparoscopic liver segments" have been widely performed, posterior and superior lesions have been classically unamenable to laparoscopic resection. This has changed in the last 6 years.

In a series of 300 patients, including 103 with malignant liver tumors, Koffron *et al*[48] reported 8 caudate lobectomies, 2 of which were for cancer. Cho *et al*[42] documented 10 right posterior segmentectomies in a series of 71 patients with hepatocellular carcinoma and colorectal metastasis.

Abu Hilal *et al*[51] reported 2 cases of pure laparoscopic en bloc left hemihepatectomy and caudate lobe resection for intrahepatic cholangiocarcinoma. The first patient's operative time was 360 min and blood loss was 390 mL. The second patient's operative time was 310 min and blood loss was 300 mL.

Hu *et al*[52] reported a case of multiple hepatic colorec-

Table 1 Published studies of laparoscopic liver resection for malignancy

Ref.	Year	*n*	HCC	CRM	GB CA	Cholangio	Lypmhoma	NET mets	Other	Size (cm)	EBL (mL)	Conversion	OT (min)	M	Death	LOS (d)	Margin (cm)
Choi *et al*[23]	2013	57	57	0		0	0	0	0	0.8-5.5	150-800	NA	95-380	NA	0	5 17	2.08 ± 1.68
Guerron *et al*[63]	2013	40		40						3.3	376 ± 122	5%	239 ± 17	15%	NA	3.7	1 ± 0.2
Gumbs *et al*[21]	2012	40	4	30	6	1		4	5	NA	300	6%	265	11.30%	NA	6 (1-31)	NA
Abu Hilal *et al*[13]	2012	133	18	83		2	2	17	11	0.5-14	(10-4000)	NA	30-540	0 40 %	NA	0 15	Pos 0-35%
Topal *et al*[24]	2012	81								NA	50 (10-300)	NA	120 (80-200)	11%	0	5 (3-7)	NA
Yoon *et al*[25]	2012	89	89							3 ± 1.6	NA	4.70%	2675 ± 138	NA	NA	NA	1.4 ± 1.4
Cannon *et al*[26]	2012	35		35						NA	202	NA	NA	23%	0	4.8 *vs* 8.3	Neg 97%
Ikeda *et al*[27]	2012	30	16	13		1				2.6 ± 1	146 (0-550)	0	79-697	NA	0	5-44	5 (1-30)
Dagher *et al*[28]	2010	163	163							3.6 (1-20)	250 (30-2000)	9.20%	180 (60-655)	11.60%	1.20%	7 (2-76)	12 (0-58)
Shafaee *et al*[29]	2011	66	3	55			1	3	2	0.5-12.5	300 (0-5000)	11%	180 (80-570)	26%	0	6 (2-42)	0.3 (0-4)
Lai *et al*[30]	2011	56	42	14						0.9-5.4	175 (5-2000)	3.60%	150 (75-307)	14.30%	0	6.5 (2-13)	89.3% R0
Belli *et al*[31]	2011	65	65							3.8 (1-9)	311 ± 180	10.70%	NA	20%	1.50%	8.2 (3-15)	NA
Truant *et al*[32]	2011	36	36							2.9 ± 1.2	452 ± 442	19.40%	NA	25	0	NA	0.95
Nguyen *et al*[43]	2011	108								3.2	101	NA	256	NA	NA	NA	1.12, 1.5
Lee *et al*[33]	2011	31	31							2.5 (1.5-9)	150 (10-1610)	18.20%	225 (100-420)	6.10%	0	5 (2-15)	1.8 (0-4)
Hu *et al*[34]	2011	30	30							6.7 ± 3.1	520 ± 30	NA	180 ± 45	13.30%	NA	13 ± 2.1	NA
Kazaryan *et al*[35]	2010	107		107						3 (0.5-12)	300 (50-4000)	4.20%	188 (64-488)	NA	0.90%	3 (1-42)	NA
Martin *et al*[5]	2010	65	14%	48%		12%			26%	4 (2-15)	150 (20-1000)	4%	140 (50-240)	23%	1%	3 (1-13)	Pos 3%
Zhang *et al*[41]	2010	70	29	28		2	1		10	NA		8.80%	150 (20-390)	14.80%	0	6 (1-20)	Neg 100%
Tranchart *et al*[36]	2010	42	42							3.58 ± 1.75	346 ± 435.7	NA	233.1 ± 92.7	20.40%	2.40%	6.7 ± 5.9	1.04 ± 0.8
Yoon *et al*[8]	2010	69	69							3.1 ± 1.5		7.20%	280.9 ± 128.2	21.70%	NA	9.9 ± 5.6	1.5 ± 1.6
Nguyen *et al*[62]	2009	109		109						NA	200 (20-2500)	3.70%	234 (60-555)	12.00%	NA	4 (1-22)	Neg 94.4%
Sasaki *et al*[37]	2009	72	37	35						2.5 (1.5-8.5)	64 (1-917)	NA	177 (70-430)	5.50%	NA	8.5-10	0.6 (0-4)
Bryant *et al*[16]	2009	100	64	22		3			11	NA	(0-2000)	9.60%	30-480	15.10%	0	7.9 (2-76)	1.53 (0-5.8)
Inagaki *et al*[38]	2009	52	36	10		3			3	3.1 ± 1.8	393 ± 564	2.90%	214 ± 93	10%	NA	17	NA
Cho *et al*[4]	2009	35	27	8						3.4 (1.5-7.5)	619.5 (20-1800)	NA	299.9 (80-630)	27.50%	NA	10.9 (5-38)	1.3 (0.2-5)
Huang *et al*[39]	2009	33	27	3		1			2	3.4 (1-11)	200 (100-400)	6.70%	120 (90-177.5)	11.11%	NA	5	0.2-3.2
Otsuka *et al*[40]	2009	76	55	16		2			3	3.68 ± 2.8	262 ± 344.8	NA	268 ± 123.1	11%	0	11.8 ± 7.3	NA
Castaing *et al*[14]	2009	60		60						3.3 ± 1.1	NA	10%	NA	27%	1.70%	10 (5-50)	Neg 87%
Dagher *et al*[3]	2009	210								NA	300 ± 391	12%	250 ± 103.8	22%	1.00%	6 ± 3.5	10.5 ± 13.6
Zhang *et al*[41]	2009	49	33	10		6			3	6.2 (0.8-15)	280 (10-1000)	NA	NA	NA	0	NA	1.2 (0.5-6)
Cho *et al*[42]	2008	71	52	19						3.7 ± 3	425 (20-900)	5%	240 (30-540)	15%	0	9 (4-21)	1 (0.3-6.8)
Topal *et al*[6]	2008	77								3.8 (0.5-17)	500 (10-7000)	9%	95 (30-385)	5.50%	NA	6 (0-41)	Pos in 1.2%
Chen *et al*[53]	2008	116	116							1.3-5.1	101.6-667.2	NA	118.4-488.7	6%	NA	6	NA
Buell *et al*[17]	2008	106	36	31		8			31	3.1-6.4		NA	NA	NA	3.70%	NA	2.80%
Hompes *et al*[22]	2007	45	8	32	1	4		1	1	4 (0.8-17)	200 (5-4000)	6.60%	115 (45-360)	24%	0	7 (3-41)	1 (0.1-3)
Dagher *et al*[47]	2007	38	24	9		3			2	3.8 (2.2-8)	397 (100-2300)	10%	227 ± 109	16%	1.40%	5.9 ± 5.6	1.1 (0.1-3.2)
Koffron *et al*[48]	2007	103								NA	102	6% to ha	99	9.30%	0	NA	NA
Vibert *et al*[9]	2006	65	16	41		2		3	3	0.8-18	NA	13%	85-515	19%	1.10%	11 (3-47)	NA
Mala *et al*[10]	2005	47	1	42				1	3	3 (0.8-15)	700 (< 100-5000)	6%	187 (80-334)	16%	0	3.5 (1-14)	Pos in 6%
O'Rourke *et al*[7]	2004	33		22					11	NA	20-2000	9.40%	40-370	14%	0	NA	1.1 (0-3)
Inagaki *et al*[45]	2003	52	36							3.1 (1-14)	393 ± 564 (5-3500)	2.90%	214 (61-375)	26.40%	0	14.8	NA
Gigot *et al*[59]	2002	37	10	12				5	10	3.3 (1-6)	NA	10.80%	NA	21%	0	7 (2-16)	Pos in 6.7%

HCC: Hepatocellular carcinoma; CRM: Colorectal metastasis; NET mets: Neuroendocrine metastasis; GB CA: Gallbladder adenocarcinoma; Cholangio: Cholangiocarcinoma; NA: Unavailable; EBL: Estimated blood loss; OT: Operative time; LOS: Length of stay; Margin: Resection margin size; Pos: Positive margin rate; R0: R0 resection rate.

tal metastases of the left lateral and right posterior segments who underwent laparoscopic partial hepatectomy of the right posterior segment using a retroperitoneal approach, followed by laparoscopic hepatic left-lateral segmentectomy using a transabdominal approach. The operative time was 120 min, blood loss volume was 150 mL and the patient was discharged on postoperative day 9.

Hand-assisted technique

Hand-assisted technique entails the creation of a 7-8 cm incision that would allow the operating surgeons' hand access to the abdominal cavity through a gas-tight port. The theoretical advantages of the hand-assisted technique is the ability to apply liver traction and mobilization, palpate the liver with tactile feedback, and help achieve hemostasis by applying compression[17,45,48].

The Hand-assisted technique has been proposed to provide a safer and more attainable approach to laparoscopic resection[17,48]. The application of the hand-assisted technique has been proposed to help with difficult resections like those involving the posterior-superior segments[53]. In their published series in 2007, Koffron *et al*[48] reported 103 patients with laparoscopic liver resection. In 6% of the patients a conversion from a totally laparoscopic to hand-assisted surgery was necessary while the conversion to open surgery was nil. They suggested that the use of hand-assistance may help prevent conversion to open surgery. However, there is no consensus on the usefulness of the hand-assisted technique as other authors have doubted its usefulness[7,54].

Robotic resection

Robotic laparoscopic resections are now well reported in the literature. While the technique of port placement is different from laparoscopic surgery, most studies have showed encouraging results with comparable results to laparoscopic approach[55]. In a series of 70 patients, 42 of which had malignant lesions, Giulianotti *et al*[56] reported 4 conversions to open surgery (5.7%), a median operative time for a major resection of 313 min and 198 min for minor resection, median blood loss of 150 mL for minor resection and 300 mL for major resection. The rate of complications was 21%, while the mortality rate was 0%.

In a matched analysis study, Daouadi *et al*[57] showed that patients undergoing robotic liver resection had longer operative times when compared to laparoscopic resection (253 min *vs* 199 min), however, the robotic approach increased the percentage of major hepatectomies that were completed in a purely minimally invasive approach. There was no difference between the two groups in term of other surgical outcomes like blood loss, resection margin, and 3-mo mortality.

Operative technical details

Precoagulation of the surface of hepatic parenchyma using a variety of instruments and techniques like the Salient monopolar Endo FB 3.0 or Endo SH 2.0 (Salient Surgical Technologies, Inc., Dover, NH, United States) combined with the Microtaze (Alfresa-Pharma Co., Inc., Osaka, Japan), the Cool-tipTM RFA system (Valleylab, Tyco Healthcare, Mansfield, Massachusetts, United States), and Radiofrequency precoagulation (Laparoscopic Habib 4 ×, Angiodynamics, Queensbury) was postulated as a way to help reduce blood loss by many authors[37,40,53].

The most commonly used equipment for parenchymal transection were the Harmonic scalpel (Ethicon Endo-Surgery), the laparoscopic ultrasonic surgical system (USU; Olympus Optical, Tokyo, Japan), and Cavitron Ultrasonic Surgical Aspirator CUSA (Valleylab)[13,30,32,37,38,58].

Other less common techniques included the use of staplers[17,30,38] and crush-clamp technique[40]. These are largely dependent on surgeon or center preference.

The Pringle maneuver in which the portal triad is clamped is the most common method used to minimize blood loss during liver resections. There was no consensus in the published literature as to the role of the Pringle maneuver in laparoscopic resections. It was used intermittently by some groups to reduce blood loss[13,30,32].

Belli *et al*[31] described the laparoscopic application of Pringle maneuver using tape that was placed around the porta hepatis by the use of Endo Retract TM Maxi (Tyco Healthcare, Norwalk, Conn., United States). This was passed through a 16-Fr rubber drain and used as a tourniquet when necessary[31]. Others, like Tranchart *et al*[58], purposely didn't use the Pringle maneuver although an explanation to this approach was not provided.

A number of studies have reported that inflow occlusion is required less often and for shorter periods during laparoscopic liver resections[5,35,48]. This was postulated to be due to the magnification and improved visualization of the hepatic parenchyma as well as the tamponade effect of pneumoperitonium on venous bleeding.

Outcomes of laparoscopic liver resection

Operative blood loss: Due to the heterogeneity of the reported cases, blood loss was highly variable in different studies. Average blood loss ranged between 50 to 700 mL. Dagher *et al*[28] and Otsuka *et al*[40] showed that with late experience, blood loss was significantly lower than in early cases, *i.e.*, surgeons had lower blood loss during laparoscopic resection with more procedure performed. Six studies have showed that laparoscopic resection was associated with lower blood loss than open surgery[5,6,24,26,48,58]. Martin *et al*[5] showed lower rates of transfusions in laparoscopic resections when compared to open resections (10% *vs* 48%).

Operative time: In terms of Operative time, the average operative time ranged from 95 to 280 min. Although one study showed increased operative time when compared to open surgery[33], 3 studies demonstrated decreased operative time in laparoscopic surgery[5,24,48]. Dagher *et al*[47] showed decreased operative times when early experience is compared to an established technique period. (270 ± 143 min *vs* 171 ± 95 min, $P < 0.001$), which points out that there is a learning curve with lapa-

Table 2 Reported survival after laparoscopic resection for hepatocellular carcinoma

Ref.	Disease-free survival				Overall survival			
	1 yr	2 yr	3 yr	5 yr	1 yr	2 yr	3 yr	5 yr
Gigot *et al*[59]		43.70%				62.50%		
Chen *et al*[53]					85.4%-94.7%		66.4%-74.2%	59.4%-61.7%
Tranchart *et al*[36]			60.90%	45.60%			74.40%	59.50%
Yoon *et al*[8]			60.40%				90.40%	
Lai *et al*[30]	85%		47%	38%	96%		67%	52%
Belli *et al*[31]	81%		62%	32%	95%		70%	55%
Truant *et al*[32]				35.50%				70%
Lee *et al*[33]	78.80%		51%	45.30%	86.90%		81.80%	76%
Hu *et al*[34]								50%
Yoon *et al*[25]			52.90%	46.40%			93.30%	85.90%
Choi *et al*[23]			71%				81%	
Inagaki *et al*[45]								79.30%

roscopic liver surgery.

Conversion to open surgery and length of stay: Conversion to laparotomy rates in the literature ranged from 0% to 19.4%. Koffron *et al*[48] converted to Hand-assisted technique in 6% of the resections and had 0% conversion to open surgery which signifies that the use of the hand-assisted technique may decrease the rate of conversion to open surgery. Ikeda *et al*[27] had a 0% conversion rate in a series of 30 patients. In the series published after 2011, conversion rates never exceeded 6%, which also may point to a learning curve effect in laparoscopic liver surgery. The main reasons for conversion were bleeding, adhesions, and inability to complete the resection laparoscopically due to technical or anatomical considerations.

The average length of stay ranged from 4.8 to 13 d in the studies and many of them found a shorter length of stay when compared to open surgery[4-6,26,33,53,58].

Morbidity and mortality: The average morbidity rate was 5.5% to 27.5%. Common complications included bile leak, liver abscess, and transient hepatic failure. General complications included pleural effusions, pneumonia, urinary tract infection, and cardiac arrhythmia. Lower morbidity as compared to open surgery was observed in many studies[5,6,24,26,48].

Inagaki *et al*[38] showed markedly decreased rate of pulmonary complications in the patients who underwent laparoscopic resection as compared to open surgery (3% *vs* 17%).

Mortality rate varied between 0% and 3.7%. Reported causes of death included liver failure[28,58], cerebral infarction secondary to hypotension[9], postoperative hepatorenal failure[17], pseudomembranous colitis, technical clip failure leading to massive hemorrhage[14], acute respiratory distress syndrome[28,31], bleeding from esophageal varices[13], and multi-organ failure[35].

Potential disadvantages: While the safety of laparoscopic liver resection has been documented, possible limitations include the significant learning curve[47], loss of tactile feedback and inability to manually palpate the liver that may cause missing other lesions, and potential bleeding that may be harder to control laparoscopically[2].

Oncologic results

Resection margin: The surgical margins were free of cancer in 87% to 100% of patients in the published studies. The Size of the margin varied with an average ranging between 0.3 cm to 2.08 cm. Topal *et al*[6] showed a lower rate of positive surgical margin with laparoscopic surgery as opposed to open resection; 1.2% *vs* 2.1%.

Castaing also showed higher rate of R0 resection with laparoscopic resection 87% compared to open surgery 72%[14]. The addition of intraoperative ultrasound was associated with lower rate of positive margins[59]. Buell *et al*[17] reported the only case of port site metastasis in the literature which was in a patient who underwent laparoscopic resection for CRM.

Hepatocellular carcinoma: Hepatocellular carcinoma is the most common primary liver malignancy. 52% of reported laparoscopic liver resections done for malignancy are performed for HCC[2]. In the literature, the 3-year disease-free survival was 51% to 62% and the overall 3-year survival ranged from 66.4% to 90.4%. The 5-year disease-free survival ranged from 32% to 46.4%, while 5-year overall survival was 50% to 85.9% (Table 2).

Three studies found no difference in survival between patients with hepatocellular carcinoma who were treated with laparoscopic resection when compared to open resection[32,33,52].

Belli *et al*[60] showed reduced morbidity, especially postoperative ascites, and a shorter length of stay in cirrhotic patients who underwent laparoscopic resection for hepatocellular carcinoma when compared to those who underwent open resection.

In the largest series of 163 patients with hepatocellular carcinoma treated at 3 European centers by Dagher *et al*[28], the mean operative time was 180 min, mean estimated blood loss was 250 mL, the mortality rate was 1.2% and the mean resection margin was 1.2 cm. The researchers also found that there has been a decrease in operative time and blood loss, increase in the size of tumors re-

Table 3 Reported survival after laparoscopic resection for colorectal metastasis

Ref.	Disease-free survival				Overall survival			
	1 yr	2 yr	3 yr	5 yr	1 yr	2 yr	3 yr	5 yr
Gigot *et al*[59]		53.3%				100%		
O'Rourke *et al*[7]	81%				88%			
Castaing *et al*[14]	65%		30%	30%	97%		82%	64%
Shafaee *et al*[29]			27%				83%	55%
Lai *et al*[30]	92%		72%		100%		88%	
Topal *et al*[24]	61.3%	41.8%		29.9%	94.5%	83.5%		59.5%
Nguyen *et al*[62]	65%		43%	43%	88%		69%	50%

sected, and lower rate of morbidity in patients who were operated on in the later experience series[28].

Colorectal liver metastasis

Surgery is the only curative option for metastatic colorectal cancer to the liver. 35% of laparoscopic liver resections for malignancy are performed for CRM[2].

The goal of resection in patients with CRM is resection of all liver metastasis with a negative margin but at the same time preserving adequate post-resection liver volume. Liver resection offers long-term survival in up to 60% of patients with CRM[61].

Disease-free survival at 1 year was 61.3% to 81%, but dropped at 5 years to 30% to 42%. Overall survival at 1 year was 88% to 100%, at 3 years ranged from 82% to 88%, and at 5 years ranged from 51% to 64% (Table 3).

Nguyen *et al*[62] reported the largest series of 109 patients with laparoscopic resection for CRM. The mean estimated blood loss was 200 mL, the transfusion rate was 10%, the average length of operation was 234 min, the resection margin was negative in 94.4%, and the conversion rate was 3.7%. Conversion was due to hemorrhage.

Shafaee *et al*[29] showed that the survival rates for patients undergoing repeat hepatectomy laparoscopically were equivalent or even superior to the long-term outcomes of patients undergoing open resection. Two other studies have showed no statistical difference in disease-free and overall survival rates between laparoscopic and open surgery[14,24].

CONCLUSION

In conclusion, Although laparoscopic liver surgery requires a great deal of experience by hepatobiliary surgeons, this approach is deemed safe for malignant liver lesions with comparable oncological results to open surgery. In addition, it offers better short term results including shorter hospital stay, lower costs, less postoperative pain, and lower complication rates. While operative blood loss has been a major concern with laparoscopic resection, a number of reports is showing that minimally invasive approach is associated with lower risk of bleeding and transfusions. Tumor size is no longer an obstacle to laparoscopic resection, although laparoscopic major hepatectomy is still limited to experienced centers. The disadvantages of the laparoscopic approach are the loss of tactile sensation and palpation of the liver as well as the learning curve that is associated with laparoscopic resection. It should be noted that there has been no randomized clinical trials involving laparoscopic liver resection for malignancy and such trial is needed to clarify the risks *vs* benefits and help standardize the approach.

COMMENTS

Background

After being initially described for small peripheral benign tumors, laparoscopic liver resection for malignant and larger lesions is now reported extensively in the literature.

Research frontiers

This purpose of this study is to review the published literature on laparoscopic liver resection for malignant lesions. Authors discuss the different type of resection, the most common as well as the innovative techniques, the surgical outcomes, postoperative complications, and oncologic results.

Innovations and breakthroughs

Although laparoscopic liver surgery requires a great deal of experience by hepatobiliary surgeons, this approach is deemed safe for malignant liver lesions with comparable oncological results to open surgery.

Peer review

This manuscript thoroughly reviews the history and advances on the laparoscopic resection for liver malignancy, including the indications and contraindications, minor and major resections, hand-assisted technique, robotic resection, operative technical details, and the outcomes. The text is generally well written.

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