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SURGICAL ENDOSCOPY
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# Laparoscopic liver resection of benign liver tumors

## Results of a multicenter European experience

**B. Descottes,[1] D. Glineur,[2] F. Lachachi,[1] D. Valleix,[1] J. Paineau,[3] A. Hamy,[3] M. Morino,[4] H. Bismuth[5] D. Castaing,[5] E. Savier,[5] P. Honore,[6] O. Detry,[6] M. Legrand,[6] J. S. Azagra,[7] M. Goergen[7] M. Ceuterick,[7] J. Marescaux,[8] D. Mutter,[8] B. de Hemptinne,[9] R. Troisi,[9] J. Weerts,[10] B. Dallemagne[10] C. Jehaes,[10] M. Gelin,[11] V. Donckier,[11] R. Aerts,[12] B. Topal,[12] C. Bertrand,[13] B. Mansvelt,[13] L. Van Krunckelsven,[14] D. Herman,[15] M. Kint,[16] E. Totte,[17] R. Schockmel,[18] J. F. Gigot[2]**

[1] Hopital Universitaire Dupuyten, Limoges, France
[2] Cliniques Universitaires Saint-Luc, Brussels, Belgium
[3] Centre Hospitalier Universitaire de Nantes, Nantes, France
[4] Centro Universitario di Chirurgia Mini-invasiva, Torino, Italy
[5] Centre Hépato-Biliaire, Paris, France
[6] Hospital Universitaire du Sart-Tilman, Liège, Belgium
[7] CHU Vésale, Montignies-le-Tilleul, Belgium
[8] Hopital Civil, Strasbourg, France
[9] Academish Ziekenhuis Gent, Gent, Belgium
[10] Clinique Saint-Joseph, Liège, Belgium
[11] Hospital Erasme, Brussels, Belgium
[12] AZ Gasthuisberg, Leuven, Belgium
[13] Hospital de Jolimont, Haine-St-Paul, Belgium
[14] AZ Jan Yperman, Ieper, Belgium
[15] Centre Hospitalier de l'Ardenne, Libramont, Belgium
[16] AZ Sint-Lucas, Gent, Belgium
[17] Academic Surgical Center of Stuivenberg, Antwerp, Belgium
[18] Hospital Princesse Marie, Astrid, Niedercorn, Grand-Duché du Luxembourg

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**Abstract**
*Objective:* The objective of this study was to assess the feasibility, safety, and outcome of laparoscopic liver resection for benign liver tumors in a multicenter setting.
*Background:* Despite restrictive, tailored indications for resection in benign liver tumors, an increasing number of articles have been published concerning laparoscopic liver resection of these tumors.
*Methods:* A retrospective study was performed in 18 surgical centres in Europe regarding their experience with laparoscopic resection of benign liver tumors. Detailed standardized questionnaires were used that focused on patient's characteristics, clinical data, type and characteristics of the tumor, technical details of the operation, and early and late clinical outcome.
*Results:* From March 1992 to September 2000, 87 patients suffering from benign liver tumor were included in this study: 48 patients with focal nodular hyperplasia (55%), 17 patients with liver cell adenoma (21%), 13 patients with hemangioma (15%), 3 patients with hamartoma (3%), 3 patients with hydatid liver cysts (3%), 2 patients with adult polycystic liver disease (APLD) (2%), and 1 patient with liver cystadenoma (1%). The mean size of the tumor was 6 cm, and 95% of the tumors were located in the left liver lobe or in the anterior segments of the right liver. Liver procedures included 38 wedge resections, 25 segmentectomies, 21 bisegmentectomies (including 20 left lateral segmentectomies), and 3 major hepatectomies. There were 9 conversions to an open approach (10%) due to bleeding in 45% of the patients. Five patients (6%) received autologous blood transfusion. There was no postoperative mortality, and the postoperative complication rate was low (5%). The mean postoperative hospital stay was 5 days (range, 2–13 days). At a mean follow-up of 13 months (median, 10 months; range, 2–58 months), all patients are alive without disease recurrence, except for the 2 patients with APLD.
*Conclusions:* Laparoscopic resection of benign liver tumors is feasible and safe for selected patients with small tumors located in the left lateral segments or in the anterior segments of the right liver. Despite the use of a

*Correspondence to:* J. F. Gigot

laparoscopic approach, selective indications for resection of benign liver tumors should remain unchanged. When performed by expert liver and laparoscopic surgeons in selected patients and tumors, laparoscopic resection of benign liver tumor is a promising technique.

**Key words:** Laparoscopy — Hepatectomy — Liver resection — Benign tumor — Liver tumor

With a more clear classification of hepatocellular tumors [1], a better understanding of the natural history of these tumors, and recent improvement of modern imaging techniques, the indications for surgical resection of benign liver tumors have been progressively restricted and tailored according to each type of liver tumor. Due to their indolent natural history, liver hemangiomas and focal nodular hyperplasia (FNH) should not be treated [2–7]. Surgical excision is restricted to truly symptomatic, compressive, or enlarging tumors [8–12]. On the other hand, a more aggressive surgical approach is justified for liver cell adenoma (LCA) due to the potential for bleeding and to the rare but well-documented malignant transformation of LCA [11–18]. Finally, differentiation of LCA with well-differentiated hepatocellular carcinoma (HCC) is difficult on preoperative liver workup, and conservative treatment of such lesions could thus overlook malignancy [12, 18–20]. Determination of the tumor type on radiological liver workup is thus essential. By using combined imaging modalities, including magnetic resonance imaging (MRI), the diagnostic accuracy of benign hepatocellular liver tumors ranges between 90% and 92% for liver hemangiomas [9, 12, 21] and between 70% and 90% for FNH [7, 12, 22, 23]. However, despite extensive radiological workup, the exact nature of the liver tumor remains undetermined in many patients. When considering surgical excisional therapy in selected patients suffering from benign liver tumors, the paramount objectives of surgical treatment should be the absence of postoperative mortality and a low complication and transfusion rate [11, 12, 14, 18, 23].

Since the introduction of laparoscopic cholecystectomy in 1987 [24, 25], minimally invasive surgery has been progressively applied to various benign gastrointestinal conditions [26, 27] and to solid organs, such as the spleen [28, 29], kidney [30, 31], pancreas [32], and adrenal gland [33, 34]. The role of laparoscopic surgery has already been emphasized for benign cystic liver diseases, such as congenital liver cysts [35–37]. In 1992, Gagner et al. [38] reported the first nonanatomical resection of a FNH. However, the first true anatomical liver resection, namely a left lateral segmentectomy, was reported in 1996 by Azagra et al. [39]. There has been an increasing number of publications concerning the laparoscopic management of benign liver tumors for surgical biopsy [40], resection [41–47], or local ablation [48]. Except for two recent European published series [49–51] most of these articles report a limited number of patients with limited follow-up. The purpose of the current study was therefore to analyze the feasibility, safety, and outcome of patients undergoing laparoscopic resection for benign liver tumors in a large multicenter setting.

## Materials and methods

From March 1992 to September 2000, 87 patients suffering from benign liver tumors were retrospectively enrolled in the current study, from 18 European surgical centers. Eleven of these 18 centers (61%) were academic hospitals. Patient data were collected by using standardized questionnaires. The mean age of the patients was 41 years (median, 38 years, range, 17–75 years) and, 91% of the patients were female. Thirty-two patients (37%) were younger than 35 years old. All patients were classified ASA I or II according to the American Society of Anesthesiologists physical status score [52]. Eighty-one patients suffered from solid benign liver tumor, including 48 patients with FNH (55%), 17 patients with LCA (20%), 13 patients with hemangioma (15%), and 3 patients with hamartoma (3.5%). Six patients (7%) suffered from cystic benign liver tumors, including 3 patients with hydatid liver cysts, 2 patients with adult polycystic liver disease (APLD), and 1 patient with liver cystadenoma. Previous liver procedures included open segmentectomy V for LCA and open fenestration procedure for APLD in 1 patient each.

Preoperative liver workup included ultrasound in 85 patients (98%), computed tomography (CT) in 74 patients (85%), MRI in 44 patients (51%), arteriography in 5 patients (6%), scintigraphy in 6 patients (7%), and tumor biopsy in 16 patients (18%) (laparoscopically, 10 patients; percutaneously, 6 patients). In this series, the overall accuracy of tumor biopsy was 44%, with false-positive results in 5 patients (3 patients with FNH were thought to suffer from LCA, and 1 patient with FNH and 1 patient with LCA were thought to suffer from hepatocellular carcinoma), false-negative results in 2 patients (diagnosis of steatosis), and unconclusive results in 2 patients (suffering from a liver hamartoma and from a LCA).

In 10 patients (11.5%), liver tumors were incidentally detected during another laparoscopic procedure (cholecystectomy, 7; Nissen fundoplication, 2; appendectomy, 1). In the remaining patients, indications for surgery included symptomatic liver tumor in 43 patients (49%) (pain, 38; mass, 7; elevated liver function tests, 2), complicated liver tumor with hemorrhage in 2 patients (LCA and liver cystadenoma in one case each), increasing tumor size in 1 patient, and detection during oncologic follow-up in 2 patients (previously operated for gastric cancer and ovarian cystadenocarcinoma, respectively). Finally, 29 of the 87 patients had liver tumors of undetermined nature despite extensive liver workup, including ultrasound (US) in 29 patients (100%), Doppler ultrasound in 5 patients (17%), CT in 25 patients (86%), and MRI in 17 patients (59%).

In the group of patients with liver hemangioma (13 patients), indications for surgery included incidental detection during laparoscopic cholecystectomy in 1 patient (a 12-cm bulging hemangioma located in segment III), increasing size of a bulging hemangioma in 2 patients (12 and 14 cm, respectively), painful hemangioma in 7 patients (mean size, 9 cm; median, 8 cm; range, 4–14 cm) (Fig. 1), and tumors of undetermined nature with atypical aspect in 3 patients (mean size, 5 cm; median, 4 cm, range, 2–9 cm). In the latter group, US and CT were performed in all patients, but MRI was not used.

In the combined group of patients with FNH (48 patients) and liver hamartoma (3 patients), indications for surgery included incidental discovery in 10 patients (mean size, 4 cm; median, 4 cm; range, 1–6 cm), suspicion of metastasis during carcinologic follow-up in 1 patient with previous laparoscopic gastrectomy for cancer, symptomatic tumors in 23 patients (pain, 21 patients; mass; 2 patients; increasing size, 1 patient) (mean size, 5 cm; median 5 cm; range, 2–11 cm), and undetermined nature of the tumor with atypical appearance in 17 patients (mean size, 5 cm; median, 4 cm; range, 3–8 cm). In the latter group, preoperative liver workup included US in 17 patients, CT in 14 patients, MRI in 13 patients, and laparoscopic biopsy in 3 patients—all with a false-negative result. Overall, 11 patients with FNH underwent percutaneous (3 patients) or laparoscopic tumor biopsy (8 patients), with 6 true-positive results (55%) (including 3 patients with symptomatic FNH), 4 false-positive results (3 for LCA and 1 for hepatocellular carcinoma), and 1 unconclusive result.

In the group of patients with liver cell adenomas (17 patients), indications for surgery included incidental detection during another

**Table 1.** Segmental intrahepatic location of resected liver tumor according to Couinaud classification [53] and to the type of liver tumors[a]

| Liver segment | Hemangioma (13 patients) | FNH and hamartoma (51 patients) | LCA (17 patients) | Cystic tumor (6 patients) |
|---|---|---|---|---|
| I | 1 | — | — | — |
| II and III | 10 | 30 | 9 | 3 |
| IV | 2 | 9 | 3 | — |
| V | — | 2 | 3 | 1 |
| VI | 2 | 10 | 4 | 2 |
| VII | 1 | 1 | — | — |
| VIII | 1 | 1 | — | 1 |

FNH, focal nodular hyperplasia; LCA, liver cell adenoma
[a] Multiple segments can be affected by the same tumor

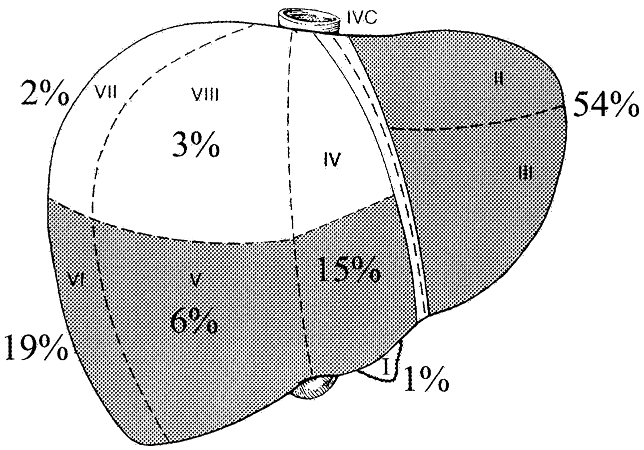


**Fig. 1.** A 49-year-old woman suffered from a painful 14-cm well-diagnosed liver hemangioma located in segments II, III, and IV of the liver requiring a laparoscopic left hepatic lobectomy. The postoperative course was uneventful, and the patient was discharged 8 days after the procedure without need for blood transfusion.

laparoscopic procedure in 1 patient (a 4-cm superficial tumor located in segment VI), suspicion of metastasis during carcinologic follow-up in 1 patient previously operated on for ovarian cancer, symptomatic tumors in 8 patients (pain, 6 patients; mass, 1 patient; elevated liver function tests, 2 patients) (mean size, 7 cm; median, 7 cm, range, 3–15 cm) (Fig. 2), and complicated tumor with intratumoral hemorrhage in 1 patient (with an 8-cm bulging tumor located in segment III), and undetermined nature of the liver tumor in 6 patients (mean size, 6 cm; median, 7 cm; range, 3–10 cm). In the latter group, preoperative liver workup included US and CT in all patients and MRI in 3 patients. Tumor biopsy was performed in 4 patients (percutaneously and laparoscopically in 2 patients each), with one true-positive result (25%), one false-positive result for HCC, and two false-negative results for liver steatosis.

Excluding the 2 patients with APLD, the tumor was unique in 81 patients (95%) and multiple in 4 patients. Tumors were located in the right lobe of the liver in 24 patients (28%), in the left lobe in 59 patients (70%), and were bilobar in 2 patients (2%). The distribution of segmental location of the tumor according to Couinaud classification [53] is illustrated in Table 1 and Fig. 3. The tumor was bulging in 14 patients (16%), visible at the liver surface in 27 patients (31%), superficial (< 1 cm from the liver surface) in 21 patients (24%), and deeply sited in 25 patients (29%). In the group of deep-sited tumors, 17 tumors (68%) were located in the left lateral segments of the liver. The mean tumor size was 6 cm (median, 5 cm; range, 1–20 cm).

Laparoscopic liver resection was performed on patients in the supine position. Pneumoperitoneum with carbon dioxide was used with an abdominal pressure maintained at less than 15 mmHg. Pneumoperitoneum was performed in 81 patients (93%) with the Veress needle. The abdominal lift technique was used in 5 patients. The mean number of trocars was 5 (median, 4; range, 3–10). Tumor location was explored by laparoscopic ultrasound in 40 patients (46%). Liver parenchymal transection was performed using mainly ultrasonic dissector in 33 patients (38%), harmonic shears in 32 patients (37%), and crushing forceps in 16 patients (18%). Intraparenchymal vascular control was obtained by clips in 78 patients (90%), electrocautery in 5 patients (6%), harmonic shears in 4 patients (4%), intraperitoneal ligation in 9 patients (10%), and endostapler in 22 patients (25%), including 14 patients (64%) operated for left lateral segmentectomy or major hepatectomy. An atraumatic Lucane liver clamp was used in 2 patients (2%) [49, 51]. Hemostasis of the transsection line was obtained in 39 patients by monopolar cautery (45%), by bipolar cautery in 17 patients (20%), by the use of Argon Beam coagulator in 15 patients (17%), by hemostatic swabs in 13 patients (15%), and by the use of fibrin glue in 43 patients (49%). Control of biliary leak at the liver surface was assessed by inspection in all cases and by intraoperative cholangiography in 4 patients (4.5%). Extraction of the surgical specimen was performed within an endobag in 63 patients (72%), through an enlarged trocar site in 49 patients (57%), through a minilaparotomy in 28 patients (32%) (Pfannenstiel incision, 14 patients; supraumbilical incision, 14 patients), or by conversion to an open approach in 9 patients (10%). Six specimens (one hemangioma, one FNH, one cystadenoma, and three LCA) were crushed for extraction. For these 6 patients, the preoperative nature of the tumor was known before the operation. Accurate pathological diagnosis was not impaired by the crushing technique. Peritoneal drainage was used in 72 patients (83%).

Criteria of evaluation included type and details of the operative procedures, early postoperative course including complications, transfusion and reoperation rate, postoperative hospital stay, and late outcome of the patients. Postoperative mortality and complications were assessed at a postoperative delay of 2 months. Eighty-two patients (94%) had radiological investigations at follow-up by US in 59 patients, CT in 20 patients and MRI in 8 patients in order to exclude disease recurrence. Five patients refused postoperative radiological investigations, including 1 patient with hemangioma, 3 patients with FNH, and 1 patient with LCA.

Statistical analysis included chi-square tests or student's *t*-test when indicated. Survival curves were calculated according to the Kaplan–Meyer method.

## Results

According to the Goldsmith and Woodbrune classification [54], liver resections included 1 right hepatic lobectomy, 2 left hepatic lobectomies, 20 left lateral segmentectomies, 1 bisegmentectomy V–VIII, 25 segmentectomies, and 38 nonanatomical resections. Liver resection was solitary in 84 patients and multiple in 3 patients, including left lateral segmentectomy with segmentectomy VI and double wedge resection in 1 and 2 patients, respectively. Details of liver resection according to the tumor type are illustrated in Table 2. Portal triad clamping was used in 8 patients (9%) (unilateral in 2 patients and total in 6 patients) by using a laparoscopic clamp or a tourniquet. The mean duration of total portal triad clamping was 59 min (median, 50 min; range, 20–120 min). Total portal clamping was used for

**Table 2.** Liver resection procedures according to the type of liver tumor

| Procedure | Hemangioma (13 patients) | FNH and hamartoma (51 patients) | LCA (17 patients) | Cystic tumor (6 patients) |
|---|---|---|---|---|
| Wedge resection | 6 | 25 | 7 | — |
| Segmentectomy | 3 | 12 | 7 | 3 |
| Bisegmentectomy S5 + S8 | — | — | — | 1 |
| Left lateral segmentectomy | 1 | 14 | 3[a] | 2 |
| Major hepatectomy | 3 | — | — | — |

FNH, focal nodular hyperplasia; LCA, liver cell adenoma
[a] Associated to segmentectomy 6 in one patient

**Fig. 2.** Magnetic resonance imaging of a 17-year old female suffering from right upper quadrant abdominal pain from a 6-cm bulging liver cell ademona located in segment VI of the liver. The patient underwent uneventful laparoscopic resection of segment VI and was discharged from the hospital 4 days after the operation.

right and left hepatic lobectomy in 1 patient each, for left lateral segmentectomy in 1 patient, and for segmentectomy in 3 patients (segmentectomy VI, 1 patient; segmentectomy IV, 2 patients). Unilateral portal clamping was used for 80 and 45 min, respectively, in 1 patient each. Peroperative complications included bleeding in 7 patients (8%), which was responsible for conversion in 4 (57%). There were no signs of gas embolism. Conversion to an open approach was required in 9 patients (10%) due to bleeding in 4 patients, close vascular adhesion to the left hepatic vein in 1 patient (Fig. 4), deep or posterior location of the tumor in 2 patients, instrumental dysfunction in 1 patient, and risk of rupture of an hydatid liver cyst in 1 patient. Converted procedures included one left hepatic lobectomy for a 13-cm hemangioma, three left lateral segmentectomies for FNH, one segmentectomy IV for FNH, two wedge resections of segment VI and segment VII for FNH, one wedge resection of segment III for LCA, and one segmentectomy VI for an hydatid liver cyst. Details of peroperative complications and reasons for conversion are presented in Table 3.

Intra- and/or postoperative autologous blood transfusion was required in five patients (6%), including left lateral segmentectomy for FNH in one patient, wedge resection for FNH in three patients (segments II, IV, and VIII one patient each), and segmentectomy VI for LCA in one patient. The mean transfusion volume in these patients was 604 ml (median, 600 ml; range, 321–900 ml).

There was no mortality in this series. Postoperative complications occurred in four patients (5%), including general complications in two patients (one pneumonia after left hepatic lobectomy and one urinary infection after a wedge resection of segment III) and local complications in two patients, including residual cystic stones in a patient operated for segmentectomy VI for LCA associated with laparoscopic cholecystectomy and common bile duct exploration. The other patient with local complications presented self-limiting bleeding from the transection line following left lateral segmentectomy associated with segmentectomy VI for multiple LCA. The patient with residual cystic stones was treated by extracorporeal shock-wave litotripsy and endoscopic sphincterotomy with stones extraction, for a retreatment rate of 1%. The mean postoperative hospital stay (POHS) was 5 days (median, 5 days; range, 2–13 days), which was significantly affected by the extent of hepatectomy and the need for conversion to an open approach. Indeed, the mean POHS was 4.7 days (median, 5 days; range, 2–11 days) when less than one liver segment was resected, whereas it was 6 days (median, 6 days; range, 3–13 days) when more than one liver segment was resected ($p = 0.003$). In patients successfully treated laparoscopically, the mean POHS was 5 days (median, 5 days; range, 2–11 days) whereas it was 8 days (median, 7 days; range, 5–13 days) in converted patients ($p < 0.001$).

The mean follow-up in the whole series was 13 months (median, 10 months; range, 2–72 months). All patients are alive without symptoms and recurrence. On postoperative liver workup, no recurrence was found in these patients. The two patients suffering from APLD presented persistent asymptomatic liver cysts. In the group of patients resected for solid benign liver tumors, the overall and disease-free survival at 2 years were both 100%. There were no late complications.

## Discussion

There is no reason for the management of patients suffering from benign liver tumors to be modified with the introduction of minimally invasive surgery. Surgical indications for removal of these tumors should remain based on their natural history and on the ability of im-

**Table 3.** Details of patients suffering from intraoperative complications and/or conversions during laparoscopic resection of benign liver tumors

| Type of liver tumor | Surgeon experience | Couinaud segments | Aspect of the tumor | Size (cm) | Type of liver resection | Intraoperative complications | Cause of conversion |
|---|---|---|---|---|---|---|---|
| FNH | 7 | 8 | Visible | 5 | Wedge | Bleeding | — |
| FNH | 9 | 2 + 3 | Visible | 8 | Wedge | Bleeding (LHV) | — |
| FNH | 2 | 4 | Superficial | 6 | Wedge | Bleeding | — |
| Hemangioma | 4 | 2 + 3 + 4 | Deep | 13 | Left hepatic lobectomy | Bleeding (MHV) | Bleeding (MHV) |
| FNH | 2 | 6 | Visible | 5 | Wedge | None | Instrumental dysfunction |
| FNH | 2 | 4 | Visible | 4 | S 4 | None | Posterior tumor location |
| FNH | 3 | 2 | Deep | 7 | LLS | None | Tumor close to LHV |
| FNH | 2 | 2 + 3 | Deep | 11 | LLS | Bleeding (LHV) | Bleeding (LHV) |
| FNH | 12 | 7 | Deep | 4 | Wedge | None | Deep-sited tumor |
| FNH | 2 | 2 + 3 | Deep | 10 | LLS | Bleeding (LHV) | Bleeding (LHV) |
| LCA | 6 | 3 | Visible | 7 | Wedge | Bleeding (LHV) | Bleeding (LHV) |
| Hydatid cyst | 6 | 6 | Superficial | 6 | S 6 | None | Risk of cyst rupture |

FNH, focal nodular hyperplasia; LHV, left hepatic vein; LLS, left lateral segmentectomy; MHV, middle hepatic vein; S, liver segmentectomy

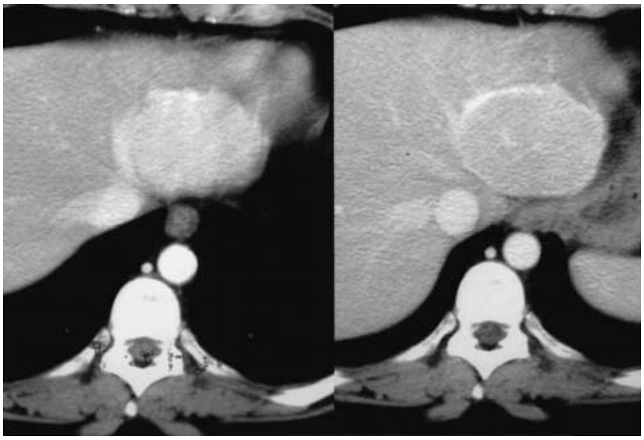

**Fig. 3.** Segmental intrahepatic location of resected liver tumor according to Couinaud classification in the whole series. Multiple segments can be affected by the same tumor.

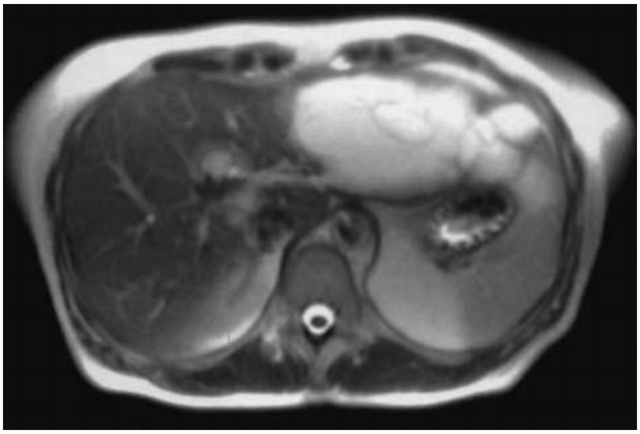

**Fig. 4.** Computed tomography of a 37-year-old female suffering from right upper quadrant abdominal pain from a 7-cm liver tumor deeply sited in segment II of the liver requiring left lateral segmentectomy. The procedure was converted to an open approach due to the close contact of the tumor with the left hepatic vein. The postoperative course was uneventful, and the patient was discharged on postoperative day 7.

aging techniques to ensure a precise diagnosis of the tumor's type. All types of benign liver tumors were encountered in this large clinical multicenter series. In particular, there is a significant number of liver hemangiomas and FNH, for which restrictive indications should indeed be applied. However, as observed in open surgical series, this laparoscopic clinical series is clearly suffering from bias of surgical population, with symptomatic tumors or tumors of undetermined nature at liver workup, due to their atypical appearance, being overrepresented in comparison to observational medical series [7, 18, 55]. In some surgical series [7, 18], the accuracy of preoperative liver workup for FNH ranges between 43% and 50%, a particularly low percentage due to the significant incidence of atypical radiological presentation in these surgical series. In the multicenter setting of the current series, truly symptomatic or complicated tumors and tumors of undetermined nature were encountered in 52% and 33% of the patients, respectively. For example, in patients with liver hemangiomas, large and symptomatic cavernous hemangiomas exceeding 10 cm represent half of the selected patients in this series, requiring laparoscopic major hepatectomy only in this group of patients. The diagnostic accuracy for liver hemangiomas by imaging techniques, including MRI, is approximately 90% in expert series [9, 12, 21] but remains difficult for small lesions [56], as encountered in this series. There is also a high number of patients with FNH in this series. Again, the vast majority of FNHs were resected due to symptomatic tumor, undetermined nature of the tumor, or suspicion of metastasis in a patient previously operated for cancer, representing 86% of all selected FNH patients in this series. On the other hand, all patients with incidental detection of FNH during another laparoscopic procedure had small, superficial lesions, easily and safely amenable for associated liver resection. Even by combining different imaging modalities and especially by using MRI, a precise diagnosis of FNH can be achieved in only 70% to 90% of cases in expert centers [7, 12, 22, 23]. However, many reports have emphasized the difficult differentiation between FNH and LCA and that between LCA and HCC. In a multicenter setting such as in this series, the results of imaging modalities are probably less satisfactory. Despite extensive liver workup, it is not uncommon that a difficult therapeutic decision has to be made when the tumor's nature is undetermined. When the diagnosis remained dubious at radiological workup, percutaneous guided tumor biopsy has been suggested as an option to improve diagnostic accuracy, despite the risk of inadequate sampling, bleeding, and the difficulty of differentiating benign and malignant tumors [11, 12, 19, 23, 60–62]. Cherqui et al. [23] suggested that laparoscopically guided biopsy could be an interesting option in selected cases. However, in the current series, the overall diagnostic accuracy of percutaneous and laparoscopic biopsy was 44% in the whole series, 55% in patients suffering from FNH, and 25% in patients suffering from LCA. Finally, excluding patients with truly symptomatic FNH, there were only 3 patients in this series (representing 6% of the FNH group) who underwent unjustified laparoscopic resection, again emphasizing the need for not changing the general practice of restricting surgical indications in benign liver tumors, even with the development of minimally invasive surgery.

When surgery is considered in the management of patients with benign liver tumors, the paramount objectives should be the absence of operative mortality, a low complication rate, the absence of heterologous blood transfusion, and satisfactory late outcome. These objectives were clearly achieved in this largest reported series of laparoscopically resected benign liver tumors, with no mortality and a 5% complication rate. All transfused patients (6%) received autologous blood transfusion, but it should be noted that the same resection procedures performed by an open approach would probably not have required blood transfusion. The need for blood transfusion in minor liver resections on a noncirrhotic liver parenchyma is indeed minimal when using an open approach [63–65]. This feature confirmed that bleeding remains the most important intraoperative problem during liver resection, as in open surgery, but is obviously more difficult to control laparoscopically, even for minor resections. Intraoperative bleeding was thus the major reason for converting the procedure to an open approach.

Adequate selection of patients and liver tumors is a key factor of success for laparoscopic resectional surgery. High-risk patients were not selected for laparoscopic resection of benign liver tumors in this series, which probably partially explains the low postoperative rate of general complications. On the other hand, not all liver tumors are amenable to laparoscopic resection. This series represents a selected group of patients, with the vast majority of tumors being small, superficial, peripheral lesions located in the left lateral segments (segments II and III) or in the anterior segments of the right part of the liver (namely the anterior part of segment IV, segment V, and segment VI). Large tumors, tumors close to the hepatic veins or the cavohepatic junction, and centrally or posteriorly located tumors in the right part of the liver are not ideal candidates for laparoscopic resection since mobilization of the liver, peroperative control of major intrahepatic vessels, and application of the total vascular isolation technique are difficult to achieve laparoscopically. Laparoscopic surgery should thus be proposed for selected tumor sizes and locations respecting appropriate selection of indications for surgical removal. Practically, when taking into account the restrictive philosophy of surgery in benign liver tumors and the need for adequate selection of patients, we believe that the performance of laparoscopic surgery in the management of benign hepatocellular tumors should be limited to less than 10% of the patients referred to expert HPB centers. On the other hand, as demonstrated in this and other series [44–47, 49–51], only limited liver resections (namely nonanatomical resections and segmentectomies or *réglée* left lateral segmentectomies) can be safely performed through a laparoscopic approach. Such selection of liver resections limited to one or two liver segments is encountered in most reported series. However, in this selected group of patients, when the technique is appropriately performed by an expert surgical team, the technique appears to be safe, with a low morbidity and a short postoperative hospital stay. However, it should be remembered that open resectional liver surgery has achieved a significant reduction in postoperative morbidity, especially for minor liver resections [64, 65]. Additional comparative studies are needed to evaluate the benefit of the laparoscopic approach in terms of postoperative recovery. However, an improved postoperative recovery with the laparoscopic approach was suggested by Rau et al. [66] in a retrospective matched series of 34 patients. On the other hand, the legitimacy of laparoscopic major hepatectomies remains questionable [46, 67, 68]. Complete mobilization of the liver, safe exposure of the suprahepatic junction, easy and safe intraparenchymal control of major vascular trunks, three-dimensional determination of the transection line's orientation, and control of severe bleeding are difficult to replicate laparoscopically. To date, except for Hüscher's group [68], which reported major laparoscopically assisted hepatectomies in 17 patients with benign and malignant liver tumors, only a few major liver resections have been reported [49, 50]. Hüsher et al. [68], Fong et al. [69], and Cuschieri [70] suggested facilitating these major resectional procedures by hand-assisted procedures in order to improve liver exposure and vascular control and to increase the safety of the procedure. Until more scientifically relevant results are available from expert centers, we believe that caution should be used for the laparoscopic performance of major liver resections in young patients suffering from benign liver tumors.

Laparoscopic resectional procedures are time-consuming and technically demanding operations, with a need for complex and expensive materials and instrumentations. High-flow $CO_2$ insufflator, a high-quality optical system, laparoscopic ultrasonography, Argon Beam Coagulator, endostaplers with vascular cartridges, and a harmonic dissector are the most common tools necessary for laparoscopic liver resections. Despite deleterious effects of pneumoperitoneum associated with the Pringle maneuver in animal models [71, 72], the use of this combination was well tolerated in 6% of the patients in the current series, with an occlusion time varying from 20 to 120 minutes. However, it should be noted that portal triad clamping was used in the current series for liver resections, namely segmentectomies and left lateral segmentectomy, for which it should not have been used during an open approach. By comparison, portal triad clamping was used in 67% of patients in the Cherqui et al.[50] series of laparoscopic liver resection. For minor liver resection of superficial or bulging liver tumors, Descottes et al. [51] described an alternative to portal triad clamping by the use of an atraumatic liver clamp, the Lucane clamp a laparoscopic adaptation of the LIN liver clamp [73] that can minimize bleeding during transection and therefore lower the transfusion rate. Finally, the laparoscopic approach carries an increased potential risk of gas embolism compared to the open approach [41, 74–76]. Despite the absence of such a potentially life-threatening complication in the current series, the use of gasless laparoscopy and cautious use of the Argon Beam Coagulator to achieve hemostasis of the transection line are recommended [41, 72, 74, 76–78].

In conclusion, data from the current series suggest that laparoscopic resection of benign liver tumors is feasible and safe in selected patients and liver tumors. The data suggest that liver laparoscopic surgery is a good alternative to open surgery in selected patients. The procedure should be performed by surgical teams experienced in hepatobiliary and laparoscopic surgery. Moreover, comparative studies are still needed before the laparoscopic approach for highly selected benign liver tumors can be accepted as the ideal approach for these patients.

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## References

1. Ishak KG, Anthony PP, Sobin LH (1994) Histologic typing of tumors of the liver. Springer-Verlag, Berlin
2. Gibney RG, Hendin AP, Cooperberg PL (1987) Sonographically detected hepatic hemangiomas: absence of change overtime. Am J Roentgenol 149: 953–957
3. Gandolfi L, Leo P, Solmi L, Vitelli E, Verros G, Colecchia A (1991) Natural history of hepatic haemangiomas: clinical and ultrasound study. Gut 32: 677–680
4. Mungovan JA, Cronan JJ, Vacarro J (1994) Hepatic cavernous hemangiomas: lack of enlargement over time. Radiology 191: 111–113
5. Leconte I, Van Beers B, Lacrosse M et al. (2000) Focal nodular hyperplasia: natural course observed with CT and MRI. J CAT 24: 61–66
6. Di Stasi M, Caturelli E, De Sio I, Salmi A, Buscarini E, Buscarini L (1996) Natural history of focal nodular hyperplasia of the liver: an ultrasound study. J Clin Ultrasound 24: 345–350
7. Pain JA, Gimson AES, Williams R, Howard ER (1991) Focal nodular hyperplasia of the liver: results of treatment and options in management. Gut 32: 524–527
8. Trastek VF, van Heerden JA, Sheedy PF, Adson MA (1983) Cavernous hemangioma of the liver: resect or observe? Am J Surg 145: 49–53
9. Farges O, Daradkeh S, Bismuth H (1995) Cavernous hemangiomas of the liver: are there any indications for resection? World J Surg 19: 19–24
10. Foster JH (1982) Benign liver tumors. World J Surg 6: 25–31
11. Nagorney DM (1995) Benign hepatic tumors: focal nodular hyperplasia and hepatocellular adenoma. World J Surg 19: 13–18
12. Weimann A, Ringer B, Klempnauer J et al. (1997) Benign liver tumors: differential diagnosis and indications for surgery. World J Surg 21: 983–991
13. Kerlin P, Davis GL, McGill DB, Weiland LH, Adson MA, Sheedy PF (1983) Hepatic adenoma and focal nodular hyperplasia: clinical, pathologic and radiologic features. Gastroenterology 84: 994–1002
14. Leese T, Farges O, Bismuth H (1988) Liver cell adenomas. A 12-year surgical experience from a specialist hepato-biliary unit. Ann Surg 208: 558–564
15. Foster JH, Berman MM (1994) The malignant transformation of liver cell adenomas. Arch Surg 129: 712–717
16. Tao LC (1991) Oral contraceptive-associated liver cell adenoma and hepatocellular carcinoma. Cancer 68: 341–347
17. Neuberger J, Nunnerley HB, Davis M, Portmann B, Laws JW, Williams R (1980) Oral-contraceptive-associated liver tumours: occurrence of malignancy and difficulties in diagnosis. Lancet 11: 273–276
18. Belghiti J, Pateron D, Panis Y et al. (1993) Resection of presumed benign liver tumours. Br J Surg 80: 380–383
19. Shimizu S, Takayama T, Kosuge T et al. (1992) Benign tumors of the liver resected because of a diagnosis of malignancy. Surg Gynecol Obstet 174: 403–407
20. Arrivé L, Fléjou JF, Vilgrain V et al. (1994) Hepatic adenoma: MR findings in 51 pathologically proved lesions. Radiology 193: 507–512
21. Stark DD, Felder RC, Wittenberg J et al. (1985) Magnetic resonance imaging of cavernous hemangioma of the liver: tissue-specific characterization. Am J Roentgenol 145: 213–222
22. Benhamou JP (1996) Diagnostic approach to a liver mass: diagnosis of an asymptomatic liver tumor in a young woman. J Hepatol 25: 30–34
23. Cherqui D, Rahmouni A, Charlotte F et al. (1995) Management of focal nodular hyperplasia and hepatocellular adenoma in young women: a series of 41 patients with clinical, radiological and pathological correlations. Hepatology 22: 1674–1681
24. Dubois F, Berthelot G, Levard H (1991) Laparoscopic cholecystectomy: historical perspective and personal experience. Surg Laparosc Endosc 1: 52–60
25. Reddick EJ, Olsen DO (1989) Laparoscopic laser cholecystectomy. A comparison with mini-lap cholecystectomy. Surg Endosc 3: 131–133
26. Dallemagne B, Weerts JM, Jehaes C, Markiewicz S, Lombard R (1991) Laparoscopic Nissen fundoplication: preliminary report. Surg Laparosc Endosc 1: 138–143
27. Faynsod M, Stamos MJ, Arnell T, Borden C, Udani S, Vargas H (2000) A case-control study of laparoscopic versus open sigmoid colectomy for diverticulitis. Am Surg 66: 841–843
28. Friedman RL (1996) Laparoscopic splenectomy for ITP. The gold standard. Surg Endosc 10: 991–995
29. Gigot JF, de Ville de Goyet J, Van Beers BE et al. (1996) Laparoscopic splenectomy in adults and children: experience with 31 patients. Surgery 119: 384–389
30. Flowers JL, Jacobs S, Cho E et al. (1997) Comparison of open and laparoscopic live donor nephrectomy. Ann Surg 226: 483–489
31. Dunn MD, Portis AJ, Shalhav AL et al. (2000) Laparoscopic versus open radical nephrectomy: a 9-year experience. J Urol 164: 1153–1159
32. Gagner M, Pomp A, Heniford BT (1997) Laparoscopic pancreatic resection: is it worthwhile? J Gastrointest Surg 1: 20–26
33. Gagner M, Pomp A, Heniford BT, Pharand D, Lacroix A (1997) Laparoscopic adrenalectomy: lessons learned from 100 consecutive procedures. Ann Surg 226: 238–247
34. Thompson GB, Grant CS, van Heerden JA et al. (1997) Laparoscopic versus open posterior adrenalectomy: a case-control study of 100 patients. Surgery 122: 1132–1136
35. Morino M, De Guili M, Festa V, Garrone C (1994) Laparoscopic management of symptomatic nonparasitic cysts of the liver: indications and results. Ann Surg 219: 157–164
36. Gigot JF, Métairie S, Etienne J et al. (2001) The surgical management of congenital liver cysts: the need for tailored approach with appropriate patient selection and proper surgical technique. Surg Endosc 15: 357–363

37. Katkhouda N, Hurwitz M, Gugenheim J et al. (1999) Laparoscopic management of benign solid and cystic lesions of the liver. Ann Surg 229: 460–466
38. Gagner M, Rheault M, Dubuc J (1992) Laparoscopic partial hepatectomy for liver tumor. Surg Endosc Abstract 6: 99
39. Azagra S, Goergen M, Gilbart E, Jacobs D (1996) Laparoscopic anatomical (hepatic) left lateral segmentectomy—technical aspects. Surg Endosc 10: 758–761
40. Lefor AT, Flowers JL (1994) Laparoscopic wedge biopsy of the liver. J Am Coll Surg 178: 307–308
41. Croce E, Azzola M, Russo R, Golia M, Angelini S, Olmi S (1994) Laparoscopic liver tumour resection with the Argon Beam. Endosc Surg 2: 186–188
42. Gugenheim J, Mazza D, Katkhouda N, Goubaux B, Mouiel J (1996) Laparoscopic resection of solid liver tumours. Br J Surg 83: 334–335
43. Marks J, Mouiel J, Katkhouda N, Gugenheim J, Fabiani P (1998) Laparoscopic liver surgery. A report on 28 patients. Surg Endosc 12: 331–334
44. Samama G, Chiche L, Brefort JL, Le Roux Y (1998) Laparoscopic anatomical hepatic resection. Surg Endosc 12: 76–78
45. Katkhouda N, Hurwitz M, Gugenheim J et al. (1999) Laparoscopic management of benign solid and cystic lesions of the liver. Ann Surg 229: 460–466
46. Mouiel J, Katkhouda N, Gugenheim J, Fabiani P (2000) Possibilities of laparoscopic liver resection. J Hepatobiliary Pancreatic Surg 7: 1–8
47. Rau HG, Meyer G, Cohnert TU, Schardey HM, Jauch K, Schildberg FW (1995) Laparoscopic liver resection with the water-jet dissector. Surg Endosc 9: 1009–1012
48. Buscarini L, Rossi S, Fomari F, Di Stasi M, Buscarini E (1995) Laparoscopic ablation of liver adenoma by radiofrequency electrocautery. Gastrointest Endosc 41: 68–70
49. Descottes B, Lachachi F, Sodji M et al. (2000) Early experience with laparoscopic approach for solid liver tumors: initial 16 cases. Ann Surg 232: 641–645
50. Cherqui D, Husson E, Hammoud R et al. (2000) Laparoscopic liver resections: a feasibility study in 30 patients. Ann Surg 232: 753–762
51. Descottes B, Lachachi F, Durand-Fontanier S, Sodji M, Pech de Laclause B, Valleix D (2000) Traitement laparoscopique des tumeurs solides et kystiques du foie. Etude de 33 cas. Ann Chir 125: 941–947
52. American Society of Anesthesiologists (1963) New classification of physical status. Anesthesiology 24: 111
53. Couinaud C (1957) Le foie: études anatomiques et chirurgicales. Masson, Paris
54. Goldsmith NA, Woodbrune RT (1957) The surgical anatomy pertaining to liver resection. Surg Gynecol Obstet 105: 310–318
55. Vilgrain V, Fléjou JF, Arrivé L et al. (1992) Focal nodular hyperplasia of the liver. MR imaging and pathologic correlation in 37 patients. Radiology 184: 699–703
56. Itai Y, Ohtomo K, Furui S, Yamauchi T, Minami M, Yashiro N (1985) Noninvasive diagnosis of small cavernous hemangioma of the liver: advantage of MRI. Am J Roentgenol 145: 1195–1199
57. Welch TJ, Sheedy PF, Johnson CM et al. (1985) Focal nodular hyperplasia and hepatic adenoma: comparison of angiography, CT, US and scintigraphy. Radiology 156: 593–595
58. Mattison CR, Glazer GM, Quint LE, Francis IR, Bree RL, Ensminger WD (1987) MR imaging of hepatic focal nodular hyperplasia: characterization and distinction from primary malignant hepatis tumor. Am J Roentgenol 148: 711–715
59. Nokes SR, Baker ME, Spritzer CE, Meyers W, Herfkens RJ (1988) Hepatic adenoma: MR appearance mimicking focal nodular hyperplasia. J Comput Assisted Tomogr 12: 885–887
60. Iwatsuki S, Todo S, Starzl TE (1990) Excisional therapy for benign hepatic lesions. Surg Gynecol Obstet 171: 240–246
61. John TG, Garden OJ (1993) Needle track seeding of primary and secondary liver carcinoma after percutaneous liver biopsy. HPB Surg 6: 199–204
62. Vergara V, Garripoli A, Marucci MM, Bonino F, Capussotti L (1993) Colon cancer seeding after percutaneous fine needle aspiration of liver metastases. J Hepatol 18: 276–278
63. Hemming AW, Scudamore CH, Davidson A, Sigfried RE (1993) Evaluation of 50 consecutive segmental hepatic resection. Am J Surg 165: 621–624
64. Strong RW, Lynch SV, Wall DR, Ong Th (1994) The safety of elective liver resection in a special unit. Aust NZ J Surg 64: 530–534
65. Tsao Jl, Loftus JP, Nagorney DM, Adson MA, Ilstrup DM (1994) Trends in morbidity and mortality of hepatic resection for malignancy. Ann Surg 220: 199–205
66. Rau HG, Buttler E, Meyer G, Schardey HM, Schildberg FW (1998) Laparoscopic liver resection compared with conventional partial hepatectomy. A prospective analysis. Hepato-Gastroenterology 45: 2333–2338
67. Huscher CGS, Lirici MM, Chiodini S, Recher A (1997) Current position of advanced laparoscopic surgery of the liver. J R Coll Surg Edinburgh 42: 219–225
68. Huscher CGS, Lirici MM, Chiodini S (1998) Laparoscopic liver resections. Sem Laparosc Surg 5: 204–210
69. Fong Y, Jarnagin W, Conlon KC, Dematteo R, Dougherty E, Blumgart LH (2000) Hand-assisted laparoscopic liver resection. Arch Surg 135: 854–859
70. Cuschieri C (2000) Laparoscopic hand-assisted surgery for hepatic and pancreatic disease. Surg Endosc 14: 991–996
71. Haberstroh J, Ahrens M, Munzar T et al. (1996) Effects of the Pringle maneuver on hemodynamics during laparoscopic liver resection in the pig. Eur Surg Res 28: 8–13
72. Takagi S (1998) Hepatic and portal vein blood flow during carbon dioxide pneumoperitoneum for laparoscopic hepatectomy. Surg Endosc 12: 427–431
73. Lin TY (1973) Results of 107 hepatic lobectomies with a preliminary report on the use of a clamp to reduce blood loss. Ann Surg 177: 413–421
74. Hashizume M, Takenaka K, Yanaga K et al. (1995) Laparoscopic hepatic resection for hepatocellular carcinoma. Surg Endosc 9: 1289–1291
75. Moskop RJ, Lubarsky DA (1994) Carbon dioxide embolism during laparoscopic cholecystectomy. South Med J 84: 414–415
76. Yacoub OF, Cardona I, Coveler LA, Dodson MG (1982) Carbon dioxide embolism during laparoscopy. Anesthesiology 57: 533–535
77. Intra M, Viani MP, Ballarini C et al. (1996) Gasless laparoscopic resection of hepatocellular carcinoma (HCC) in cirrhosis. J Laparoendosc Surg 6: 263–270
78. Watanabe Y, Sato M, Ueda S et al. (1997) Laparoscopic hepatic resection: a new and safe procedure by abdominal wall lifting method. Hepato-Gastroenterology 44: 143–147