Appraisal of Laparoscopic Liver Resection in the Treatment of Liver Metastasis with Special Reference to Outcome in Colorectal Malignancies

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Abstract Treatment of metastatic liver disease is at the crossroads of an evolutionary transformation with more and more reports reiterating the benefits of resectional therapy in various cancers. A quest for application of laparoscopic approaches to the management of liver metastasis has arisen due to the projected benefits of less morbidity, early recovery, and equivalent oncological outcome in selected malignancies. However, the diverse and heterogenous data on indications, operative technique, and outcome evaluation make a comparative analysis of these studies difficult. This review is an appraisal of technique and outcome of minimally invasive liver resection as reported in the current literature with special reference to treatment of metastatic colorectal cancers.

Keywords Liver metastasis · Minimal access · Laparoscopic surgery

Introduction

The liver is a common site of metastasis from gastrointestinal and soft tissue malignancies. Hepatic metastases develop in

approximately 50–60 % of colorectal cancers and malignant neuroendocrine tumors [1–3]. Most patients with metastatic liver disease do not survive 5 years in the absence of definitive treatment of liver secondaries. Metastatic liver disease with its presumed dismal prognosis has been conventionally treated with systemic therapy and or locoregional therapies, with a primary intent for palliation. However, in selected patient subgroups, treatment for liver metastasis with a curative intent confers a survival advantage over and above palliative benefits.

Resectional therapy forms the cornerstone of curative treatment for liver metastasis as it confers the best survival benefit. The role of liver resection is outstanding in metastatic colorectal cancer and neuroendocrine cancers and continues to evolve in other malignancies. An estimated survival benefit of 27–39 % has been reported in colorectal cancers [1, 2]. In neuroendocrine tumors, it helps in controlling the distressing manifestations of carcinoid syndrome, prevents the development of carcinoid heart disease, and improves survival in up to 70 % of cases [3]. Liver resection/ablation has been shown to be beneficial in other tumors as well, i.e., sarcomas, renal cell carcinoma, melanomas, breast cancer [4–7]. A multi-institutional review, evaluating liver resection for metastatic cancer, cites 20 % morbidity, 2 % mortality, and 31 % 5-year survival rate irrespective of the primary tumor site [4]. Nevertheless, with the availability of good imaging techniques, ablative procedures are being frequently deployed in curative setting.

The transformational evolution of minimally invasive surgery is being witnessed in the arena of liver resections with more and more reports embracing the procedure, thus necessitating a reappraisal of these approaches for a better understanding on their applications. This article reviews the outcome of minimally

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invasive liver resection for metastatic disease with special reference to laparoscopic liver resection (LLR) for colorectal cancer and other common malignancies.

Review

Laparoscopic Liver Resection

LLR was first performed in 1991 for benign disease and thereafter in 1994 for malignant disease. After a long transition period, data on the safety and efficacy of LLR are gradually emerging [8]. The other minimal-access resectional approaches that have been utilized include thoracoscopic approach and natural orifice transluminal endoscopic (NOTES) approach [9–12]. Laparoscopic liver resection can be of the following types: (1) total laparoscopic approach, (2) laparoscopy-assisted techniques, (3) hybrid techniques, and (4) other variants, i.e., single-incision laparoscopic surgery, use of robotic assistance for lesions located in difficult anatomic locations, and navigational laparoscopic procedures, which are the new technological advances that are being investigated in LLR [13–24].

Important Issues in LLR

The important considerations in using the laparoscopic approach for the resection of malignant liver metastasis which have been discussed below are as follows: (1) patient selection: lap versus open approaches, (2) extent of resection: anatomic versus nonanatomic, (3) role of laparoscopic intraoperative ultrasound (IOUS) (4) port placement, (5) accessibility of lesions in posterosuperior segments or centrally located lesions, (6) conversion, (7) control of intraoperative bleed, (8) gas embolism, (9) short-term outcome, (10) cost, (11) oncologic outcome as compared with open procedures, (12) synchronous versus metachronous approach, and (13) laparoscopic rehepatectomy.

Patient Selection

Selection of patients for LLR, in general, conforms to the norms of open liver resection (OLR) viz: general operability (comorbidity); achievability of R0 resection status with ablative methods and/or neoadjuvant chemotherapy and ability to eradicate extrahepatic tumor, maintaining a functional residual volume of 25 % with or without use of adjunctive portal vein embolization or staged resection; feasibility of maintaining two contiguous liver segments with intact vascularity and biliary drainage; biological aspects of the tumor (prognostic factors); and experience of the surgeon and center [25]. Though earlier it was proposed that LLR should be limited to solitary metastasis, <5 cm, peripheral anterior location in

the right lobe or in the left lobe precisely in 2, 3, 4b, 5, and 6 Couinaud segments, the literature is emerging on the successful performance of the procedure on lesions that are more posteriorly or superiorly located [24, 26, 27].

Role of Intraoperative Ultrasonography with Special Reference to LLR

Inability to palpate the tissues is an inherent drawback of laparoscopic surgery particularly in the context of LLR; thus, accurate imaging to locate the number and size of lesions is important to define the extent of resection and ensure a R0 resection. However, preoperative imaging methods alone are insufficient as additional lesions may be detected in up to 25–30 % of cases with the use of intraoperative ultrasonography (USG) (IOUS) [28]. The diagnostic accuracy further improves with contrast-enhanced USG (CE IOUS) aiding in detection of 50 % additional lesions [29]. IOUS can also delineate vascular structures in close proximity to the lesion, thereby guiding a difficult resection, assessing resection margins, helping in the application, and monitoring on ablative therapy.

Port Placement

In a standard LLR, usually four to six ports are used which include (1) a supraumbilical 10-mm optical port; (2) a 12-mm port for laparoscopic USG usually 10 cm above and to the right of optical port, which also serves as a port for insertion of stapling devices; and (3) three to four working ports around the optical port [30]. Simultaneous resection of colorectal malignancy and hepatectomy may be performed through the same ports as, for an LLR, some authors use an additional suprapubic port for extracting the specimen of stapled or hand-sewn anastomosis [31]. In a metachronous situation with a prior colonic resection, the port position is similar. Additionally, for diverting ileostomy, the stoma site has been occasionally used as a hand port.

Extent of Resection: Anatomic Versus Nonanatomic

The extent of resection can vary from a simple wedge excision to more complex anatomic resections. By conventional definition, an anatomic resection implies the resection of at least one entire anatomic segment [30]. Performance of a complex anatomic resection wherein a limited resection can suffice is not justified as, besides increasing the chances of liver failure, it has been postulated to enhance tumor proliferation due to regeneration of the resected liver parenchyma [32]. Anatomic resections are more common in hepatocellular carcinoma (HCC) than metastatic liver disease, as the latter has pushing rather than infiltrative margin-decreasing chances of an adjacent skip lesion. Moreover, HCC metastasizes by portal vein

invasion, which justifies an excision defined by portal vein territory [33]. Irrespective of the width of resection, obtaining a clear margin is an important predictor of long-term survival months [1]. Incomplete resection has no role, and care should be taken to address all metastatic lesions [32]. Strategies to improve liver volume like portal vein embolization and or staged resection can be planned where there are concerns regarding the adequacy of residual liver volume [32].

Table 1 depicts the relative proportion of patients undergoing nonanatomic and anatomic resections in various studies comparing open and laparoscopic liver resections in colorectal cancers [34–39]. Left lateral sectionectomy is the most commonly performed anatomic major resection laparoscopically [38].

Accessibility Issues with Reference to the Anatomic Location of the Metastasis in the Liver Particularly the Segments 7 and 8

The issue of accessibility of lesions especially in the first, seventh, and eighth segments (i.e., nonperipheral segments) is certainly a drawback. The importance of proper positioning of such patients and access routes needs to be evaluated. A prone/semiprone position or use of a hanging liver technique might be advantageous in such situations [15, 23, 27, 40]. Appropriately adjusted positioning of trocars, use of gravity force, extensive mobilization of the right lobe, use of flexible laparoscopes, IOUS, and navigational surgery can be beneficial [27]. Use of hand-assisted technique and robotic assistance has been suggested to improve accessibility of lesions located in posterosuperior segments and very close to major hepatic vessels [23, 41]. Other authors have tried a

thoracoscopic transdiaphragmatic approach for tumors at the superior dome [10]. With the use of appropriate access techniques, the outcome has been shown to be not different in nonperipheral segments as compared to conventional peripheral segments [27].

Conversion

Conversion rates are low in LLR varying from 0–10 % in various studies and improve with overcoming the learning curve [27, 34, 42, 43]. An earlier extensive meta-analysis on LLR for benign and malignant liver lesion estimated a cumulative conversion rate of 7 % [8]. Accessibility issues and bleeding are the main causes for conversion [34, 44]. Conversion can be to an open procedure or hand-assisted procedure and rarely an ablative technique like a laparoscopic radiofrequency ablation [27]. A low threshold for conversion minimizes blood loss [45].

Blood Loss

Bleeding is an inherent phenomenon in liver surgery, and proper control of the bleed is paramount. Though conversion rates have been consistently reported to be low, bleeding has been one of the reasons for conversion [45]. Severe intraoperative bleeding in laparoscopic surgery has been reported to be seen in 7 % [8]. The blood loss in liver resection is reported to be proportional to the pressure gradient across vascular walls and diameter of the cut vessels; therefore, hypotensive anesthesia with maintenance of a low central venous pressure of 2–5 cm H₂O is advisable [44]. Laparoscopic hepatectomy can be performed with electrosurgical equipments or staplers.

Hemostatic dissectors and vessel coagulators are a boon to laparoscopic liver surgery. Various instruments have been used like staplers, saline cautery, precoagulators, ultrasonic dissectors, ultrasonic shears, bipolar coagulators, vessel sealing devices, bipolar radiofrequency devices, lasers (argon laser coagulators and Nd:Yag laser dissectors) [46, 47]. Ultrasonic dissectors are the commonly used devices for parenchymal transection with vessel sealing devices and staplers reserved for larger vessels. Unlike the conventional cautery, most of the current electrosurgical devices produce less smoke, and therefore visibility is less hampered. Authors have vouched concern regarding tumor dissemination by pressure effects of argon laser spray, leading to abandonment of the use of argon laser coagulation [44].

In a large series comparing outcome of stapler hepatectomy and electrosurgical hepatectomy, with data acquired from an international database, it was observed that stapler hepatectomy was more often used in larger tumors and resulted in significantly decreased operative time, blood loss, and hospital stay but had a higher trend towards complications, particularly bile leak. However, equivalent oncological outcome was noted with respect to local recurrence and survival [48].

Table 1 Anatomic versus nonanatomic liver resection in metastatic colorectal cancers

Author/year	Type of surgery		
		Nonanatomic/ wedge	Anatomic: uni-segment/ pluri-segment/hemi- hepatectomy
Guerron et al. 2012	Lap	24	16
	Open	18	22
Huh et al. 2011	Lap	12	8
	Open	11	9
Topal et al. 2012	Lap	3	17
	Open	7	13
Topal et al. 2012	Lap	34	18
	Open	90	82
Cannon et al. 2012	Lap	5	30
	Open	52	88
Hu et al. 2012	Lap	9	4
	Open	9	4

Innovative methods of complete or partial hepatic blood inflow and outflow occlusion are being practiced laparoscopically. Broadly, the types of inflow occlusion can be classified as total pedicle occlusion, hemihepatic, or selective vascular occlusion. Authors have reported that a hemihepatic vascular occlusion is easier for the left lobe and selective vascular occlusion, for the right lobe [49]. These methods may be implemented intracorporeally or rarely be controlled with an extracorporeal approach. Some of the techniques that are being implemented are hanging liver technique, Pringle maneuver, hemi-Pringle, extrahepatic Glissonean occlusion, intrahepatic Glissonean occlusion, marionette technique, hepatic venous outflow occlusion, and total venous occlusion [40, 50–55]. With the availability of efficient electrosurgical equipments and vessel sealing devices, the routine use of these maneuvers is questioned. The use of portal triad clamping is also seen to be less in LLR [8]. Fibrin sealants and other hemostatic agents that form a hemostatic coagulum on the cut liver edge have been used in laparoscopic surgery as is in vogue in open approaches [56, 57]. Other approaches that have been suggested to reduce bleeding during laparoscopic surgery are radiofrequency pre-coagulation and portal vein or hepatic artery embolization prior to resection [58].

If performed with proper care, LLR has been shown to result in less blood loss, and blood transfusion requirements are minimal (Table 2) [34, 36–39, 59]. This is despite the fact that pedicle clamping procedures are less frequently resorted to in laparoscopic procedures. Some of the reasons cited are (1) the availability of better vessel sealing equipment and coagulators that leads to efficient coagulation, (2) the positive pressure effects of the pneumoperitoneum decreases bleeding, and (3) the magnified view helps in the control of small bleeders [44].

Gas Embolism in Laparoscopic Liver Resection

Gas embolism is an issue of concern in laparoscopic hepatic resections. Whereas the potential risk of gas embolism exists in major laparoscopic hepatectomies, maintaining a low-pressure pneumoperitoneum 8–10 mmHg is advised [60]. The use of carbon dioxide in laparoscopic surgery has a very low risk of embolism due to its high solubility. The issue of gas embolism arises when argon laser is used for coagulation. The high pressure of pneumoperitoneum in the presence of an open vein in the liver can facilitate gas embolism [44]. Some authors have reported it to be more common if a prior ablative procedure was done.

Laparoscopic Versus Open Approach to Liver Resection Short-Term Outcome

LLR if performed in expert centers has been shown to confer the same benefits of minimally invasive surgery viz: better cosmesis, early recovery, less pain, less blood loss, and reduced morbidity and mortality with equivalent oncological outcome when compared with OLR [3, 8, 61, 62]. A world review of LLR in 2,804 patients quotes a 10.5 % morbidity and 0.3 % bile leak, with liver insufficiency being the commonest post-op complication [63]. Comparative studies evaluating morbidity and mortality rates after laparoscopic and open surgery for colorectal liver metastasis report equivalent [35] or lesser morbidity with LLR at 23 versus 50 % and 11 versus 4 % [36, 38]. In view of the reduced morbidity and early recovery, LLR may be particularly beneficial in the elderly, provided that they are fit for the procedure [44]. These benefits have also been noted in laparoscopically assisted procedures [14]. Table 2 shows the short-term outcome of LLR versus open liver resection OLR in

Table 2 Results of laparoscopic liver resection for metastatic colorectal cancers with reference to operative time, blood loss, and recovery

Author/year	Indications	Number of patients	Op time (min)	Blood loss (ml)	Recovery/hospital stay (days)
Guerron et al. 2012	CRLM	LLR 40	Lap 239	LLR 376 ^a	3.7 ^a
		OLR 40	Open 219	OLR 753	6.5
Hu et al. 2012	CRLM	LLR 13	Lap 313 ^a	LLR 259	8.5 ^a
		OLR 13	Open 350	OLR 273	11.2
Topal et al. 2012	CRLM	LLR 81	Lap 120 ^a	LLR 50 ^a	5 ^a
		OLR 193	Open 190	OLR 500	9
Topal et al. 2012	CRLM	LLR 20	Lap 257	LLR 550	8
		OLR 97	Open 232	OLR 550	8
Cannon et al. 2012	CRLM	LLR 35	–	LLR 202 ^a	4.8 ^a
		Open 140		OLR 392	8.3
Cheung et al. 2012	CRLM	LLR 20	Lap 180	LLR 200	4.5
		OLR 40	Open 210	OLR 310	7

CRLM colorectal liver metastasis, LLR laparoscopic liver resection, OLR open liver resection

^a Significant difference

recent trials with specific relevance to colorectal liver metastasis [34, 36–39, 59]. It is interesting to note that the operative time is variable; in some studies, LLR merited with decreased operative time, whereas in others, LLR had a significantly more average operative time. The variability can be explained by (1) the type of resection major/minor and (2) surgeons experience.

Cost

In a study on cost analysis of implementation of laparoscopic liver surgery program in a university hospital, it was seen that the cost outcome was equivalent to open, as laparoscopic surgery requires less operative time, lower blood loss, decreased morbidity, and reduced hospital stay [64].

Laparoscopic versus Open Resection for Liver Metastasis: Oncological Outcome

Resection Margin

One of the important concerns of LLR in the context of a malignancy is the issue of obtaining an adequate resection margin. This is especially important in the setting of metastatic disease as they are often multiply located in various anatomic zones and cannot be assessed easily in the absence of tactile sensations in laparoscopy. Cracking of the liver parenchyma by ultrasonic dissectors, ablative procedures, and formaldehyde fixation can make assessment of the resection margin difficult in LLR [44]. A positive resection margin is detrimental for an oncologic outcome. Most studies report that the

margin positivity rates are low in laparoscopic resection [27, 34, 35]. In a study evaluating oncological outcome of LLR for primary and metastatic liver tumors in 133 patients wherein both colorectal and noncolorectal cancers as well as neuroendocrine tumors were included, an overall 97 % resection-free margin rate was reported [42]. The use of intraoperative laparoscopic USG is helpful.

Survival

An earlier meta-analysis reported on a trend for better overall survival with LLR over OLR for metastatic colorectal cancers [8]. Most recent studies show that LLR provides equivalent survival outcomes as observed in open surgery (Table 3) [34–39, 59, 65]. In a study evaluating laparoscopic hepatic resection for neuroendocrine tumors, it was observed that the 3-year disease-free survival was better after laparoscopic surgery (73.3 %) as compared with open (47.6 %) [3]; however, it may be noted that there was a selection bias as patients with synchronous metastatic liver disease underwent open surgery in the study.

Port-Site Metastasis

Port-site metastasis has been known to occur following laparoscopy and has been thought to occur due to mechanical seedling of tumor at the site of extraction of the tumor and also due to dissemination at the time of evacuation of the pneumoperitoneum. Port-site metastases after LLR have not been reported even in large series [44].

Table 3 Results of laparoscopic versus open liver resection for colorectal metastasis with reference to survival

Author/year	Indications	Number of patients	Survival
Castaing et al. 2009	CRLM	LLR 60	LLR 5-year OS 64 %, DFS 35 %
		OLR 60	OLR 5-year OS 56 %, DFS 25 %
Huh et al. 2011	CRLM	LLR (S) 20	LLR 3-year OS 52.8 %
		OLR (S) 20	OLR 3-year OS 61.0 %
Cannon et al. 2012	CRLM	LLR 35	LLR 36 %
		OLR 140	OLR 42 %
Cheung et al. 2012	CRLM	LLR 20	LLR 69.4 months median
		OLR 40	OLR 42.1 months median
Hu et al. 2012	CRLM	LLR 13	LLR OS 27 %
		OLR 13	OLR OS 31 %
Guerron et al. 2012	CRLM	LLR 40	LLR DFS 23 months
		OLR 40	OLR DFS 23 months
Topal et al. 2012	CRLM	LLR 81	HR=1.05 (CI=0.74–1.47) for DFS
		OLR 193	HR=0.88 (CI=0.52–1.48) for OS
Topal et al. 2012	CRLM	LLR 20	LLR 5-year DFS 43 %, OS 48 %
		OLR 20	OLR no difference from LLR

CRLM colorectal liver metastasis, LLR laparoscopic liver resection, OLR open liver resection, S synchronous

Synchronous versus Metachronous Metastasis: What Should Be the Approach in Minimally Invasive Surgery?

One of the inherent hesitations in tackling the colorectal primary and liver metastasis synchronously in open surgery is the issue of accessibility of both lesions at extreme ends of the abdomen through a small incision. Increased morbidity was reported after synchronous resection using the open technique [32]. Thus, a laparoscopic synchronous approach may be advantageous in this situation [39]. Total laparoscopic synchronous resection of the liver metastasis and primary tumor is being increasingly reported [31, 43, 66–68]. Synchronous approach may be advisable in the following disease categories: (1) major/complex colonic resection with minor hepatic resection and (2) minor colonic resection and minor or major hepatic resection [68]. Alternatively, a hybrid procedure with resectional approach for the primary and ablation of liver secondaries may be adopted. In a metachronously detected lesion in the event of a prior open surgery, LLR may be relatively difficult due to adhesions, and the presence of a previous scar of open surgery negates the projected advantages of cosmesis. Nevertheless, a minimally invasive approach should be adopted as the postoperative morbidity is low and recovery, early. There are reports of safe performance of LLR in patients with a history of prior abdominal surgery [69].

Laparoscopic Rehepatectomy

The issue of repeat hepatectomy for malignant disease raises an important concern regarding functional remnant liver volume. Rehepatectomy should always be attempted, as survival after rehepatectomy is considerably increased [32]. A few authors have reported equivalent clinical outcome with laparoscopic rehepatectomy in malignant liver tumors [70, 71]. In a multi-institutional study evaluating laparoscopic and open rehepatectomy in malignant disease in which most of the study population constituted metastatic tumors, an 11 % conversion rate was noted due to bleeding or technical difficulty. The postoperative morbidity and recovery were not different. R0 resection was achievable in 91 % of patients, there were no port-site metastasis, and the 5-year survival rate was 55 %. The authors concluded that laparoscopic resections were safe and feasible especially in patients who had a prior laparoscopic resection [71].

Laparoscopic versus Open Liver Resection: Are the Indications Different?

Most of the studies comparing laparoscopic and open liver resection for metastatic liver disease are retrospective cohorts or matched case–control studies. The data in these studies are largely heterogeneous, and often, selection criteria vary

considerably. There are no randomized controlled trials to date; thus, an element of selection bias cannot be negated. In an interesting study, patients with metastatic liver disease were categorized into potentially laparoscopic suitable or unsuitable based on tumor location and other characteristics, and subsequently, both groups underwent open hepatectomy. It was noted that the group which was suitable for LLR but underwent open surgery had a better short-term and long-term outcome [72].

Laparoscopic Resection for Noncharacterizable Lesions

Another postulated benefit of the procedure is in small noncharacterizable lesions in a patient with primary malignancy elsewhere, wherein a laparoscopic wedge resection can be utilized with both a diagnostic and therapeutic intent with less morbidity. By virtue of the small size and location of such lesions, they may not be amenable to ablative therapies. Indeed, with the demonstration of the safety and feasibility of LLR, the procedure demerits being over utilized in some benign lesions which could have been otherwise followed with serial imaging [73].

Laparoscopy in Ablation of Liver Metastasis

The ablative and injection therapies can be administered either percutaneously or by a laparoscopic approach. The relative disadvantages of the percutaneous approach are (1) tumor seedling, (2) difficulty in inaccessible locations, and (3) risk if the lesion is in close relation to a bowel or other vital structures. The other advantage of laparoscopic approach is that intraoperative USG can be used which can upstage the disease in up to 30–50 % of cases [28, 29, 74].

Role of Ablative Therapy as an Adjunct to Resection

The use of thermal ablation as a preoperative adjunct to hepatic resection has been proposed to increase the rate of resectability and decrease intrahepatic dissemination or extrahepatic recurrences in metastatic colorectal cancers [75]. It can also facilitate precoagulation to prevent intraoperative hemorrhage [58], control intraoperative hemorrhage, and aid in ablation of components of residual disease in inaccessible locations or after incomplete resections. Ablative therapies have also been used in conjunction with hepatic arterial embolization for unresectable disease [76].

Other Approaches: Single-Incision Laparoscopic Surgery, Robotic Surgery, NOTES, Navigational Surgery

Single-incision laparoscopic surgery is being performed for liver resection as well [16–18]; however, the technique is challenging, and other than cosmesis, the outcome is the same as in multiport laparoscopic surgery.

Robotic liver resection is being tried in some centers and has been shown to confer the same initial results as that of laparoscopic surgery; however, the number of patients in which they have been performed are small [19–21]. In a study comparing robotic versus laparoscopic liver resection, inferior outcomes were noted with respect to rate of minor complications, ICU admission, and cost in patients undergoing robotic surgery [22], but the results may be influenced due to a learning curve, as other authors have noted an equivalent surgical outcome barring cost issues [20]. Robotic liver surgery combines the attributes of open surgery viz a three-dimensional vision, dexterity with extended degree of freedom, and minimization of fine tremors along with the benefits of minimal access technique [20]. An improved camera control and coaxial alignment also adds to the ergonomic benefits of robotic surgery and is especially helpful in complex maneuvers like suturing or operating in difficult anatomic locations. This may be particularly relevant in colorectal cancers where operating with wrist-like articulating instruments in the pelvis or in posterosuperior locations of the liver may be advantageous in robotic surgery [77].

Natural orifice transluminal endoscopic approaches with or without robot is also being investigated as an approach for hepatic wedge resection, though the practical applicability of such maneuvers is not known [11, 12]. Navigational therapy with computer-aided planning of resection and use of intraoperative MRI guidance are also being evaluated.

Image-Guided Navigational Surgery

Navigational surgery with preoperative and intraoperative mapping systems is the vivid technological advance in the field of imaging and hepatic surgery. Oncological liver resections are a challenging surgery. On one hand, the surgeon has to ensure a complete tumor resection with free margins to avoid litigation, and simultaneously, on the other hand, one has to avoid potential injury to vital structures that can be life-threatening. In navigational surgery, the surgeon orients himself to the vital structures and the target lesion by a combined preoperative and intraoperative computer-aided imaging system, conventionally accomplished by a CT imaging technology. However, with the development of MRI-compatible instruments and trocar, the role of MRI in navigational therapy is being investigated. In laparoscopy, the issue of tumor deformation due to pneumoperitoneum and respiratory movement synchronization of MRI needs to be considered in navigational surgery [78, 79].

Conclusion

Treatment of metastatic liver disease can prolong survival in selected patients, the benefits being more pronounced in colorectal cancers and neuroendocrine tumors. Evidence from

systemic reviews and meta-analysis of nonrandomized trials suggest a superior outcome with resectional therapy as compared with nonresectional therapy. In the absence of well-designed RCTs, the conclusions may be flawed with selection bias, as nonresectional therapy is often resorted to an unresectable disease. Minimal-access techniques merit the benefits of less morbidity, cosmesis, and early recovery and currently form the essence of both resectional and nonresectional therapy. Laparoscopic liver resection appears to be promising with a better short-term and equivalent long-term oncological outcome as that of open surgery in the context of the treatment of metastatic liver disease. A wider indication and application of laparoscopic liver resection is evolving with safe performance of complex anatomic resections and use of innovative techniques for access in difficult locations. Another novel role of laparoscopic approach is its use in application of ablative procedures as an isolated treatment strategy or in conjunction with resectional therapy to decrease complications and increase local control. Thoracoscopic approaches, SILS, NOTES, and robotic resections are the newer emerging techniques of minimal-access resectional therapies for liver metastasis that are currently being tested for their safety, efficacy, and applicability in the clinical scenario.

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