Background: Recent innovations in laparoscopic instrumentation make routine resection of solid organs a clinical possibility.

Hypothesis: Hand-assisted laparoscopic liver resection is a safe and feasible procedure for solitary cancers requiring removal of 2 segments of liver or less.

Design and Patients: Eleven patients with liver tumors deemed technically resectable by laparoscopic techniques were subjected to laparoscopic evaluation and attempted hand-assisted laparoscopic resection between July 1998 and July 1999. During the same period, 230 patients underwent open liver resection.

Setting: Tertiary care referral center for liver cancer.

Main Outcome Measures: Success of laparoscopic resection, reasons for conversion to open liver resection, blood loss, tumor clearance margin, complications, and length of hospital stay.

Results: Five patients underwent successful resection by the hand-assisted laparoscopic technique. Data from the 5 successful cases and the 6 aborted cases are presented to outline the issues and the lessons learned.

Conclusions: In selected patients, hand-assisted laparoscopic liver resection can be safely performed and might have potential advantages over traditional liver resection if the tumor is limited to the left lateral segment or is at the margins of the liver.


Advances in laparoscopic techniques have revolutionized surgical therapy for a number of common conditions. For patients with gallstone disease, laparoscopic cholecystectomy and common bile duct exploration have been instrumental in effective treatment and in decreasing the morbidity involved with such treatments.1,2 Laparoscopic fundoplications have also provided effective relief for many patients with gastric reflux.3 Recent improvements in laparoscopic staplers now allow facile resection and anastomosis of hollow organs laparoscopically, which has led to active investigation of the safety and long-term results of laparoscopic colonic resection13 and gastric resection6-8 for cancer that may well change the standards of surgical techniques for disease at these organ sites.

Laparoscopic instrumentation and techniques are also beginning to be extended to resection of solid organs. Splenectomy,9 adrenalectomy,10 and nephrectomy11-14 are now performed using laparoscopic techniques at several major medical centers. For certain organ sites, however, including the liver and the pancreas, resection using laparoscopic techniques has been regarded with skepticism. Although isolated case reports15,16 and small series17-20 have been published, these procedures have been considered curiosities. In particular, resection in these organs for cancer has been thought unlikely to become part of routine clinical practice. Obstacles to routine laparoscopic surgery on these organs are mainly related to difficulty in retraction with current instrumentation, difficulty in assessing safe margins of resection with loss of tactile senses, difficulty in safe parenchymal transection laparoscopically, and the potential catastrophic consequences of injuring major adjacent structures.

Technological advancements in recent years now make routine use of laparoscopic liver resection a clinical possibility. These advancements include refinement in laparoscopic ultrasound,21,22 experience in stapling techniques in the liver,23 development of coagulating parenchymal...
PATIENTS, MATERIALS, AND METHODS

PATIENT CHARACTERISTICS

This experience was culled from treatment of 241 patients by liver resection between July 1998 and July 1999 at the Memorial Sloan-Kettering Cancer Center, New York, NY. Patient characteristics and tumor types of the 11 patients who underwent hand-assisted laparoscopic resection in this initial experience are listed in Table 1. The patients were chosen because they had solitary lesions in an area thought to be resectable by laparoscopic means. In addition, these patients had tumors thought to be removable by resecting 2 segments of liver or less. The resection specimens, therefore, were considered to be easily removable through a hand port.

SURGICAL TECHNIQUE

Port Placement

All operations were performed with the patient in the supine position; if the lesions were at the extreme right or left of the liver, the patient was rotated slightly and supported with rolls under the flank of the appropriate side. Laparoscopic port site placement for left lateral segmentectomy is illustrated in Figure 1 and Figure 2. For lesions in segments 5 or 6, the hand port was placed in the right upper quadrant and the ports for the harmonic scalpel or stapler were placed in the left upper quadrant. Port sites were planned such that using the hand port, the surgical specimen could be retracted away from the line of transection. The hand provided traction while the natural diaphragmatic attachments of the liver provided countertraction. The camera port was planned so that it was directed at the tumor site. When placing additional ports, 10- or 12-mm ports were favored because the laparoscope could then be placed in each of the ports to allow visualization of the resection from multiple angles. A 12-mm port was placed when it was anticipated that a stapling device would be used. If additional ports were needed for use with only the ultrasonic dissector (harmonic scalpel), then additional 5-mm ports were placed without hesitation.

Anesthetic Technique

The anesthetic technique for laparoscopic liver resection was similar to that for open resection of the liver.26 Briefly, central venous pressure was kept low to decrease bleeding from any cut hepatic veins. To maintain blood pressure and decrease the chance for air embolism or carbon dioxide embolism, the patient was placed in the Trendelenburg position. Positioning of patients is as for open hepatectomy, in which air embolism is also a theoretical risk because of our practice of keeping central venous pressure between 0 and 5 cm H2O. Using the Trendelenburg position, we did not experience any clinically apparent air embolisms.28 This preliminary experience with laparoscopic hepatectomy indicates that use of a low–central venous pressure anesthetic technique is possible even in patients undergoing laparoscopy and abdominal insufflation.

Procedure

A single 10-mm port was placed first, usually in the right or left upper quadrants in the midclavicular position, along the line of a subcostal incision. The first port is placed in the side opposite the anticipated side of the hand port. We preferred the open technique for port introduction because many patients undergoing liver resection will have had previous abdominal operations. The most common indication for hepatectomy in the United States is metastatic colorectal cancer. Adhesions resulting from a previous colon

transsection tools such as the ultrasonic dissector (harmonic scalpel),9,24 and development of hand-assisted laparoscopic techniques.25-27 The present article represents 11 attempted resections by the laparoscopic technique for liver tumors and demonstrates that such resections can be done with safety and expedience. The difficulties and pitfalls of such a technique for liver resection are also presented to guide future trials of such resections.

RESULTS

REASONS FOR IRRESECTABILITY

There were 3 patients who were explored for possible laparoscopic resection for whom resection was not carried out laparoscopically because of difficulty in identifying tumor margins and difficulty in retraction. These tumors were in segments 4a and 4b and at the junction of segments 6 and 7.

Two other patients were converted to open surgery because dense adhesions prevented laparoscopic resection with expedience. One of these patients previously underwent right-sided nephrectomy and colectomy. He presented with a metastatic colon cancer in segment 6. One other patient previously underwent open cholecystectomy and colonic resection. Dense adhesions in the right upper quadrants in these patients prevented laparoscopic resection.

One other patient with a cystic neoplasm of the liver arising in segment 3 had a tumor that was inseparable from the transverse colon. A combined liver and colon resection was necessary for resection, which was performed using an open technique to ensure negative margins.

RESULTS OF LAPAROSCOPIC RESECTION

Details of the 5 successful resections are shown in Table 2. Median operative time was 248 minutes (range, 143-358 minutes). The patient who required 358 minutes for resection was the first patient subjected to laparoscopic liver resection. Median hospital stay was 5 days. Three of the 5 patients had no complications from surgery. Hospital stays for patients with uncomplicated recoveries were 2, 3, and 5 days. Two patients had complications. One had a bile leak after resection that was treated by percutaneous external drainage. This bile leak stopped spontaneously and
resection make open introduction of laparoscopic ports safer. The angled telescope was used, and abdominal exploration was performed visually. In patients in whom irresectable disease is found, a second port could be placed for biopsy or laparoscopic ultrasound. The second port also allows introduction of other instruments to assist in abdominal exploration. If, on inspection, there are no signs of irresectability, the template for the hand port is traced on the abdominal wall with the abdomen insufflated, which allows for use of an incision of minimal size, an airtight fit, and optimum planning in the placement of various ports for therapeutic maneuvers. A cutdown was then performed through the abdominal wall to allow placement of the hand port (Pneumo Sleeve; Dexterity Inc, San Antonio, Tex). The hand was then introduced into the abdomen and the abdomen was reinsufflated. Full exploration of the abdomen was performed under laparoscopic vision, with manual palpation of the various areas. The hand can also be removed and the laparoscopic ultrasound can be introduced through the hand port or through other ports to perform laparoscopic ultrasound of the liver. After such full exploration of the abdomen and the liver, a decision on resection can sensibly be made.

If at this point the decision was to proceed with the resection, several items were introduced into the abdomen, including a laparotomy sponge to facilitate retraction and absorb blood, as would be used in an open operation. We also introduced a long bulldog clamp into the abdomen to be used for the Pringle maneuver. A long umbilical tape was tied to the bulldog clamp before its introduction to help locate this instrument throughout the procedure. Additional ports were placed as necessary at this time for use of other instruments, including the stapler or the harmonic scalpel. Ten- or 12-mm ports were preferred because they allow flexibility for instrumentation. It is recommended that the hand be removed from the abdomen during introduction of additional ports.

The hand was then reintroduced. The liver on the side of the resection was mobilized. Division of the triangular ligaments was performed with electrocautery, scissors, or a harmonic scalpel. Usually, the lesser omentum was divided to allow access to the lesser sac during exploration because evaluation of the portal, portacaval, and celiac nodes is best performed with the lesser omentum divided. Care must be taken to protect any replaced or accessory left hepatic arteries crossing the lesser omentum from the left gastric artery. If an accessory or a replaced left hepatic artery was noted at this point, 2 bulldog clamps were placed within the abdomen since the porta hepatis and this accessory vessel required clamping for an effective Pringle maneuver to be performed.

The area of liver to be resected was outlined using electrocautery after evaluation by palpation and by laparoscopic ultrasound. Major portal pedicles and hepatic veins were found by laparoscopic ultrasound so that the parenchymal transection could be planned with the appropriate instruments for ligation of these major structures.

With retraction of the liver using the hand, parenchymal transection was performed under intermittent Pringle application. Liver parenchyma remote from major portal pedicle or hepatic veins was transected using an ultrasonic dissector (US Surgical Corp, Norwalk, Conn) or finger fracture with ligation of the vessels using surgical clips. At areas of major pedicles or hepatic veins, an endogastrintestinal anastomotic (endo-GIA) vascular stapler was introduced, and these major vascular structures were divided with hemostasis.

The inner sheath of the hand port provides a good wound protector for the removal of the tumor. The specimen was immediately examined for clearance of tumor. Hemostasis was confirmed. An argon beam coagulator (Conmed Corp, Utica, NY) and hemostatic agents were used. Laparoscopic ports were removed under direct vision. All the ports except the hand port can be closed from the inside. The hand port was then closed directly. No abdominal drainage was necessary.29

In comparison, 230 patients who were not subjected to attempted laparoscopic hepatectomy in this same period had mean±SEM blood loss of 767±73 mL (median, 450 mL; range, 20-5000 mL). For this group of patients undergoing open hepatectomy, mean±SEM op-

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Table 1. Characteristics of All Patients Considered for Laparoscopic Resection*

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Primary Cancer</th>
<th>Segments Involved</th>
<th>Previous Surgery</th>
<th>Reason for Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/65</td>
<td>HCC</td>
<td>3</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>2/F/67</td>
<td>Met CR Ca</td>
<td>2 and 3</td>
<td>Colectomy</td>
<td>NA</td>
</tr>
<tr>
<td>3/F/60</td>
<td>HCC</td>
<td>2</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>4/F/53</td>
<td>Met breast Ca</td>
<td>6</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>5/M/75</td>
<td>HCC</td>
<td>5</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>6/F/74</td>
<td>Met CR Ca</td>
<td>6</td>
<td>Colectomy and cholecystectomy</td>
<td>Adhesions</td>
</tr>
<tr>
<td>7/M/76</td>
<td>Met CR Ca</td>
<td>4a</td>
<td>Colectomy</td>
<td>Tumor too high and deep</td>
</tr>
<tr>
<td>8/F/57</td>
<td>Cystic neoplasm</td>
<td>3</td>
<td>None</td>
<td>Adherence of transverse colon</td>
</tr>
<tr>
<td>9/F/65</td>
<td>HCC</td>
<td>4b</td>
<td>None</td>
<td>Severe cirrhosis, tumor poorly defined</td>
</tr>
<tr>
<td>10/M/51</td>
<td>Met CR Ca</td>
<td>5 and 6</td>
<td>Right nephrectomy</td>
<td>Adhesions</td>
</tr>
<tr>
<td>11/F/71</td>
<td>Met CR Ca</td>
<td>4b</td>
<td>Colectomy and cholecystectomy</td>
<td>Adhesions</td>
</tr>
</tbody>
</table>

* Patients 1 through 5 were resected laparoscopically and patients 6 through 11 had conversion to open resection. HCC indicates hepatocellular carcinoma; Met CR Ca, metastatic colorectal cancer; Met breast Ca, metastatic breast cancer; and NA, not applicable.
operative time was 256±7 minutes (median, 238 minutes; range, 85-690 minutes), and mean±SEM hospital stay was 9.2±0.3 days (median, 8 days; range, 4-37 days).

**COMMENT**

Laparoscopic techniques have clearly advanced the treatment of many diseases related to the liver and biliary tree. Laparoscopic cholecystectomy has radically changed the treatment of gallstone disease and is now standard treatment for patients with cholecystolithiasis.1,2 Laparoscopic common bile duct exploration now allows minimally invasive treatment of choledocholithiasis.30 These procedures no doubt have provided effective therapy while minimizing the morbidity of surgical treatment in gallstone disease. Laparoscopic resections of cystic lesions of the liver have also been described20,31 and are a sensible way of treating symptomatic benign cysts or infected simple cysts of the liver. Although laparoscopic staging is increasingly used to prevent unnecessary laparotomies in patients with hepatobiliary cancers,21,32,33 laparoscopic resections of liver tumors are still reported only in case reports or small series.15-20 The largest of these series20 reported

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Operation</th>
<th>Blood Loss, mL</th>
<th>Operating Room Time, min</th>
<th>Tumor Size, cm</th>
<th>Margin, cm</th>
<th>Complications</th>
<th>Length of Hospital Stay, d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>Segment 3 resection</td>
<td>500</td>
<td>358</td>
<td>5.0</td>
<td>2.2</td>
<td>Biloma</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>Thoracoscopy and wedge lung resection; left lateral segmentectomy</td>
<td>200</td>
<td>270</td>
<td>5.0</td>
<td>0.6</td>
<td>Clostridium difficile colitis</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Segment 2 resection</td>
<td>100</td>
<td>143</td>
<td>4.0</td>
<td>0.4</td>
<td>None</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Segment 6 resection</td>
<td>400</td>
<td>248</td>
<td>2.0</td>
<td>0.4</td>
<td>None</td>
<td>3</td>
</tr>
<tr>
<td>5*</td>
<td>Segment 5 resection</td>
<td>100</td>
<td>180</td>
<td>2.5</td>
<td>0.3</td>
<td>None</td>
<td>5</td>
</tr>
</tbody>
</table>

*Patients with cirrhosis of the liver.
laparoscopic resections of benign lesions. In general, laparoscopic resections of liver parenchymal tumors is still regarded as adventurous and a surgical curiosity by the surgical community. This is the first study of hand-assisted laparoscopic resection of liver tumors and demonstrates that such resections are feasible. These operations can be done with expediency and safety.

Several technological advances have greatly facilitated laparoscopic liver resections. Familiarity with laparoscopic ultrasound and use of stapling devices on the liver are invaluable in planning and assisting with such resections. Availability of hemostatic devices such as the ultrasonic dissector (harmonic scalpel) also greatly facilitates such resections because although finger fracture, clamp fracture, or dissection with the jet dissector followed by clipping of vessels as is done in open surgery can be imitated in laparoscopic resection, the repeated exchange of instruments through the ports to accomplish this would make such techniques cumbersome and too time consuming for routine use. The laparoscopic ultrasonic dissector (harmonic scalpel) allows division and coagulation of the liver parenchyma with sealing of the blood vessels and biliary radicals. The hand port for hand-assisted resection, however, represents one of the most important advances because there is no good laparoscopic retractor of the liver that is atraumatic and versatile. The hand represents the best-known liver retractor to date, and the ability to use the hand for retraction in laparoscopic resection greatly facilitates such surgery.

Great concern about performing laparoscopic resection for cancer has been raised regarding adequacy of tumor clearance. This is the basis of current multicenter trials of laparoscopic colon resection vs open resection. In the liver, it could be argued that the risk of violating tumor during parenchymal transection is even greater than in resection of hollow organs. With hand-assisted resection, palpation of the tumor is possible, and parenchymal transection can be performed with greater confidence than in non–hand-assisted laparoscopic resection of the liver. In addition, the hand also allows for finger fracture of the liver to identify major pedicles and hepatic veins for stapling. In contrast to open surgery, during laparoscopic resection there needs to be a major technical change in the practice of parenchymal transection. In open surgery, the practice is to bring the transection instruments to the liver, whereas in laparoscopic resections, because the port site is fixed, the liver needs to be guided to the line of the instruments coming through the ports. The hand allows this maneuver to be performed efficiently.

Another major obstacle to laparoscopic resection of the liver has been concerns regarding catastrophic consequences of vascular injury that might lead to hemorrhage or carbon dioxide embolus if the hepatic veins are transgressed. We did not experience such problems in this initial experience. However, we still do not recommend laparoscopic resection of tumors that are in intimate relation to the vena cava or its junctions with major hepatic veins. For small hepatic veins, even if the vein is cut during hand-assisted resection, immediate hemostasis using finger compression of the open vein can be obtained. Hemostasis generally can be achieved by suture ligation or application of hemostatic clips. However, conversion to open surgery, if necessary, can also be performed expeditiously because the hand port can be extended to a full laparotomy incision with expediency.

Patient selection is essential for safe laparoscopic resection of liver tumors. Resection of the left lateral segment performed in this initial experience, for example, had tumor at the tip of segments 2 and 3 (Figure 3); therefore, transecting parenchyma near the umbilical fissure would give clearance of tumor with confidence. The best
patients for laparoscopic resection are therefore those with tumors at the inferior edges of the liver or with tumor confined only to the left lateral segment because of technical issues with access to the tumor and ease of retraction of these areas for parenchymal transection. Tumors in segment 4a, 7, or 8 are poor candidates for laparoscopic resection because these tumors near the dome of the liver are difficult to expose and tumor transgression or vascular injury during parenchymal transection is a major concern.

Our preliminary experience leads us to believe that many of the technological barriers to laparoscopic resection have been overcome. Doubtless future advances in instrumentation will facilitate such resections even further. We believe that tumors at the lower free edge of the liver or solely in the left lateral segment are the best candidates for such resection. In addition, benign tumors in which margins are of much lesser importance are particularly good candidates for laparoscopic resection. The hand-assisted technique represents a sensible approach to such resections because it increases confidence in margins, increases safety, and facilitates removal of the resected specimens. The greatest potential for benefit of such laparoscopic resections is minimalization of the size of incision and minimization of heat loss and evaporation during surgery. A 4-cm hand port incision should lead to a more rapid recovery than a 35-cm subcostal incision and should result in a decreased chance for ascitic leaks. Although major resections are feasible with current instruments, the best candidates for laparoscopic hepatectomy are therefore those requiring removal of 2 or fewer segments of liver because these specimens are readily removable through an incision the size of a hand port. Whether such resections are in fact superior to traditional open resection will require future comparative trials with long-term oncologic results, length of hospital stay, and cost as outcome variables.

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