Application of devices for safe laparoscopic hepatectomy

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Abstract
The continuing evolution of a variety of laparoscopic instrument and device has been gradually applied to the laparoscopic hepatectomy in many countries. Recent experience has persuaded us that there are great potential benefits derived from laparoscopic hepatectomy and much has been learned about patient selection, the grade of surgical difficulty with respect to tumor location, and the required instrumentation. Among these efforts, various ways of hepatic parenchymal transection with mechanical devices have been attempted and continuing to innovate to perform safe laparoscopic hepatectomy.

Important technologic developments and improved endoscopic procedures are being established equipment modifications. For safe laparoscopic hepatectomy, it is important to have all necessary equipment. The intraoperative laparoscopic ultrasonography, microwave coagulators, ultrasonic dissection, argon beam coagulators, laparoscopic coagulation shears, endolinear staplers and TissueLink monopolar sealer are essential. This procedure is in need that well experienced endoscopic surgeon and well-experienced liver surgeon should be collaborated in laparoscopic hepatectomy and the indications are strictly followed based upon the location and size of tumors. Finally critical determinant for success and safe laparoscopic hepatectomy is through familiarity with the relevant laparoscopic instruments and equipments. Laparoscopic hepatectomy is expected to develop further in the future as a new surgical instrument, equipment and method, which improves patients' quality of life.

Key Words: laparoscopic surgery, laparoscopic hepatectomy, laparoscopy-assisted hepatectomy, surgical device for laparoscopic hepatectomy

Introduction
The application of laparoscopy to hepatectomy has been slowed, because of technical difficulties such as hemostasis from the transection plane, controlling hemorrhage from intrahepatic vessels, and exploration of deep regions. However, the continuing evolution of a variety of laparoscopic instrument and device has been gradually applied to the laparoscopic hepatectomy in many countries. The recent experience has persuaded us that there are great potential benefits derived from laparoscopic hepatectomy and much has been learned about patient selection, the grade of surgical difficulty with respect to tumor location, and the required instrumentation [1–4]. Among these efforts, various ways of hepatic parenchymal transection with mechanical devices have been attempted and continuing to innovate to perform safe laparoscopic hepatectomy.

In this paper, we address the devices which are used mainly to perform the parenchymal transection during laparoscopic hepatectomy.

Materials and methods
Surgical equipment and instruments
Important technologic developments and improved endoscopic procedures are being established by equipment modifications.

Intraoperative laparoscopic ultrasonography. Intraoperative flexible laparoscopic ultrasonography (Aloka Ind., Tokyo, Japan) is not only useful but also indispensable. It clearly displays the extent of the tumor, its relationship to the hepatic vasculature, and the potential plane of resection.
Microwave coagulators. A microwave tissue coagulator (Alfresa Ind., Osaka, Japan) generated a 2450 MHz microwave, which is transmitted to a monopolar type of needle electrode, called a microwave scalpel, by way of a coaxial cable. This endoscopic surgical device has a hand piece with needle-shape monopolar applicators. Microwave emission is started after the liver tissue is punctured with a microwave scalpel. Electric currents are induced in the tissue as a result of absorption of the microwave-produced heat. This thermal energy is used for tissue coagulation. Coagulation with emission of white smoke begins after a few seconds. The liver parenchyma around the scalpel is coagulated. The coagulation region reaches a depth equal to the length of the scalpel. It can be recognized as a superficial yellow–whitish coagulation approximately 1 cm in diameter.

Ultrasonic dissection. Ultrasonic dissection (Olympus Ind., Tokyo, Japan) has a built-in power supply. It works ultrasonically with vibrating suction of the liver tissue and also provides coagulation of small vessels less than 2 mm in diameter and fibrotic tissue.

Argon beam coagulators. Argon beam coagulators (Bircher Ind., Ltd., Englewood, Colo. USA) which have been recognized for their efficacy especially for achieving hemostasis in the plane of transection. It allows for rapid and diffuse superficial coagulation at the plane of transection. However, it is less used in recent cases.

Laparoscopic coagulating shears. Laparoscopic coagulating shears (Ethicon Endo Surgery Ind., Cincinnati, OH, USA) is a surgical device utilizing ultrasonic energy to cut and coagulate tissue by converting electric energy to mechanical vibration with a frequency of 55,500 Hz. In comparison with other energy sources such as electric surgery or laser surgical unit, the system coagulates with relatively low heat and limited lateral thermal injury without charring the tissue. It also generates no smoke and the patient is completely isolated from the electrical circuit. This device is widely used in the field of endoscopic surgery.

Endolinear staplers. Endoscopic stapling devices have become increasingly utilized in laparoscopic operations. However, stapling devices have been rarely used in operations of the abdominal solid organs. Its applications in liver surgery have been emerging. We introduced the versatility and efficacy of stapling devices in hepatic surgery for transection of large vessels such as main hepatic vein or Glisson’s pedicle and liver tissue parenchyma [5].

TissueLink Monopolar Sealer (TL-MS). TL-MS employs the radio frequency energy (RF) focused near the tip. Electrical energy is conducted through a continuous low-volume saline irrigation and then into tissue where it is converted into heat by ohmic heating of the tissue.

The saline facilitates energy transfer between the device-tissue interface, maintaining contact with the hepatic tissue even when the tip is moving, and evenly dispersing thermal energy. The saline also provides surface cooling to prevent tissue from getting hotter than 100°C. The RF and saline causes the tissue and blood vessels to shrink, resulting in sealing and hemostasis.

The power cord of TL-MS is connected to the standard RF generator used for standard electrosurgery. A sterile saline is connected to the fluid pathway of TL-MS. The rate of saline delivery at the tip of TL-MS is set between 4–6 cc/minute, with a coagulation power setting between 70 and 110 watts on the electrosurgical generator.

These are the essential equipments and improved instruments that have greatly contributed to safe laparoscopic hepatectomy (Figure 1).

Surgical technique

The technique of laparoscopic hepatectomy has been described elsewhere. Briefly, the patients are generally anesthetized according to the standard procedure. Each patient’s position and trocar placement are decided based upon the location of the tumor. Laparoscopic hepatectomies are generally performed with the four or five trocar techniques.

Laparoscopic flexible ultrasonography is indispensable for assessing the anatomic landmarks, such as vasculobiliary connection, as well as the surgical margins.
The line of the intended liver parenchymal transection is marked on the liver surface using diathermy or microwave. The liver is punctured by the microwave scalpel along the line of the transection and it is irradiated with microwaves. Ultrasonic dissection of the liver is performed using an ultrasonic surgical system. Once resection is started from the liver surface, exposed small vessels and biliary structure...
less than 2 mm in diameter are coagulated with laparoscopic coagulating shears or ultrasonic surgical system. The branched vessels larger than 2 mm are clipped and transected. In cirrhotic patient, the use of combination microwave with laparoscopic coagulating shears obtains satisfactory hemostasis during liver parenchymal transection (Figure 2). In recent cases, TL-MS have been actively employed (Figure 3), and an endolinear stapler has been applied for the liver transection if the tumor is pedunculated. Furthermore, using an endolinear stapler has allowed the surgeon to achieve a quick dissection and transection of Glisson’s sheath as well as the hepatic veins with liver tissue in a left lateral segmentectomy as long as it is possible to insert the hepatic parenchyma planned for resection (Figure 4). The enlarged liver with cirrhosis would not be amenable to this technique, unless the staple could hold liver tissue or vessels. The resected liver is maneuvered into a plastic bag to avoid the possibility of tumor implantation. Extraction of the undivided specimen is performed in all patients through the slightly enlarged trocar incision, thus enabling histological review. Laparoscopy-assisted hepatectomy is performed with relatively large liver requiring resection of the left lobe [6]. The round ligament is initially divided and dissection of the coronary and triangular ligaments, and also mobilization of the liver toward the left hepatic vein and ligament venosum could be performed with laparoscopic coagulation shears. These procedures are carried out by totally laparoscopy. In accomplishing this maneuver, an upper median skin incision of 7 cm is made. The left lobe is exposed to be lifted up the tape around the liver. Liver parenchymal transection is performed with instruments used for open procedures and endoscopic surgery by both endoscopic and direct views. When tumor is located in relatively upper segment, hand assisted surgery is carried out (Figure 2). It is easy to mobilize the liver, diagnose the tumor location by palpation, and achieve hemostasis by immediate compression with hand manipulation [7,8]. The technique of these operations would be given less challenge to the surgeon.

Results
Laparoscopic hepatectomy were performed on 81 cases. Laparoscopic surgery represented 22% of liver resection activity in our department. The localization of tumor was mainly left lateral segment and lower segment by Couinaud’s classification except segment VIII in four cases and segment VII in two cases. Laparoscopic left lateral segmentectomy was carried out 24 cases, 49 cases in partial hepatectomy, three cases in resection of segment VI, three cases in left lobectomy, one case in right lobectomy, and one case in posterior segmentectomy. Conversion to open hepatectomy was one early case. Six patients received blood transfusion.
When the laparoscopic hepatectomy groups were divided into early periods (~2000) and late periods (2000~), there was a significant difference with respect to operative time between the early period groups and the late period groups in both the partial hepatectomy and left lateral segmentectomy groups. Blood loss was also less different although there was no significant difference. We have accumulated laparoscopic hepatectomy case experience for over 15 years’ experience, and the operative time has been shortened with less bleeding in recent cases. The operative time for laparoscopic partial hepatectomy and left lateral segmentectomy has been shortened to less than two hours and less than four hours, respectively, indicating that our technique has been improving through our accumulated clinical experiences. We believe that learning curve exists in laparoscopic hepatectomy even less clinical cases. In addition, the development of laparoscopic instruments above mentioned has greatly contributed safe and fast laparoscopic liver resection.

It is generally difficult to evaluate minimally invasive surgery. In order to evaluate less invasive surgery, we utilized an E-PASS (Estimation of Physiologic Ability and Surgical Stress) scoring system as it relates to the postoperative clinical course. The E-PASS scoring system is considered to predict the morbidity and mortality of the post-surgical risk by quantifying the patient’s reserve and surgical stress [9]. Laparoscopic hepatectomy was found to be less invasive than conventional hepatectomy after examination by the E-PASS Scoring System for surgical stress in combination with the postoperative clinical course by our historical matched case-control studies. However, this procedure requires the surgeon to overcome the technical difficulties inherent in laparoscopic hepatectomy.

Furthermore, postoperatively, the peak values of total bilirubin, aspartate aminotransferases (AST), and C-reactive protein (CRP) did not statistically differ between the two procedure groups. The patients started walking and eating significantly earlier in the laparoscopic hepatectomy group, and these more rapid recoveries consequently allowed shorter hospitalizations. The laparoscopic hepatectomy group revealed a 11% in complication rate while the open hepatectomy group showed a complication rate of 19%, though this difference did not reach statistical significance. We did not find any serious complication, which related with laparoscopic instrument. Similarly, a comparative study between laparoscopic versus open hepatectomy in a pair-matched analysis was reported that same rates of mortality and morbidity and reduction of blood loss and postoperative hospital stay were observed [10].

Discussion

For safe laparoscopic hepatectomy, it is important to have all necessary equipment. The microwave tissue coagulator, laparoscopic coagulating shear and the ultrasonic dissection are essential. Microwave tissue coagulator produces satisfactory hemostasis during liver resection, but caution is necessary to prevent puncturing the liver near a main hepatic vein. In addition, microwave tissue coagulator has been associated with a high incidence of bile leakage and abscess formation, although we did not encounter this complication. The advantage of the ultrasonic dissection device we use is the built in power supply for diathermy. Thus, adequate hemostasis is achieved even in patients with cirrhosis. One precaution is that the power supply must be turned down when working near the main hepatic vein.

Laparoscopic coagulating shears has been widely used in endoscopic surgery. It is greatly contributed for transection of ligament and superficial layer of the liver tissue with achieving hemostasis. Especially the use of combination microwave with laparoscopic coagulating shears obtains satisfactory hemostasis even cirrhotic liver parenchymal transaction. However, it is not suitable instrument for hemostasis of deep layer of liver tissue near the hepatic vein. In addition, caution has been taken for the injured vessels by cavitation from the active blade. Although the argon beam coagulator effectively secures hemostasis of the liver transection, the intraabdominal pressure should be carefully monitored, along with a low flow of argon gas. Intraabdominal hypertension is prevented by opening a trocar valve.

Several techniques are developed in our series. Dissection of the portal and hepatic veins is a critical point. Endolinear stapler is used for transection of the hepatic vein. Its safety has been experimentally confirmed in clinical cases. Furthermore, the endolinear stapler is utilized for transection of liver parenchymal tissue as long as it is possible to insert the hepatic parenchyma planned for resection. Improvement of the laparoscopic suturing technique also contributes ensuring secure ligation of large intraparenchymal vessels during parenchymal dissection, although double clipping might have been sufficient.

The TL-MS device is a new technology that has been developed as mainly use in liver resection. It is confirmed that intraoperative blood loss during liver transection can be reduced using TL-MS compare with conventional hepatectomy without extension of operative duration in open hepatectomy cases. Same satisfactory hemostasis is obtained during liver parenchymal transaction in laparoscopic procedure. Small vasculature (less than 2 mm in diameter) can be sealed. It is useful even in the deep layer of liver tissue or cirrhotic liver. However, technique of using TL-MS needs learning curve for effective use. In addition, coagulation degeneration of 3~5 mm in depth on the cut surface is observed on histological assessment of ablation with TL-MS. Thus postoperative liver damage was occasionally encountered, although it was not serious complication.
The important considerations for deciding upon the indication of laparoscopic hepatectomy includes size, type and location of the tumor. Tumors smaller than 4 cm of the nodular type or smaller than 6 cm of the pedunculated type serve as proper indication although we have successfully experienced the patient with giant hepatocellular carcinoma sized 15 cm in the left lobe who was treated using a laparoscopic-assisted technique [6]. Concerning location, tumors in the lower segment and the left lateral segment are good candidates. As for tumors located in the upper segment, thoracoscopic hepatectomy or hand assisted surgery may be feasible. Concerning the operative methods, laparoscopic hepatectomy involving partial hepatectomy and left lateral segmentectomy is a feasible and less invasive operation in our experience. However, the overarching principle of laparoscopic surgery is to achieve minimal invasiveness with optimal safety; thus, laparoscopic right lobectomy is relatively invasive to provide the expected benefits of laparoscopic surgery so far, unless more advanced technology is acquired.

Although, liver resection is one of the last areas of resistance to the offensive of laparoscopic surgery, hepatic resection stands alone in procedure, without any need of reconstruction, and it might therefore be considered suitable for a laparoscopic approach. Laparoscopic hepatectomy will not totally supplant open hepatectomy, but the laparoscopic approach in selected patients should be considered the treatment of choice. Laparoscopic hepatectomy avoids the disadvantages of standard hepatectomy, and is beneficial for the patients’ quality of life as a minimally invasive operation although prospective randomized trials are still required to confirm those results. This procedure is in need that well experienced endoscopic surgeon and well-experienced liver surgeon should be collaborated in laparoscopic hepatectomy and the indications are strictly followed based upon the location and size of tumors. Finally, critical determinant for success and safe laparoscopic hepatectomy is through familiarity with the relevant laparoscopic instruments and equipments.

Laparoscopic hepatectomy is expected to develop further in the future as a new surgical instrument, equipment and method, which improves patients’ quality of life.

References