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Laparoscopic liver resection: benefits and controversies

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In 1992, Gagner et al reported the first complex laparoscopic liver resection for a 6 cm, focal nodular hyperplasia, using an ultrasonic dissector, monopolar cautery, and clip appliers [1]. In 1995, Ferzli et al reported excision of 8×9 cm segment IV hepatic adenoma, using ultrasonic dissector and endoscopic vascular staplers [2]. The first successful laparoscopic anatomical hepatectomy was reported in 1996 by Azagra et al, who performed a left lateral segmentectomy (segments II and III) in a patient with a benign adenoma of segments II and III [3].

Many comparative studies favor the laparoscopic approach over open surgery for several reasons: a reduced postoperative analgesic requirement, shorter delay to oral intake, reduced hospital stay, and quicker improvement in the serum transaminase levels. These advantages are often exemplified in patients undergoing cyst or benign tumor resections [4,5]; however, indications for a laparoscopic resection with a curative intent for liver malignancies are not yet established. Tumor dissemination and inadequate margins are potential disadvantages of the laparoscopic approach. Moreover, its feasibility is frequently limited to the group of patients requiring wedge resections of superficially located tumors [6]. A comparison of survival of patients undergoing laparoscopic malignant liver tumor resection to the open approach is not established. Until now, none of the studies reporting limited experience with laparoscopic resection of hepatocelullar carcinoma (HCC) or liver

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metastases have provided data on long-term outcomes. Controversies regarding tumor cell seeding and port-site metastases in laparoscopic liver resection of malignancies persist because of limited numbers of reported patients. Nevertheless, short-term outcome is comparable to that of conventional surgery, with the additional benefits derived from minimally invasive therapy [7].

Gas embolism may be caused by pneumoperitoneum. This potentially dangerous complication is relatively rare and is not reported as a major problem in the largest series of laparoscopic liver resection. Advances in surgical techniques, such as abdominal-wall lifting, were developed to prevent such a complication. The effectiveness of gasless laparoscopy has been well-documented, particularly in extensive resections of large liver masses [8].

Despite the recent improvements in methods of sealing parenchymal vessels, hemorrhage remains the most common perioperative complication. Hemorrhage is difficult to control laparoscopically and may lead to postoperative complications and the need for massive blood transfusion. Almost 80% of procedures are converted to open surgery in such situations [9]. Careful selection of patients and meticulous operative technique may reduce postoperative complications.

Indications

Patient selection

Localization of lesions has a crucial importance in the indications for laparoscopic resection. Small, focal, and localized tumors on antero-lateral segments (segments II–VI according to the classification of Couinaud) are typically considered for resection.

Hepatic resections requiring porta hepatis isolation and dissection are usually done by open approach. Partial resection of the peripheral liver or a left-lateral segment resection is more feasible for laparoscopic approach, because the periphery of the liver is devoid of large venous structures and bleeding can be easily controlled with clamps or cautery.

Similarly to open surgery, in cirrhotic patients the balance between postoperative organ reserve and surgical curability will greatly influence the prognosis. Patients with an indocyanine green 15-minute clearance retention rate (ICG R15) of more than 20% [10], prothrombin activity test result less than 75% [11], serum albumin level below 3.5 g/dl, and total bilirubin of more than 1.5 mg/dl are not good candidates for major hepatic resection [12]. Cirrhosis is considered a limiting factor for a massive excision, and extensive surgery may be hazardous in such patients [13].

Benign tumors

Benign tumors of the liver are relatively frequent incidental findings. A variety of clinical presentations, diagnostic methods, and treatments are presented in detail in the article by Dr. Gibbs.

Indications for resection are determined by the presence of symptoms, danger of rupture, and amount of liver tissue involved. Symptoms usually indicate enlargement or tumor rupture.

Malignant tumors

Hepatocellular carcinoma, the most common hepatic malignant tumor, is associated with cirrhosis in the vast majority of patients. The optimal treatment for hepatocelullar carcinoma is curative surgical excision. Only 15% to 30% of patients are referred with potentially resectable tumors [14].

The liver is the primary site of metastases for many malignant neoplasms. Gastrointestinal malignancies, most frequently colorectal cancer, spread to the liver via portal venous drainage. Surgical resection is the treatment of choice for patients with one to three metastases from a colorectal primary cancer [15].

Other possible but rare solid tumors are teratomas, carcinoid tumor, and mesenchymal hamartomas. Carcinoid is an exceptionally rare primary liver tumor and may be associated with carcinoid syndrome.

In laparoscopic resection of liver malignancies, the same oncologic principles should be applied as in open surgery: radical resection, and achievement of at least a 1 cm free surgical margin [16]. The lack of digital palpation during laparoscopic resection makes determining the appropriate surgical margin very difficult and challenging [17]. Intraoperative ultrasonography should be used as a direct guide for localizing tumors and division of the liver parenchyma. Combined use of laparoscopic inspection and intraoperative ultrasonography provides better visualization of liver anatomy and tumor margin [18].

Other limitations of laparoscopic management of liver tumors include difficulties in liver mobilization and tumor extraction, as well as presence of dense adhesions related to previous procedures [19].

Port-site metastases

Problems of tumor cell seeding and port-site metastases are addressed in several reports on laparoscopic treatment of gastrointestinal malignancies [20]. Paolucci et al reported the probability of developing abdominal-wall metastases was higher after laparoscopy for hepatic cancer compared with open surgery. Maintaining an intact surgical specimen and using plastic retrieval bags decrease but do not exclude the risk of port-site metastases [21]. It is hypothesized that pneumoperitoneum may cause damage to the peritoneum that induces intraperitoneal tumor growth [22]; however, this has not been reported in laparoscopic hepatectomy for malignant tumor.

Hepatic cysts

Hepatic cysts are detected in 2.5% to 5% of the population. Symptoms are present in about 15% of cases. Patients with very large cysts often present with nonspecific abdominal pain, occasional bleeding, or infection. Obstructive jaundice is rarely encountered. Since laparoscopic unroofing for liver cysts was first reported in 1991, a number of reports have described successful laparoscopic management of hepatic cysts. Laparoscopic unroofing of uncomplicated liver cysts is associated with a high recurrence rate (10%–25%), but there is less morbidity and mortality compared with open surgery. Open surgery remains the standard approach for treatment of complex liver cyst and hydatoid cyst [23].

Technique

Instrumentation

Intraoperative ultrasonography (IOUS) is commonly used for liver staging. Its sensitivity is comparable to that of preoperative computed tomography (CT), helical CT, and magnetic resonance imaging, both for malignant and benign liver lesions. It is concluded that IOUS has immense diagnostic value and significant impact on surgical decision-making in hepatectomy candidates by improving resectability [24]. Intraoperative ultrasonography is currently the most sensitive modality for the detection of small hepatic lesions (<1.0 cm) previously undetected by dynamic CT scans [25]. Intraoperative ultrasonography helps optimize the balance between necessary oncological radicalism and the sparing of functioning liver parenchyma. It frequently allows accomplishing anatomical resections otherwise not possible. If nonanatomical resection is performed, intraoperative ultrasonography guidance allows a better tumor clearance. Precise localization of hepatic vessels with color Doppler expands the indication of laparoscopic surgical resection [26].

A 30° laparoscope is essential to provide a wide-angle view of the operative field. Endoscopic, disposable clip appliers and vascular staplers contribute to a reduction of major intraoperative bleeding during laparoscopic hepatectomy. Because of their safety, rapidity, and ease of application, these stapling devices are efficient for controlling and dividing the major hepatic veins [27].

The Cavitron Ultrasonic Surgical Aspirator (CUSA) (Valley Lab, Boulder, Colorado) allows selective fragmentation and aspiration of collagen-sparse tissues such as liver parenchyma. Blood vessels and bile ducts are preserved.

The argon-beam coagulator is useful for hepatic resections, primarily for superficial hemostasis; however, the plume of the argon flows into the peritoneal cavity, and in the presence of CO_2 pneumoperitoneum, it can increase intra-abdominal pressure and might cause hemodynamic instability.

An ultrasonic scalpel can effectively seal small vessels and bile ducts with minimal fogging of the camera lens. It seldom sticks to the liver parenchyma as conventional electrocautery does. The ultrasonic scalpel works by means of a vibrating blade or scissors, and can be used for tissue dissection, coagulation, and preparation. The most important advantages when compared with electrocautery are limited heat generation, lack of smoke production, and lack of current flow through adjacent tissue.

The Jet-Cutter (Helix Hydro-Jet, Erbe, Tubinger, Germany) is a promising new instrument in liver surgery that uses a high-pressure water stream for safe dissection of hepatic tissue [28].

A microwave coagulator is used along the resection line to prevent bleeding from the surrounding hepatic parenchyma. A combination of microwave coagulation and ultrasonic dissection minimize intraoperative blood loss [29].

Gasless laparoscopy is an alternative to use of a CO_2 pneumoperitoneum and uses an abdominal-wall lift device. It provides a tent-shaped operative field rather then the more spacious dome-shaped field provided by a pneumoperitoneum. In effect, intra-abdominal organs are closer to the laterally situated port sites, increasing risk of injury and limiting working area; however, gasless laparoscopy avoids the rapid changes in intra-abdominal pressure that are associated with greater risk of gas embolism. Maintaining intra-abdominal pressure equal to that of the ambient environment may minimize this risk, specially if the hepatic vein is lacerated intraoperatively [30].

Patient positioning and trocar placement

The patient is positioned on the operating table in a supine position and the surgeon stands on the right side of the patient. A 10-mm trocar and 30° type of laparoscope are placed below the umbilicus. After the pneumoperitoneum is created by infusion of the carbon dioxide, more trocars are inserted at the epigastrium and the bilateral subcostal line for dissection.

When hepatic resection is performed on the anterior-inferior segment (S V) or posterior-inferior segment (S VI), the patient is placed on left-side semidecubitus position. After pneumoperitoneum is created, three more trocars are inserted at the right subcostal line, on the anterior clavicular line, and at the epigastrium. For resection of the superior or posterior segment of the right hepatic lobe, a lateral approach is considered to be more convenient.

Pneumoperitoneum

To minimize a risk of air embolism, insufflation pressure should be kept as low as possible (preferably below 10 mmHg). In selected cases, use of an abdominal-wall lift device for gasless laparoscopy should be considered. The patient should also be closely monitored for vital parameters and end-tidal CO_2 level throughout the entire operation. Special precautions have to be taken when the argon plasma coagulator is in use, because it may lead to overpressurization.

Preparation and resection

For liver mobilization, the ligaments of the liver are divided (ie, left triangular ligament for left lobectomy and right triangular ligament for right lobectomy). The falciform ligament is routinely transected, using the endostapler or electrocautery, and the stump is grasped for retraction.

Understanding hepatic anatomy is of great importance in liver resection. Because each segment of liver has its own supply from the portal triad, it can be resected separately from other segments. Glisson's capsule extends as a condensation of fascia around the biliary and vascular branches of the portal triad (Glissonian sheaths). Therefore, if the segmental supply branches are approached from within the liver parenchyma, ligations of a sheath will devascularise the segment. Glisson's capsule structures within the hepatic substance do not need to be dissected individually; the sheath can be ligated en masse. This is simplified by the use of an endoscopic stapler [31]. Intraoperative ultrasound provides confirmation of the hepatic vascular anatomy in relation to the tumor for identification of each segmental triad.

In patients without comorbidities that produce gross impairment of liver reserve, such as cirrhosis, the Pringle maneuver is recommended. This maneuver can significantly cut down operative blood loss by decreasing the vascular inflow via the portal vein and the hepatic artery, at the expense of liver ischemia. In noncirrhotic patients, cross-clamping is safe if intermittent, and if it does not last for more than 60 minutes [32]. Lowering the central venous pressure below 5 cm H_2O is also a simple and effective way to reduce blood loss during hepatectomy [33]. The line of liver transection is usually marked on the liver surface with diathermy. To prevent tearing of the friable hepatic vein during a left lateral segmentectomy, an endostapler is used to transect the portal pedicles near the liver hilium and the left hepatic vein.

Ultrasonic scalpel and CUSA are usually used to resect the parenchyma. The combination of a microwave coagulator and an ultrasonic dissector helps to minimize intraoperative blood loss. Titanium endoclips or endostapler are used to close the main vascular branches and bile ducts. Small vascular or biliary radicles are divided with bipolar coagulation or between endoclips. Argon-beam coagulation can be used to achieve better hemostasis on the raw, oozing surface. Application of tissue glue on the resection surface may further improve hemostasis and prevent bile leak. Injury of the main branch of the hepatic vein may lead to a fatal air embolism. Moderate-sized hepatic veins and bile ducts in the Glisson's sheath are clamped with a clip.

Removal of the tumor

The specimen is removed with an endobag, possibly via a Pfannenstiel incision or an enlarged trocar site, depending on the size of the specimen. It is very important to select a sturdy and large enough bag. Drainage of the operative field with closed suction devices should be considered in selected cases.

Intraoperative monitoring

The risk of intraoperative gas embolism should be assessed by end-tidal CO_2 and O_2 saturation. A pulmonary artery catheter is helpful in selected high-risk patients on large resection. Hemodynamic indices should be recorded before CO_2 insufflation, cross clamping the hepatic pedicles, and after its release [34].

Complications

The most common perioperative complications are bleeding and bile leakage. They are more difficult to control during laparoscopy and often lead to conversion to open surgery; however, several advances in laparoscopic intrumentation, described above, have improved the ability to achieve hemostasis safely.

Laparoscopic liver resection carries an increased risk of gas embolism when compared with an open approach [35]. The risk of venous gas embolism can be reduced by locating the left hepatic vein using an intraoperative ultrasound, creating positive-pressure pulmonary insufflation when approaching the liver vessels, and by reducing intra-abdominal pressure with less pneumoperitoneum or by using gasless laparoscopy [36]. Other, less frequent complications, such as intestinal or organ damage, are usually the result of technical errors.

Clinical and experimental studies have shown that CO_2 pneumoperitoneum is associated with impaired portal blood flow, hemodynamic instability, increased systemic arterial pressure, and decreased central venous pressure and cardiac outflow [37,38]. These hemodynamic variations are usually reversible [39].

Literature review

A literature review was performed based on a Medline search in order to identify articles on laparoscopic liver resection. Keywords included laparoscopic liver resection, liver neoplasm, cancer, colorectal metastases, hepatocellular carcinoma, and hepatic cysts. A total number of 709 patients have been reported in 76 publications from 1991 to 2003. Included are 195 malignant tumors, 264 benign lesions, and 214 hepatic cyst resections. Of the 195 malignant resections, 102 were for metastatic disease, mostly from colorectal primary cancer, and 92 were for hepatocellular carcinomas. Other malignancies were very rare. The majority of the procedures were laparoscopic nonanatomical resections (225 patients); however, 152 patients underwent anatomical resection, predominantly left-lateral segmentectomies. The most frequently performed laparoscopic liver procedure was fenestration and unroofing of the hepatic cysts (245 patients) (Table 1). In addition, an increasing number of new, less-invasive modalities of laparoscopic liver procedures have been recently introduced: laparoscopic cryoablation (38 patients), and laparoscopic radiofrequency ablation (34 patients). A summary is given in Box 1.

The overall mean duration of hospital stay was 7 days. Mean intraoperative blood loss was 315 mL. Average operative time of the surgery was 198 minutes.

The overall morbidity was 12% (n = 55). Ascites and pleural effusion were the most frequent complications (in 12 and 9 patients respectively). Intraoperative hemorrhage remained a life-threatening complication in 1.1% of patients (n = 8). It led to conversion to open surgery in 2.7% (n = 19). Other reasons for conversion were associated with liver malignancies, including insufficient tumor excision in 1.3% of patients (n = 9), and positive margins in 0.3% (n = 2). The recurrence rate was higher in patients operated on for hepatic cysts (4.2%, n = 30) compared with those with solid tumors (1.5%, n = 10). Gas embolism, although feared, was reported in only two cases (0.3%). The mortality rate for laparosocopic resection of liver lesions is 0.3% (2 patients). One patient died on postoperative day 1 from liver failure and severe coagulopathy. The other patient died following myocardial infarction 3 days after laparoscopic cryoablation of liver tumors. The morbidity and conversion rates are summarized in Tables 2 and 3.

Discussion

Laparoscopic liver resection was introduced to clinical practice more than a decade ago. Since then, it has been proven as a feasible method of treatment of variable liver lesions. Among advantages of laparoscopic liver surgery are: shortened hospital stay, decreased postoperative pain, reduced peritoneal adhesions, improved cosmetic results, shorter reconvalescence,

Box 1. Summary of perioperative data of patients undergoing laparoscopic hepatectomy (total number of patients: 709)

Number of cases
Benign lesions 490 (69%)
Malignant lesions 195 (27.5%)
Complications 99 (14%)
Conversions to open surgery 36 (5%)

Table 1
Laparoscopic procedures for liver lesions

Procedure	Number of procedures	Percentage
Cyst fenestration/unroofing	245	33%
Non anatomical resections	225	30.5%
Anatomical resections	152	20%
Laparoscopic cryoablation	38	5.5%
Laparoscopic radiofrequency ablation	34	4.5%
Gasless laparoscopy	25	3.3%
Pericystectomy	10	1.5%
Hand assisted laparoscopic hepatectomy	10	1.5%
Laparoscopic donor hepatectomy	2	0.2%
Total	741	100%

and faster return to normal activity. Due to several improvements in laparosocpic instruments and operative technique, intraoperative blood loss is lower compared with open hepatectomy [40]. This is an especially important advantage in cirrhotic patients, in whom intraoperative blood loss is a major risk of postoperative death [41]. Reduced fluid infusion and decreased loss of protein and electrolytes make the laparoscopic approach more suitable in patients with severe liver cirrhosis, in whom open hepatectomy might cause postoperative complications [42].

The overall morbidity rate is lower in laparosocpic liver resection when compared with the open approach. Postoperative complications frequently seen in open hepetectomy, such as subphrenic fluid collection, hemorrhage, or liver decompensation, are uncommon in patients undergoing laparoscopic hepatectomy [40].

Gas embolus is a life-threatening complication in the presence of pneumoperitoneum, but it is very rare. Improvements in the instrumentarium,

Table 2
Perioperative and postoperative complications

Complication	Number of cases	Percentage
Ascites	12	1.7%
Pleural effusion	9	1.2%
Hemorrhage	8	1.1%
Bile leakage	5	0.7%
Hepatic failure	5	0.7%
Infections	5	0.7%
Incisional hernia	4	0.6%
Bowel obstruction	3	0.4%
Bowel injury not requiring conversion	2	0.3%
Colitis	1	0.1%
Phlebitis	1	0.1%
Pyodermia gangrenosum	1	0.1%
Total	56	7.3%

Table 3
Conversions to open hepatectomy

Conversion	Number of patients	Percentage
Hemorrhage	19	2.7%
Insufficient tumor excision	9	1.3%
Adhesions	4	0.5%
Insufficient resection (positive margins)	2	0.3%
Gas embolus	2	0.3%
Severe cirrhosis	1	0.1%
Instrument malfunction	1	0.1%
Total	36	5.3%

such as the abdominal-wall lifting device, may completely eliminate this danger. Some studies suggested that pneumoperitoneum impairs hemodynamic tolerance during laparosocpic liver surgery. In more recent prospective studies, no significant difference in hemodynamic was found during clamping in patients having laparoscopic liver resection with pneumoperitoneum compared with those having open hepatectomy [43].

Recent animal studies have shown that laparoscopic liver resection results in diminished stress response, as compared with open resection. It is of special importance when preservation of immune function is taken into account. As a result, tumor growth may be slower and the infection rate may be decreased after laparoscopic liver surgery [44].

The role of laparoscopy in resection of liver malignancies remains controversial. Patients should be carefully selected. Only small malignant tumors located in the left-lateral segments or in the anterior segments of the right liver are suitable for laparoscopic resection. The complication rate might otherwise be higher, especially in patients with HCC in cirrhotic liver. Free surgical margin is difficult to obtain. Late outcome needs to be evaluated in further studies. Problems of tumor cell seeding and port-site metastases have been emphasized in many reports [45]. For many patients with liver metastases, laparoscopy has an important diagnostic role. Laparoscopic ultrasound should be routinely used to achieve complete staging. In a highly selected group of patients, with appropriate technique and instruments, liver laparoscopic surgery for malignancy appears to be feasible and safe in experienced hands.

Summary

Laparoscopic liver resection is feasible and safe. Small tumors located in the left-lateral segment are the most favorable for the laparoscopic approach. Complication and conversion rates are acceptable. The laparoscopic approach to malignant lesions is controversial and results should be confirmed in further prospective studies. This highly advanced laparoscopic surgery requires experience and the availability of technologies for safe dissection of liver parenchyma.

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