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SURGICAL ENDOSCOPY
and Other Interventional Techniques

Laparoscopic vs open hepatic resection

A comparative study

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Abstract
Background: Although the feasibility of minor laparoscopic liver resections (LLR) has been demonstrated, data comparing the open vs the laparoscopic approach to liver resection are lacking.
Methods: We compared 30 LLR with 30 open liver resections (OLR) in a pair-matched analysis. The indications for resection were malignant disease in 47% of the LLR and 83% of the OLR. The average size of the lesions was 42 mm for LLR and 41 mm for OLR. Five wedge resections, 12 segmentectomies, and 13 bisegmentectomies were performed in each group.
Results: The conversion rate for LLR was nil. The mean operative time was 148 min for LLR and 142 min for OLR. Mean blood loss was minimal in the LLR group (320 vs 479 ml; $p < 0.05$). Postoperative complications occurred in 6.6% of the patients in each group; there were no deaths. The mean postoperative hospital stay was shorter for LLR patients (6.4 vs 8.7 days; $p < 0.05$). In tumors, the resection margin was < 1 cm in 43% of the LLR patients and 40% of the OLR patients (p = NS).
Conclusions: Minor LLR of the anterior segments has the same rates of mortality and morbidity as OLR. However, the laparoscopic approach reduces blood loss and postoperative hospital stay.

Key words: Laparoscopy — Liver resection — Laparoscopic hepatectomy — Laparotomic hepatectomy

Since the introduction of laparoscopic cholecystectomy in 1987, the laparoscopic approach has been applied to the full spectrum of abdominal procedures. Nevertheless, the laparoscopic approach has not been fully developed for liver resections. The reasons for this reductance are the presumed technical difficulty and concern about the intraoperative hazards of bleeding and gas embolism. Another concern is uncertainty about the long-term results of laparoscopic surgery in patients with malignant disease, who constitute the majority of candidates for liver resections.

However, technological refinements in laparoscopic instruments, the growth of practical experience in laparoscopic and hepatic surgery, and the application of laparoscopy to oncologic surgery have encouraged some practitioners to explore the role of laparoscopy in liver resections. Initial laparoscopic liver procedures included biopsies [8], tumor staging [12], and the fenestration of nonparasitic liver cysts [15]. More recently, there have been reports of limited series of laparoscopic liver resections [1, 5, 7, 9–11, 13, 16, 17]. Although limited in numbers of patients and lacking in long-term results, these series have shown the feasibility of laparoscopic liver resection and further suggested that laparoscopy will improve the postoperative course and reduce hospital stay when compared to the traditional open approach.

Nevertheless, to the best of our knowledge, comparative data, either retrospective or prospective, are limited to a single report of 34 cases: 17 laparoscopic vs 17 open [16]. Therefore, we reviewed our files to identify patients who had undergone liver resection and compared the laparoscopic cases with pair-matched open hepatectomies, with the aim of evaluating the short-term outcome of these procedures.

Materials and methods

Between January 1997 and December 2001, 155 liver resections were performed at the Second Department of General Surgery of the University of Turin, of which 30 (19%) were performed laparoscopically. The mean age of the patients in the laparoscopic group was 56 years (range, 25–78); 14 patients were male and 16 were female (Table 1).

The pathology reports showed that 16 lesions (53%) were benign and 14 (47%) were malignant. The benign lesions consisted of four hemangiomas (three of them were bulky and symptomatic, and one was believed to be a liver metastasis in a patient with a previous colonic adenocarcinoma), one hydatid cyst, four adenomas, one liver adenomatosis, one focal nodular hyperplasia [FNH] that showed severe hemobilia after an ultrasound-guided liver biopsy, and five FNH in

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Table 1. Patients and methods

	Laparoscopy	Open
No. of patients	30	30
Age (yr)	56 (25–78)	58 (23–75)
Sex (F/M)	16/14	19/11
ASA status (I/II)	28/2	28/2
Malignant lesions	47%	83%
Mean size (mm)		
mean	42	41
range	3–100	12–100
median	28	35
Tumor location		
Segments II–III	16	13
Segment IV	2	5
Segments V–VI	12	12
Procedures		
Wedge resections	5	5
Segmentectomies	12	12
Bisegmentectomies	13	13

ASA, American Society of Anesthesiologists

which all the preoperative investigations could not exclude a malignancy. The malignant lesions included 10 liver metastases; the metastasis arose from colorectal adenocarcinoma in five patients, from lung cancer in two patients, from ovarian cancer in two patients, and from cancer of the stomach in one patient. There were three hepatocellular carcinomas in cirrhotic liver (grade A according to Child-Pugh) and one large-cell lymphoma.

The average size of the lesions was 42 mm (range, 3–100). The lesion was in hepatic segments II–III in 16 cases, in segment IV in two cases, and in hepatic segments V–VI in 12 cases. The lesion was solitary in 26 patients and double in four. We performed five wedge resections, 12 segmentectomies, and 13 bisegmentectomies according to the Couinaud classification [6]. In one case of left lobectomy, a wedge resection of segment VIII was done in the same operative setting. In nine patients, another associated laparoscopic procedure was performed, including six cholecystectomies, two left hemicolectomies, and one repair of a recurrent epigastric hernia.

The clinical data of these patients were compared with 30 conventional liver resections in a matched-pair analysis. The controls were selected from a computer database of 260 liver resections performed between January 1988 and December 1996. The pairs were matched for tumor location, type of resection, and tumor size; they were also matched for sex, age, American Society of Anesthesiologists (ASA) status, and the presence or absence of cirrhosis.

The mean age of the patients in the control group was 58 years (range, 23–75); 11 patients were male and 19 were female. The lesions were benign in five cases (17%) and malignant in 25 (83%). The benign lesions included two hemangiomas, two FNH, and one adenoma. The malignant lesions comprised thirteen liver metastases; the metastasis arose from colorectal carcinoma in nine patients, from gastric cancer in one patient, from renal cancer in one patient, from pancreatic cancer in one patient, and from anal carcinoma in one patient. Nine of the malignant lesions were hepatocellular carcinomas in cirrhotic liver (Child-Pugh grade A), and three were T1 gallbladder cancers diagnosed incidentally at histology. The average size of the lesions was 41 mm (range, 12–100). In this group, we performed five wedge resections, 12 segmentectomies, and 13 bisegmentectomies. In nine patients, another associated procedure was performed, including eight cholecystectomies and one inguinal hernia repair.

All patients were evaluated preoperatively according to a specified protocol that included abdominal ultrasound and angio-CT scan. In eight patients with a liver lesion of uncertain significance, MRI was performed. Three patients underwent a liver biopsy. In both the laparoscopic and open hepatectomy groups, several patients had had previous operations. In the laparoscopic group, seven patients (23%) had had a previous abdominal operation, including one fundoplication for hiatal hernia, one subtotal gastrectomy for gastric cancer, two laparotomies for ovarian cancer, two large bowel resections, and one laparoscopic right hemicolectomy. In the open hepatectomy group, 13 patients (43%) had had a previous operation, including nine colectomies, one gastrectomy, one pancreatectomy, one nephrectomy, and one abdomino perineal resection. According to the ASA classification, the two groups were identical: There were 28 ASA I and two ASA II in each group.

Operative technique

All of the operations were done under general anesthesia and were performed by the same surgeon (M.M.). Laparoscopic liver resections were performed respecting the rules dictated by traditional hepatic surgery [4]. In this group, the patient's position on the operating table was chosen according to the location of the liver lesion. The Lloyd-Davis position was preferred for lesions in segments II, III, IV, and V of the liver; the semi left-lateral decubitus position was used for the lesion in segment VI. A carbon dioxide pneumoperitoneum was induced with a Veress needle in patients with no history of previous abdominal surgery; we used an open technique in the others. Abdominal pressure was monitored and maintained at 12 mmHg. Four to five trocars were deployed along an ideal semicircular line, with the concavity facing the right subcostal margin. In most of the cases, we used 12-mm trocars, because of their usefulness for the introduction of the endo-stapler. In all the operations, a 30° video camera (Karl Storz, Tuttlingen, Germany) was used.

The abdominal cavity was explored for carcinosis or associated pathologies. Then the tumor was identified visually, when possible, and confirmed in all cases by laparoscopic ultrasound (Aloka, Tokyo, Japan). In all cases, the hepatic pedicle was isolated and a tape was passed around it; both ends were passed in a tourniquet to enable performance of a Pringle's maneuver), if needed. The dissection line was demarcated on the liver with monopolar cautery. Liver parenchymal transection was performed with an ultrasound scalpel (UltraCision; Ethicon Endosurgery, Cincinnati, OH, USA) in 28 patients and with crushing forceps in the first two cases. Intraparenchymal control of the major vessels was achieved with clips or sutures. In all left lobectomies (resections of segments II and III), the left hepatic vein was sectioned with a linear vascular endo-stapler. Section of the segmental bile ducts was performed by extraparenchymal ligation and scissors' sectioning in cases of left lobectomy (resections of segments II and III), using the ultrasound scalpel in other procedures.

Fibrin glue (Tissucol; Baxter, Vienna, Austria) was applied along the parenchymal transection line after hemostasis and biliostasis were achieved. Extraction of the liver specimen was always performed, using a plastic bag, through a mini-laparotomy below the right or left subcostal margin (the previous laparotomy scar was used when present). In all cases, a drain was inserted next to the dissected liver.

The open hepatectomies were performed according to the technique described by Bismuth [4]. In all patients, laparotomy was via a subcostal incision, followed by exploration of the abdominal cavity and visual identification of the lesions. An intraoperative ultrasound examination was always performed. Liver parenchymal transection was done with crushing forceps; hemostasis was achieved with monopolar cautery for small vessels and with nonabsorbable sutures or clips for larger ones. The parenchymal transection line was covered with fibrin glue. In all cases, a drain was inserted next to the dissected liver.

Evaluation criteria included duration of surgery, need for and duration of Pringle maneuver, blood loss, transfusion rate, resection margins, postoperative complications, perioperative mortality, and postoperative hospital stay.

Statistical analysis was done with the support of the program InStat, GraphPAD software (San Diego, California, USA) and included the chi-square test or the Mann-Whitney test when indicated. The level of significance was established at $p < 0.05$.

Results

There were no deaths or intraoperative complications in the entire study cohort. In all laparoscopic cases, the operation was successfully performed laparoscopically (conversion rate, 0%). Operative time was a mean of 148 min for the laparoscopic resections and 142 min for the open procedures (Table 2).

In 26 of the 30 laparoscopic cases (87%), the Pringle maneuver was not needed; in four cases (13%), including

Table 2. Results

	Laparoscopy	Open	*p* value
Operative time (min)			
Mean (median)	148 (150)	142 (140)	NS
Pringle (maneuver)	13%	53%	< 0.05
Mean (median)	320 (200)	479 (400)	< 0.05
Blood loss			
Cirrhotics, mean (median)	700 (600)	743 (500)	NS
Noncirrhotics, mean (median)	278 (125)	325 (250)	NS
Transfusions	4 (13%)	2 (6.6%)	NS
Complications	2 (6.6%)	2 (6.6%)	NS
Postoperative hospital stay			
Mean (median)	6.4 (6)	8.7 (8)	< 0.05
Cirrhotics, mean (median)	12.6 (13)	9.3 (9)	NS
Noncirrhotics, mean (median)	5.7 (6)	8.5 (8)	< 0.05
Resection margins in malignant tumors			
Invaded	0%	4%	NS
< 1 cm	43%	40%	NS
> 1 cm	57%	56%	NS

three cirrhotic patients, it was necessary for a mean of 20.5 min. In 14 of the 30 open resections (47%), the Pringle maneuver was not needed, but it was necessary for a mean of 23.6 min in 16 cases (53%), including eight cirrhotic patients. Mean blood loss was 320 ml (range, 50–1500) for the laparoscopic group and 479 ml (range, 100–2100) for the open group ($p < 0.05$). Blood transfusion was required in four patients (13%) in the laparoscopic group (two cirrhotic patients, one FNH, and one acute hemobilia caused by a fine-needle biopsy) and in two cirrhotic patients (6.6%) in the open group (p = NS).

Postoperative complications occurred in two patients in each group (6.6%). In the laparoscopic group, both complications occurred in cirrhotic patients who had had a segmentectomy for hepatocarcinoma. They developed postoperative ascites, which was treated successfully with diuretics. These two complications prolonged the postoperative hospital stay to days 13 and 16, respectively. In the laparotomy group, the postoperative complications consisted of postoperative ascites and pleural effusion in one cirrhotic patient and an isolated pleural effusion in one noncirrhotic patient.

The mean postoperative hospital stay was 6.4 days (range, 2–16) in the laparoscopic group, 5.7 days for noncirrhotic patients and 12.6 days for cirrhotic ones. In the open group, the mean postoperative hospital stay was 8.7 days (range, 2–17), 8.5 days for noncirrhotic patients and 9.3 days for cirrhotic ones. The postoperative hospital stay was significantly longer in the open group than in the laparoscopic one (8.7 vs 6.4 days; $p < 0.05$). In both groups, cirrhotic patients had a longer postoperative hospital stay.

For malignant lesions, the histological report was reviewed with respect to the resection margins. In eight of 14 specimens (57%) in the laparoscopic group, the resection margin was > 1 cm; in the remaining six specimens (43%) there was a margin of < 1 cm, but in no case was the resection margin invaded by tumor. In the open group, the resection margin was > 1 cm in 14 of 25 specimens (56%) and < 1 cm in 10 cases (40%). In one patient (4%), the resection margin was infiltrated by tumor (NS).

Discussion

Despite great advances in laparoscopic technique and associated technology, the laparoscopic approach has not been fully developed for liver resections, and only limited series have been published. In a recent review of the literature, Biertho et al. [3] analyzed 186 laparoscopic liver resections performed between 1991 and 2001. This study confirmed the feasibility and safety of the laparoscopic approach for minor liver resections (92% of the reported resections) in selected patients and in the setting of a tertiary referral center for hepatobiliary surgery and advanced laparoscopic surgery. The reported mortality and morbidity rates were 0.54% and 16%, respectively, with a conversion rate of 7%. The mean postoperative stay was 7.7 days. However, the current literature does not enable any comparison with open hepatectomy, because of the limited number of cases reported (< 30 for each series), the extreme criteria for the selection of the patients, and the paucity of reports of major hepatic resection (only 16 major hepatectomies were reported) [3]. To address this gap, we performed a retrospective review of our liver resection cases and compared the laparoscopic cases with pair-matched open hepatectomies, with the aim of evaluating the advantages and disadvantages of the two approaches.

As we have already reported [15], and in the view of most other investigators in this area [5, 7, 13], the most important factor in the selection of candidates for laparoscopic resection, more so than the nature (benign or malignant) of the tumor, is the tumor's location within the liver. We believe that lesions of the left liver lobe and the anterior segments (IV anterior, V, VI) according to Couinaud [6] constitute a good indication for the laparoscopic approach, whereas lesions of the posterior and superior liver segments (VII, VIII, IV posterior, and I) are technically demanding and should only be approached with extreme caution. Another important factor in the selection of patients for a laparoscopic approach is the size of the lesion. In our series, the mean diameter of the liver lesions was small (42 mm), as in most of the reported series (average diameter, < 5 cm). Only anecdotal cases of larger lesion have been reported; and in most of these cases, the tumor was peripheral and protruding from the hepatic parenchyma [9]. Therefore, in the study period, we selected small lesions in the peripheral segments (segments II, III, IVa, V and VI) for the laparoscopic approach.

By comparing our laparoscopic cases with a similar series of open hepatectomies performed by the same surgeon (M.M.), we were able to confirm the feasibility and safety of the laparoscopic hepatectomy, with a nil mortality rate and a morbidity rate of 6.6% for the entire study cohort. Blood loss was significantly greater in the open group (mean, 479 ml; range, 100–2100) than in the laparoscopic one (mean, 320 ml; range, 50–1500) ($p < 0.05$). This significant difference cannot be explained by

the different distribution of cirrhotic patients in the study cohort; because there is no significant difference in the amount of blood loss in the two groups of cirritic patients (open vs laparoscopic). In fact, there was a tendency toward a reduction of blood loss in cirrhotic patients treated with a laparoscopic technique (700 vs 743 ml), although it was not significant. One interesting result of our study was that the operating time was about the same in both groups (148 vs 142 min; p = NS), a finding that is at odds with reports showing that the operating time was longer for laparoscopic liver resection [3]. We believe that these data, as well as our nil conversion rate, can be explained by the extensive experience of our team with laparoscopic procedures and by careful patient selection. The Pringle maneuver was necessary less often in the laparoscopic group (17% vs 53%), but there were no differences in clamping time when it was applied. We believe that the hemostatic effect of the pneumoperitoneum and the use of the ultrasonic scalpel were responsible for the reduced rate of Pringle maneuvers in the laparoscopic group. The association of reduced blood loss and reduced liver ischemia, both well-known causes of postoperative morbidity after liver resections [4], may explain the low morbidity rate in our series.

As has also been the case with to other laparoscopic procedures [2, 14], the main clinical advantage of using a minimally invasive technique to gain access for the liver resection was a significantly shorter postoperative hospital stay. The mean difference between the two groups was 2 days (6.4 vs 8.7 days; $p < 0.05$).

Although our data are encouraging, one must keep in mind that there are potential risks associated with laparoscopic liver resection, in particular with regard to gas embolism and vascular lesions. In their review of 186 laparoscopic liver resections, Biertho et al. [3] reported two cases of gas embolism (1.1%). Both of them were associated with the use of argon cautery, which causes an increase in intraabdominal pressure with a concomitant higher risk of gas embolism. One of the two patients suffered a cardiac arrest; however, after immediate cardiovascular resuscitation, the patient recovered fully.

Recently, Schmandra et al. [19] published an alarming experimental study in pigs. The pigs were divided into two groups; the first group received a laparoscopic liver resection, the second an open hepatectomy. All of the animals were monitored for gas embolism with transesophageal ultrasound throughtout the operation. In the laparoscopic group, all the operations were associated with gas micro-embolism, but there were no emboli in the open group. The microemboli caused minor self-limiting cardiac arrhythmias in 57% of episodes, but there were no long-term clinical consequences. These data provide a vivid demonstration of the potential risk of gas embolism associated with laparoscopic liver resection and suggest the need to evaluate alternative techniques, such as the use of gasless laparoscopy or a combination of low-pressure pneumoperitoneum with an abdominal lifting system.

The introduction of the ultrasound scalpel has greatly improved the ability to maintain hemostasis during laparoscopic surgery [18]; nevertheless, hemostasis is still a major challenge in laparoscopic liver resection, and there is an imperative need for technical to the current generation of improvements hemostatic devices.

There is no reason to modify the philosophy of management for patients suffering from benign liver tumors based on the availability of surgeons frained in minimally invasive surgery. All of the benign tumors in this series were either symptomatic or suspected malignancies or adenomas. The slight increase in the rate of resections for benign lesions in the laparoscopc era (7% between 1988 and 1996 and 12% between 1997 and 2001) mainly reflects a selection bias, because some patients in the recent years were specifically advised by gastroenterologists to undergo a laparoscopic procedure.

In our series, malignancy was not a contraindication for the laparoscopic approach. In fact, there is no evidence in the literature that the use of laparoscopic techniques increases the risk of tumor dissemination. Our patients have not experienced any port site or cutaneous metastasis, nor any abdominal carcinomatosis. According to the most recent reports, in contrast with some earlier reports that suggested an association between laparoscopy and a higher risk of cutaneous metastases, the reported incidence of cutaneous metastases is the same for both laparoscopic and open surgery [20]. Moreover, in a recent prospective, randomized study with a mean follow-up of 43 months, Lacy et al. [14] reported that survival was better after laparoscopic colonic resection for cancer than with the traditional open resection.

Gigot et al. [11] emphasized the potential risk of insufficient tumor clearance with respect to the resection margin when the laparoscopic approach was used for liver resection. In our series, there was no difference between the two groups in the margin of clearance. The resection margin was invaded (4%) in only one open hepatectomy. We achieved a tumor-free surgical margin of >1 cm in 57% and 56% of the malignant lesions in the laparoscopic and open groups, respectively; in 43% and 40% of the cases, respectively, the resection margin was <1 cm. None of the previous differences reached statistical significance.

In conclusion, our data suggest that laparoscopic surgery is a good alternative to open surgery for minor liver resections in selected patients. Further study with a greater number of cases, a longer follow-up, and prospective randomization is needed to better define the role of laparoscopic liver resections—in particular, with regard to malignant lesions.

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